# Senegal River Basin M&E Rapid Assessment Report

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MEWINA
مشروع التقييم والمتابعة لقطاع المياه بدول شمال أفريقيا
Monitoring and Evaluation for Water in North Africa

Senegal River Basin

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## Executive Summary

The member countries of the Northern African Ministerial Council on Water (N-AMCOW) have decided to harmonize and standardize their Water Sector Monitoring and Evaluation (M&E) framework. Monitoring and evaluation are now recognized as indispensable performance management tools that will be vital to the achievement of development objectives at national, regional, and international levels as part of the result-based management effort advocated by the Paris Declaration on Aid and Effectiveness, which laid down a practical, action-oriented roadmap to improve the quality of aid and its impact on development in Africa. M&E has been considered the weakest link in progress towards the Millennium Development Goals (MDGs) in Africa. The Center for Environment and Development for the Arab Region and Europe (CEDARE), as the hosting body of the N-AMCOW, developed the sub-regional program "Monitoring and Evaluation for Water in North Africa" (MEWINA) to support N-AMCOW and its member countries in Water Sector M&E. As part of the MEWINA project, this report offers a rapid assessment of M&E systems and water indicators in the Senegal River Basin as a transboundary basin.

The Senegal River basin is located in West Africa, and covers 1.6% of the continent and spreads over four countries: Guinea, Mali, Mauritania, and Senegal. The Senegal River is the second largest river in West Africa. It is 1800 km long and drains into the Atlantic Ocean. The Senegal River basin covers a surface area of about300, 000 km$^2$. The Senegal River basin has a total population of around 3,500,000 inhabitants, 85 percent of whom live near the river. Main activities in the basin include irrigation, which is the main driver for development in the basin, livestock raising, fishing, mining, and some underdeveloped industries. As for hydropower generation, the hydroelectric power plant in Manantali has a capacity of 200 MW, to furnish an average of 800 GWh/year to electricity companies in the three OMVS member states.

In July 1963, Guinea, Mali, Mauritania and Senegal signed the Bamako Convention for the Development of the Senegal River Basin. This convention declared the Senegal River to be an 'International River' and created an 'Interstate Committee' to oversee its development. The Bamako Convention was supplemented by the Dakar Convention, signed in February 1964, concerning the status of the Senegal River. In May 1968, the Labé Convention created the Organization of Riparian States of the Senegal River (OERS) to replace the Interstate Committee. After Guinea withdrew from the OERS, in March 1972, Mali, Mauritania, and Senegal signed the Nouakchott Convention, reconfirming the river's international status and establishing the Senegal River Development Organization (OMVS) and dissolving the OERS. The OMVS has since created a flexible and functional legal framework enabling collaboration and a co-management of the basin. In 2006, Guinea joined the initial members, Mali, Senegal and Mauritania, and became a member of OMVS.

When the OMVS was created in 1972, the major concern was to develop infrastructure to address water stress resulting from a cycle of droughts, develop agriculture, reduce the cost of hydro-electricity and open up Mali by improving navigation. At that time, OMVS was mainly dedicated to infrastructure development, although it played an important role in sharing costs and benefits between riparian countries. In 1998, the Program for the Mitigation and Monitoring of Environmental Impacts drew attention to the lack of management and the risks this involved. The Observatory of the Environment (SOE) was created in 2000, as a tool to support basin management. In 2002, the Conference of Heads of States and Governments, meeting in Nouakchott, highlighted the need for an integrated basin

management approach. The Observatory of the Environment therefore became the Observatory of Sustainable Development, shifting its focus from management of shared resources to the management of information and data for sustainable development.

Two types of funding are used to finance the development of the Senegal River basin. The first one covers the operating costs of the various OMVS bodies, and comes from the three member states. To finance the jointly owned structures and other development activities, funds are sought in the form of loans extended either to the states or directly to the OMVS. Each member state ensures the reimbursement of its share of the loans. The apportionment of costs and debts is done according to an accepted formula, subject to revision, as stipulated in the conventions.

Due to potential conflicts between power generation and the other uses of the Senegal River, the governments have embarked through OMVS on the implementation of an environmental impact alleviation and follow-up program (PASIE). PASIE was finalized by 2002, and was succeeded by the Environmental Observatory (SOE). The May 2002 effective date of the Senegal River Water Charter and the start-up of environmental monitoring by the SOE represented golden opportunities for increasing the involvement of representatives of the various stakeholders in there source management and decision making process. This participatory approach has been reinforced by the launching of the Master Plan the following year.

In March 2002, the OMVS began drafting a Master Plan for Development and Water Management (SDAGE) of the Senegal River basin. The formulation of the Master Plan for Water Development and Management (SDAGE) of the Organization for the Development of the Senegal River (OMVS) was conducted in a participatory manner. The principles and procedures for the allocation of water wiredrawn up and a Permanent Water Commission (PWC) was set up to serve as an advisory body to the OMVS's Council of Ministers that makes decisions and asks the High Commission to oversee their application.

The Diama (anti-salt dam) and Manantali Dams (hydropower and regulating dam) were respectively built in 1988 and 1990. Operation and maintenance are carried out by the Diama Dam Management and Exploitation Company (SOGED) and the Manantali Energy Management Company (SOGEM), the OMVS's Council of Ministers being the highest supervising body. The construction of the Diama anti-salt dam and the Manantali multipurpose hydroelectric dam marked the partial conclusion of a major phase, based on a development approach. Today, the OMVS is attempting to redefine medium- and long-term development strategy for the entire basin, associating development with integrated and sustainable management.

OMVS efforts are continuing today and it has conducted a number of basin-wide studies and development programs. Additional benefits are the jointly owned 1500 km power transmission lines connecting the three riparian countries power grids from Manantali dam. An optic fiber combined with the transmission lines enables increased telecommunications capacity, making Senegal telecommunication network entirely digital, and linking Mali and Mauritania to the international network. OMVS can be considered as an example and a catalyst for Peace and Regional Stability.

The Senegal River basin case study by UNESCO in 2003 indicated that OMVS had abundant quantitative data thanks to a discharge monitoring network set up in 1904, with updated records stored in a database of the OMVS High Commission. Major studies carried out by the French Research Institute for

Development and the OMVS have also made it possible to estimate withdrawal and losses during low flow stages. These studies have also made it possible to develop suitable resource management tools based on analysis of the hydrological behavior of the river in relation to needs.

Data on water quality, health, livestock-raising, agriculture, fishing, climate and the environment did exist, but were dispersed in various government services, laboratories, universities and research institutes, or even in cooperation institutions, such as the IRD, USAID, UNDP, and the World Bank. Data have been collected for many projects, but the resulting databases were incompatible or have simply been lost or abandoned upon completion of projects. The most acute need was in the upper basin, including Guinea, where the lack of data was a concern not only for the government of Guinea but for the whole basin.

Agencies that report to the OMVS are in charge of the operation of the Manantali and Diama dams, which are jointly owned by the three member countries Mali, Mauritania, and Senegal. Flow data from the Senegal have been recorded since 1904, and the large quantities of hydrological data that have been collected are stored in a database operated by the OMVS technical department. The department publishes a monthly information sheet for member-country hydrological services as well as for other actors.

The insufficiency or total lack of time-and space-related data for many water-relevant areas has stood in the way of a systematic analysis of improved water availability, the environmental and health problems caused by the projects, and their direct and indirect impacts on the living conditions of the affected population. The OMVS was reorganized in response to these problems, with new indicators defined and strategies worked out to compile the data required by the OMVS to continuously monitor the impacts of its water projects on water availability, health, the state of the environment, and socio-economic development - and if need be to adjust its management strategy.

As a result, the High Commission set up an Observatory of the Environment in November 2000 to create a network of all of the producers/possessors of thematic data and hook them up to a general database that would be managed by the Observatory's Coordination Bureau. Agreement protocols were drawn up by these organizations and the OMVS to formally define the roles and responsibilities of each of the actors in the data collection, processing and storage procedures on the one hand, and data development, dissemination and sharing on the other.

In 2007, Senegal River basin hydrology and meteorological networks have been rehabilitated and were fully operational consisting of 19hydrological stations (3 updated stations in Mali, 3 in Mauritania and 5 in Senegal and 8 fully rehabilitated stations in Guinea) and 24 meteorological stations through the Senegal River Basin Water and Environmental Management Project. Currently, data collection is based on a network of hydrological stations of the Member States. Water level data in 15 stations are automatically transmitted twice a day (8 hours and 12 hours, called the shift) with SSB radios. The OMVS collects data from countries in a data sharing meeting that is held once a year, where each country's focal point reports his country data in the following fields: climate, surface water, groundwater, human health, fish, animal health, agriculture, and energy. These data are the basis for the Environmental Status Reports that are issued by the OMVS. Currently, no surface water quality data is collected, only flow data from the dams.

A comprehensive set of detailed indicators have been suggested by the OMVS in their first annual report on the State of the Environment and Natural Resources based on the four thematic target classes mentioned above and classified according to the Pressures/State/Response (Pressions/Etat /Réponses, PER) model. Details of the selected indicators including definition and calculation methods are given in a technical report. Indicators were considered in two levels of precision: target indicators and temporary indicators. Target indicators are indicators approaching the best ideal indicators defined by scientific experts, given the available data, their quality, their homogeneity across the basin, their time of acquisition by the Observatory. In the absence of certain data to calculate these targeted indicators, similar temporary indicators are proposed.

The establishment of the Environment Observatory in the Senegal River Valley started in 2000 with support from the French Global Environment Facility (FFEM). The Environmental Observatory was set up as part of the Program for the Mitigation and Monitoring of Impacts on the Environment (PASIE). The Environmental Observatory (SOE) is a network of governmental and non-governmental organizations designed to bring together organizations and individuals that provide environmental information. The Observatory has a central database designed to make data available and to publish them on a periodic basis. The project has resulted in the development of a computerized tool labeled SOE-OMVS database, allowing each thematic network to manage the stakeholders, the handled information, the information flows between the stakeholders, and information processing resulting in actions.

The SOE-OMVS is a strategic tool for monitoring the state of Environment Basin. The first phase of the project covered 13 areas: surface water, groundwater, waterborne diseases, Wetlands, fishery resources, climatology, terrestrial and aquatic wildlife, the socio-economic situation, invasive plants, the canopy, soil science, fertilizers and pesticides, quarries and mines. Tools for monitoring and evaluation in place are: Relational Database, Metabase, MapInfo software to generate maps, and a website for publication of SOE products online.

The Water resources Dash board of the Senegal River (TBR) is another tool that centralizes and structures information on water resources and their use in the basin. It offers decision support to the management strategy with an operational approach based on forecasting to determine water allocations compatible with the current availability and anticipated availability for coming seasons, balancing between water use for irrigation and hydropower generation. The efficient operation of the TBR relies on collecting information by operational structures, data producers themes, and constituting focal points, formalized by technical and administrative protocols, and involving all actors of the 4 countries in the basin in a participatory and collaborative approach. Once collected and validated, information are published in the TBR and are accessible by data producers, partners and clients via internet connection.

The Technical Department of the High Commission also publishes a monthly hydrological bulletin for the technical services of the member states and other actors (producers, development partners, NGOs, industrial projects) carrying out activities in the basin. Currently, OMVS has a set of tools for data management of the Senegal River which are: The HYDRACCESS database, software for simulation of Manantali dam (Simulsen), Software for management of Manantali dam in real time (Progeman), Software for management of Diama dam in real time (Gesdiam), Software for calculating Diama dam backwater curve (Corediam).

Information collected by the SOE was used to issue a baseline report on the status of the environment in 2003. Although the status of the environment report was intended to be an annual report (as indicated by its title in 2006), only two other reports have since been issued. The 2006 report covered the period between the baseline report in 2003 and 2005, while another report issued in 2011 covered the period between 2006 and 2010, consisting of a final report and a synthesis report.

The OMVS, through its various programs, supports the achievement of the Millennium Development Goals (MDGs). The Master Plan for Development (SDAGE) gives details of the efforts by the OMVS to achieve the MDGs. To improve access to water and sanitation for the achievement of the MDGs, significant efforts have been made by the countries of the OMVS through several projects to improve the conditions of living for their populations.

The OMVS is an example for cooperation with a strong international competence center in charge of organizing cooperation with national authorities. It is an experienced river basin organization with a clear mandate, vision with innovative tools. It is decentralized at national levels, associated with technical bodies (Permanent Water Commission, Regional Steering Committee, and Environment Observatory), and coupled with autonomous management entities, familiar with private sector involvement, and open to stakeholder participation. To date, management of the Senegal River suffers from two on-going issues: conflicts of interest between regional/international, national and local actors; and between some farmers who prefer recession agriculture and the state's interest in irrigation. Nevertheless, the example of the OMVS shows overall that regional cooperation provides benefits and advantages over unilateral action.

The OMVS is responsible for the operational regulation of jointly run infrastructure, and as such it also operates hydrological measuring networks. The OMVS Observatory (SOE-OMVS) is an institution with an increasing importance to monitor the status of the Senegal River Basin and the environmental impact of the projects being carried out within its boundaries. In practice, significant disparities exist between countries and between ministries within member states that impede the collection and subsequent dissemination of relevant data. While each CNC (Centre Nationale de Collecte) receives some capacity building support from the OMVS to improve their data collection and storage systems, this does not solve the problem of weak data collection mechanisms in certain sectors, such as waterborne diseases, due to the nature of the data itself. Addressing these deficiencies remains a work in progress.

The recent rehabilitation and expansion of surface water monitoring network and the establishment of a groundwater monitoring network is a good achievement, but continual maintenance of the network and updating of devices and software should be considered. Financial as well as human resources should be secured to ensure sustainability of the network. On the other hand, additional parameters, including water quality parameters, need to be collected in order to better report the environmental status of the basin. It is also important to boost the use of automatic data gauging and acquisition. This could be achieved through the Senegal-HYCOS project. The purpose of the Senegal-HYCOS is to implement a device, based in part on the update of the observation network and telecommunications, and secondly on strengthening national (National Hydrological Services) and regional (OMVS) capacities to use the data and translate it into information that can improve the management capacity of water resources in the basin. A web-based database system accessible to all stakeholders may also be helpful. Additional improvement can be achieved by development of monitoring, modeling, and forecasting facilities, for

planning purposes, which take climate change into consideration. This can ultimately be promoted to a full Decision Support System (DSS) for the whole basin.

Both internal and external environments affect the performance of the OMVS and its activities. A SWOT analysis (Strengths, Weaknesses, Opportunities, and Threats) of the M&E-related operating environment of the OMVS and water indicators used in the Senegal River Basin has been performed.

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| | |
|---|---|
| AFD | Agence Française de Development |
| AMCOW | African Ministerial Council on Water |
| AWIS | African Water Documentation and Information System |
| CB | Comité de Base - Basin Committee |
| CCEG | Conférence des Chefs d'État et de Gouvernement - Conference of Heads of State and Government |
| CCPD | Comité Consultatif des Partenaires au Développment - Consultative Committee of Development Partners |
| CEDARE | Center for Environment and Development for the Arab Region and Europe |
| CNC | Centre Nationale de Collecte – National Collection Center |
| CPE | Commission Permanente des Eaux – Permanent Water Commission |
| CRP | Comités Régionaux de Planification–Regional Planning Committees |
| ENTRO | Eastern Nile Technical Regional Office |
| EWS | Early Warning System |
| FFEM | Fonds Français pour l'Environnement Mondial- French Global Environment Facility |
| GEF | Global Environment Facility |
| GWP | Global Water Partnership |
| INBO | International Network of Basin Organizations |
| IRD | Institut de Recherche pour le Développement - Research Institute for Development, France |
| MDGs | Millennium Development Goals |
| MEWINA | Monitoring and Evaluation for Water in North Africa |
| N-AMCOW | North-African Ministerial Council on Water |
| OMVS | Organisation pour la Mise en Valeur du fleuve Sénégal – Organisation for the Development of the Senegal River |
| OERS | Organisation des Etats Riverains du Sénégal– Organization of Riparian States of the Senegal River |

| | |
|---|---|
| PASIE | Plan d'Atténuationet de Suivi des Impacts sur l'Environnement - environmental impactalleviation and follow-up program |
| PWC | Permanent Water Commission |
| SDAGE | Schéma Directeur d'Aménagementet de Gestion des Eaux - Master Plan for Development and Management of Water |
| SOGED | Société de Gestionet d'Exploitation du barrage de Diama – Company for the management and development of the Diama dam |
| SOGEM | Société de Gestion de l'énergie de Manantali - Company for the management and development of the Manantali dam |
| SOE | Service de l'Observatoire de l'Environnement – Environmental Observatory Service |
| TBR | Tableau de Bord de la Ressource en eau - Water Resources Dashboard |
| UNDP | United Nations Development Program |
| UNESCO | United Nations Educational, Scientific and Cultural Organization |
| USAID | United States Agency for International Development |
| WB | World Bank |

## Appendices

Appendix 1 Definition and Methods of Calculation of Indicators

## 1. Background

The Senegal River basin, shown in Figure (1), is located in West Africa between latitudes10°30 and 17°30 N and longitudes 7°30 and 16°30 W, and covers 1.6% of the continent and spreads over four countries: Guinea, Mali, Mauritania, and Senegal. The Senegal River is the second largest river in West Africa. It is 1800 km long and drains into the Atlantic Ocean. The sources of the Senegal River are located in Guinea and in the wetter south-western part of Mali. The main tributaries, contributing 80% of the flow, are the Bafing, Bakoye, and Faleme Rivers which all originate in the Fouta Djallon Mountains located in Guinea. The Karakoro River and the Gorgol River with its two tributaries, the white Gorgol and the black Gorgol, both originate in Mauritania.

Total annual discharge leaving Guinea is estimated at about 8 $km^3$, but during the dry season the rivers frequently run dry. The Faleme River forms the border between Senegal and Mali and covers the most part of this border. By the time they reach the border point between Mali, Mauritania and Senegal, the different tributaries join to form the Senegal River, which then continues to form the border between Senegal and Mauritania. The Karakoro River flows into the Senegal River at roughly the same point. The annual discharge of the Senegal River at Bakel is 20 $km^3$. The Gorgol River joins it about 200 km downstream. Further downstream there are no other important tributaries. Lac de Guiers is a source of the freshwater supply for Dakar, the capital of Senegal. The construction of the Diama dam in 1986, located approximately 23 km from the river's mouth, has helped to raise the level of the upstream water body (confined by dykes along both shores) to facilitate irrigation, navigation and the filling of lac de Guiers in Senegal and lac Rqiz in Mauritania.

The Senegal River basin covers a surface area of about300, 000 $km^2$. The high plateau in northern Guinea covers 31,000 $km^2$ (11 percent of the basin), 155,000 $km^2$are situated in western Mali (53 percent of the basin), 75,500 $km^2$ are in southern Mauritania (26 percent of the basin) and 27,500 $km^2$ are in northern Senegal (10 percent of the basin) (UNESCO, 2003). The basin has three distinct parts: the upper basin, which is mountainous, the valley (itself divided into high, middle and lower) and the delta, which is a source of biological diversity and wetlands (Figure 2). Topographical, hydrographic and climatic conditions are very different in these three regions and seasonal temperature variations are extensive. Table (1) gives a summary of the physical data of the Senegal River Basin.

The Senegal River basin has a total population of around 3,500,000 inhabitants, 85 percent of whom live near the river. This figure includes approximately 16 percent of the total populations of Mali, Mauritania and Senegal, which are members of the Organization for the Development of the Senegal River Senegal River (OMVS), plus the population of the Guinean portion of the upper basin. The population within the basin is increasing at a rate of about 3 percent per year, which is slightly higher than the individual averages for the three member states (UNESCO, 2003). Main activities in the basin include irrigation, which is the main driver for development in the basin, livestock raising, fishing, mining, and some underdeveloped industries (UNESCO, 2003). As for hydropower generation, the hydroelectric power plant in Manantali has been in operation since September 2001 with a capacity of 200 MW, to furnish an average of 800 GWh/year to electricity companies in the three OMVS member states. Table (2) gives a summary of socio-economic data in the OMVS states. Water use statistics are shown in Table (3).

**Table 1. Senegal River basin area and rainfall by country (UNESCO, 2003)**

| | | Mali | Mauritania | Senegal | Guinea |
|---|---|---|---|---|---|
| Surface area ($Km^2$) | National | 1,248,574 | 1,030,700 | 197,000 | 245,857 |
| | Basin | 155,000 | 75,500 | 27,500 | 31,000 |
| | % of basin | 53 | 26 | 10 | 11 |
| Rainfall annual average (mm) | National | 850 | 290 | 800 | 2,200 |
| | Basin | 300 to 700 | 80 to 400 | 150 to 450 | 1200 to 2000 |
| Temperature | National | 29 | 28 | 29 | 26 |
| | Basin min and max | 15 to 42 | 18 to 43 | 17 to 40 | 10 to 33 |

**Table 2. Summary of socio-economic data in the OMVS states (UNESCO, 2003)**

| | Senegal River basin | Mali | Mauritania | Senegal |
|---|---|---|---|---|
| Population (million inhabitants) | 3.5 | 11 | 3 | 10 |
| Annual growth rate (%) | 3 | 2.97 | 2.9 | 2.8 |
| Urbanization rate (%) | NA | 41 | 53 | 51 |
| Farmland (ha) | 823,000 | NA | NA | NA |
| Irrigated land (ha) – National total | | 78,630 | 49,200 | 71,400 |
| Part in basin | | 4,000 | 44,449 | 67,830 |
| Cattle (x1000 units) | 2,700 | 6,427 | 1,394 | 2,927 |
| Sheep and goats (x1000 units) | 4,500 | 15,986 | 10,850 | 8,330 |
| Fish catch (t/year) | 26to 47,000 | 100,000 | 620,000 | 395,000 |


**Figure 1.** Senegal River Basin (UNESCO, 2003)

**Table 3. Water use within OMVS (millions m$^3$) (ENTRO, 2007)**

| | Mali | Mauritania | Senegal |
|---|---|---|---|
| Agriculture | 1319 | 1499 | 1251 |
| Domestic use | 27 | 101 | 68 |
| Industry | 14 | 29 | 41 |
| **TOTAL** | **1360** | **1630** | **1380** |

## 2. Cooperation in the Senegal River Basin

The first institutions to develop the Senegal River valley were created during the colonial period (UNESCO, 2003). However, Colonial conferences on the status of Africa's rivers had not recognized the Senegal River as an international river, as it belonged to a single colonial power (Alam and Dione, 2004). Land locked Mali sought to have the Senegal River's international status recognized in order to ensure navigation rights. Freedom of navigation on the Senegal River derives from the principle of reciprocity, not universal access (Alam and Dione, 2004). On 25 July 1963, very soon after independence, Guinea, Mali, Mauritania and Senegal signed the Bamako Convention for the Development of the Senegal River Basin. This convention declared the Senegal River to be an 'International River' and created an 'Interstate Committee' to oversee its development. The Bamako Convention was supplemented by the Dakar Convention, signed on 7 February 1964, concerning the status of the Senegal River. The Interstate Committee laid the foundation for sub-regional cooperation in development of the Senegal River basin.

On 26 May 1968, the Labé Convention created the Organization of Riparian States of the Senegal River (OERS, Organisation des Etats Riverains du Sénégal) to replace the Interstate Committee, broadening the field of sub-regional cooperation, with the mandate to develop the basin by facilitating closer coordination beyond the water and agricultural sectors. In a wide-ranging development plan the countries pledged to cooperate in other areas through OERS: harmonize civil legislation; improve education, industrial growth, transport, and telecommunications; and facilitate trade and labor movements across borders. In conformity with the Organization for African Unity Charter, the countries adopted a resolution calling for unprecedented levels of cooperation and integration. The aim was, as President Modibo Keita of Mali put it, for all citizens to "regard themselves as citizens of the Senegal River states rather than Guineans, Malians, Mauritanians, or Senegalese (Alam and Dione, 2004). After Guinea withdrew from the OERS, on March 11, 1972, Mali, Mauritania, and Senegal signed the Nouakchott Convention, reconfirming the river's international status and establishing the Senegal River Development Organization (Organisation pour la Mise en Valeur du fleuve Sénégal, OMVS) and dissolving the OERS. Although Guinea was not a party to the convention, it did not oppose it and joined the OMVS later in 2006. The OMVS has since created a flexible and functional legal framework enabling collaboration and a co-management of the basin. The principal legal texts governing OMVS are:

- The Convention concerning the status of the Senegal River (Convention relative au statut du fleuve Sénégal), 11 March 1972. By this convention, the Senegal River and its tributaries were declared an 'International Watercourse', guaranteeing freedom of navigation and the equal treatment of users;
- The Convention creating the OMVS (Convention portant creation de l'Organisation pour la Mise en Valeur du Fleuve Sénégal), 11 March 1972;
- The Convention concerning the Legal Status of Jointly-owned Structures (Convention relative au statutjuridique des ouvragescommuns), 12 December 1978, supplemented by the Convention concerning the Financing of Jointly Owned Structures (Convention relative aux financements des ouvragescommuns), 12 March 1982. These declare that:
    - all structures are the joint and indivisible property of the member states;
    - each co-owner state has an individual right to an indivisible share and a collective right to the use and administration of the joint property;

- The investment costs and operating expenses are distributed between the co-owner states on the basis of benefits each co-owner state draws from the exploitation of structures. This distribution can be revised on a regular basis, depending on profits;
- each co-owner state guarantees the repayment of loans extended to the OMVS for the construction of structures;
- two entities manage the jointly-owned structures for the OMVS: one dedicated to the management and development of the Diama dam (SOGED, Société de gestion et d'exploitation du barrage de Diama), the other to the Manantali dam (SOGEM, Sociétédegestion de l'énergie de Manantali), both created in 1997.

- In 1992, signature of a framework cooperation agreement between Guinea and the OMVS (Protocoled'accord-cadre de coopération entre la République de Guinée et l'OMVS), creating a framework for cooperation in actions of mutual interest concerning the Senegal River and its basin, including a provision allowing Guinea to attend OMVS meetings as an observer;
- The Senegal River Water Charter, May 2002 (Charte des Eaux du FleuveSénégal) whose purpose is to:
  - set the principles and procedures for allocating water between the various use sectors;
  - define procedures for the examination and acceptance of new water use projects;
  - determine regulations for environmental preservation and protection; and
  - define the framework and procedures for water user participation in resource management decision-making processes.

In 2006, Guinea joined the initial members, Mali, Senegal and Mauritania, and became a member of OMVS (GWP and INBO, 2009). Table (4) shows the chronology of cooperation in the Senegal River basin. Samples of the abovementioned treaties and other relevant documents can be found on the OMVS Portal at the following address: (http://cda.portail-omvs.org/sites/cda.portail-omvs.org/files/sites/default/files/fichiers_joint/fe10799.pdf).

When the OMVS was created in 1972, the major concern was to develop infrastructure to address water stress resulting from a cycle of droughts, develop agriculture, reduce the cost of hydro-electricity and open up Mali by improving navigation. The average annual flow of the Senegal River had fallen from 1374 $m^3/s$ in the 1903-1950 period to 840 $m^3/s$ in the 1950-1972 period (later it fell to 419 $m^3/s$ in the 1973-2002 period), inducing a severe problem of salt water intrusion from the sea (as far as 200 Km upstream of Saint Louis), creating problems with fresh water availability for domestic use and agriculture (Afouda et al., 2007). At that time, OMVS was mainly dedicated to infrastructure development, although it played an important role in sharing costs and benefits between riparian countries (UNESCO, 2003).

In 1998, the Program for the Mitigation and Monitoring of Environmental Impacts drew attention to the lack of management and the risks this involved. The Observatory of the Environment (SOE) was created in 2000, as a tool to support basin management. In 2002, the Conference of Heads of States and Governments, meeting in Nouakchott, highlighted the need for an integrated basin management approach. The Observatory of the Environment therefore became the Observatory of Sustainable

Development, shifting its focus from management of shared resources to the management of information and data for sustainable development. It is expected that a Water Development and Management Master Plan will be developed at basin level. Part of the plan will be for integrated water resources management programs at the local level. Today, OMVS is both an agency that constructs the infrastructure necessary for the sustainable development of the basin and an integrated water resources management agency (UNESCO, 2003).

**Table 4. Chronology of cooperation in the Senegal River basin (Alam and Dione, 2004; Newton, 2007; GWP and INBO, 2009)**

| | |
|---|---|
| 1963 | Bamako Convention. Guinea, Mali, Mauritania, and Senegal establish the Interstate Committee and declare the Senegal River an international river. |
| 1964 | Signing of the Dakar Convention. |
| 1965 | The heads of state of Guinea, Mali, Mauritania and Senegal meet to discuss the promotion of regional integration. |
| 1967 | Guinea suspends participation due to tensions with Senegal. |
| 1967 | Through the efforts of Mali and Mauritania, the four heads of state met again in Bamako. |
| 1968 | The four basin countries, through the Labé Convention, form the Organization for the Coastal States of the Senegal River (OERS) and define a basin-wide development program. |
| 1971 | Due to political instability, Guinea does not attend two OERS meetings and later withdraws from the organization. |
| 1971 | The Council of Ministers acknowledge the problems arising within OERS |
| 1972 | Mali, Mauritania, and Senegal sign the Nouakchott Convention and create the Senegal River Development Organization (OMVS) to implement the development program outlined by the OERS. |
| 1975 | Restructuring of OMVS into three entities: Heads of State Summit, Council of Ministers and the High Commission (technical). |
| 1978 | Mali, Mauritania, and Senegal sign a convention establishing the legal status of common works (Jointly-Owned Structures). |
| 1982 | Mali, Mauritania, and Senegal sign a convention on financing the common works. |
| 1984 | Twelve donors support building the Manantali and Diama Dams. |
| 1986 | The Diama Dam becomes operational. |
| 1990 | The Manantali Dam becomes operational. |
| 1992 | The OMVS-Guinea protocol is signed outlining framework for cooperation in projects of mutual interest, including permitting Guinea to attend OMVS meetings as an observer. |
| 1995 | Agriculture Sector Adjustment Program to provide food security, rural incomes, natural resource management through deregulation, reduced state intervention and land-tenure reform. |
| 1997 | The Regional Hydropower Project begins. The Diama Dam Management Company (SOGED) and the Manantali Dam Management Company (SOGEM), the dams' management agencies, are established. |
| 1998 | Creation of the Environment Impact Mitigation and Monitoring Program (PASIE) by |
| 2000 | Establishment of the Environmental Observatory by OMVS to monitor environmental change in the Basin as part of PASIE. |
| 2002 | Electricity generated at Manantali is transmitted to Bamako, Dakar, and Nouakchott. Mali, Mauritania, and Senegal sign and ratify the Water Charter. |
| 2002 | Water and Environmental Management Project funded by GEF |
| 2003 | Guinea participates in the OMVS Heads of State Summit in Nouakchott. |
| 2004 | The first inter-ministerial meeting between Guinea and the OMVS member states is held, in Nouakchott. |
| 2004 | The first technical meeting on establishing an inclusive framework for the basin's joint management is held, in Conakry. |
| 2006 | Guinea joins OMVS. |

# 3. The Organization for the Development of the Senegal River (OMVS)

## 3.1 Governance

Under the amended Convention of 11 March 1972, OMVS is under the high auspices of the Conference of Heads of State and Government (Conférence des Chefs d'Étatet de Gouvernement, CCEG), the supreme body that sets policy for cooperation and development of the organization. The presidency of the assembly shall be held in turn for a term of two years.

In addition to the Conference of Heads of State and Government, the restructured organization has five (5) permanent bodies that are:

1) The Council of Ministers: This is the design and control body. It details the general OMVS policy for the development of its resources. The presidency of the council is held in turn by each of the Member States for a term of two years.

2) The High Commission: This is the executive body of the OMVS. It implements the decisions of the Council of Ministers, reports regularly on their performance as well as any action taken under the guidance received and within the limits of the powers delegated to it. It is headed by a High Commissioner appointed for a term of four years, supported and assisted by a Secretary-General also appointed for the same term.

3) The Manantali Energy Management Company (Société de Gestion de l'Energie de Manantali, SOGEM): Inter-state owned company established on 7 January 1997.

4) The Diama Dam Management and Operation Company (La Société de Gestion et d'Exploitation du Barrage de Diama, SOGED): As SOGEM, SOGED is an inter-state public company, also established on 7 January 1997.

5) The Navigation Management and Operation Company (La Société de Gestionetd'Exploitation de la Navigation, SOGENAV): It is responsible for managing and administering the activities of navigation and transport on the river and the operation, maintenance and renewal works.

6) The Advisory Bodies (CB, CPE, CCPD): Basin Committee (CB) that gathers river basin stakeholders; Consultative Committee of Development Partners (CCPD) where government, financing institutions and OMVS are represented; Permanent Water Commission (CPE) that is in charge with defining the principles and modalities for allocating water resources among water use sectors, it receives, studies and submits proposals for allocation; high level member countries' representatives attend its meetings.

The decisions of the CCEG and the Council of Ministers are taken unanimously. The decisions are binding on the member states (Burchi and Spreij, 2002).

In addition to the permanent bodies described above, the following non-permanent bodies are part of the OMVS (UNESCO, 2003):

- An OMVS national coordination committee in each member state;
- Local coordination committees;

- Regional Planning Committees (CRP, ComitésRégionaux de Planification);
- Consultative Committee (CC, Comité Consultatif).

This organizational framework, statutorily strong but flexible on the operational level, enables all of the actors and stakeholders to participate effectively in the efficient management of both the basin's natural resources and its other economic potentials. For more than thirty years now, they have been able to find suitable solutions to all of the technical, social, political and other problems linked to the development of the Senegal River basin's water resources (UNESCO, 2003).

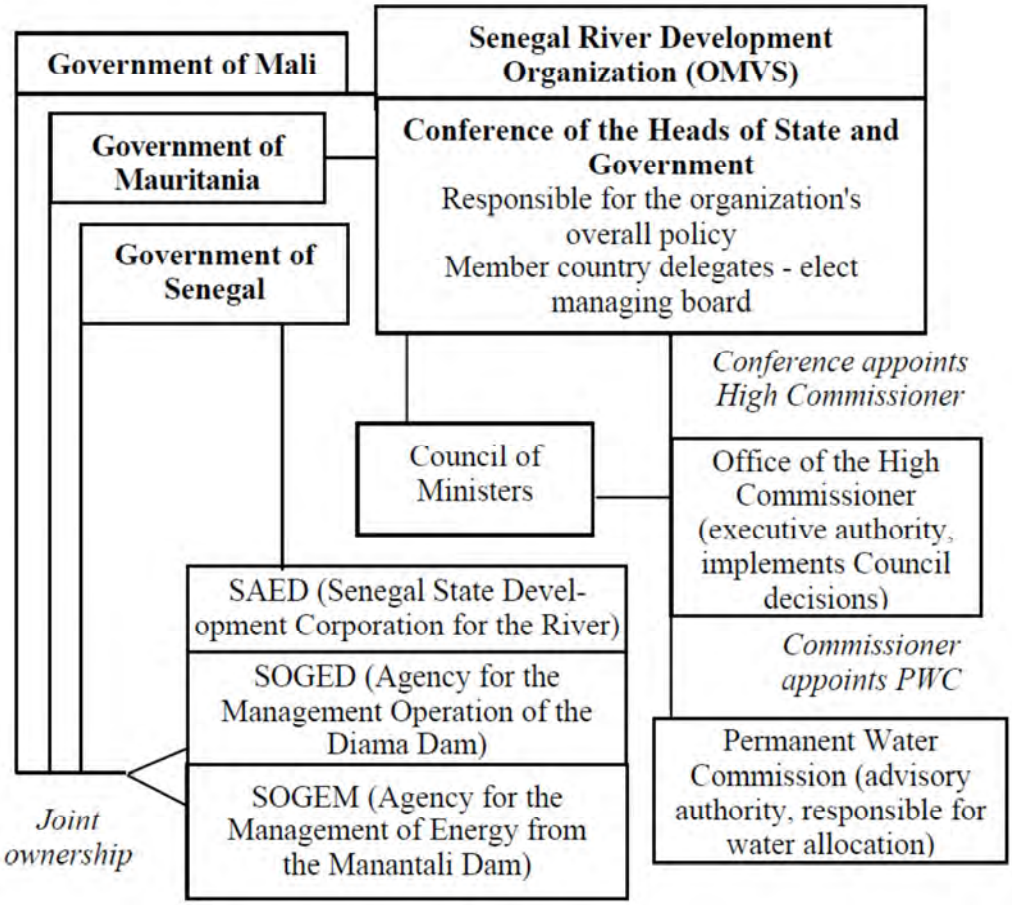


**Figure 2. Organization chart of the OMVS (Scheumann and Neubert, 2006)**

## 3.2 Finance

Two types of funding are used to finance the development of the Senegal River basin. The first one covers the operating costs of the various OMVS bodies, and comes from the three member states; each of them pays one third of the total in January of every year. To finance the jointly owned structures and other development activities, funds are sought in the form of loans extended either to the states or directly to the OMVS. In this case, the member states must guarantee the loans. Each member state ensures the reimbursement of its share of the loans (UNESCO, 2003).

The apportionment of costs and debts is done according to an accepted formula, subject to revision, as stipulated in the conventions. The underlying principle of cost recovery is that the users pay, but economic conditions are also taken into consideration. Taxes paid to the organization are used to cover operating expenses (UNESCO, 2003).

As an Example, in the early 1980s the OMVS received loans and grants from various funding agencies to finance this major infrastructure program. The contribution it would make to irrigation, energy production and navigation was calculated as well as the overall benefits to each member country (GWP and INBO, 2009) as follows:

| Benefit | Mali | Mauritania | Senegal |
|---|---|---|---|
| Irrigation | 11% | 31% | 58% |
| Energy production | 52% | 15% | 33% |
| Navigation | 82% | 12% | 6% |
| Overall | 35% | 23% | 42% |

The debt repayment was shared pro-rata among the three countries according to the benefits that would accrue to each.

The cost allocation model of the OMVS was developed by the University of Utah with the aim of allocating the costs and expenses of joint works first between facilities, then between States. The output of this model is a cost allocation key that establishes the share of each State in the responsibility for reimbursement of costs and expenses of the joint structures OMVS. The services in consideration are irrigation, hydropower generation, navigation, and urban and industrial water use; and the states are Mali, Mauritania and Senegal. With the accession of Guinea, the new layout of the OMVS and the increased precision of the data service plan, it was necessary to develop a new model of distribution of costs and expenses of joint works. A new model capable of taking care of both the present and future characteristics of the OMVS has been established, during the year 2010, in collaboration with the University of Utah. To take into account all the relevant parameters, it was necessary to develop two sub-models from which the outputs in terms of unit profit per country are used as inputs of the global model of the distribution of costs and expenses. These are a sub-model for agriculture and a sub-model for navigation (multimodal transport). The model guarantees two essential criteria, namely, economic efficiency (optimality) of the multinational program with multiple OMVS goals and equity between services on the one hand and the States on the other. As part of the development process and operation of the model, input data are of paramount importance. Attention should therefore be drawn to the relevance of the model output (cost allocation key) and that relevance depends on the completeness and reliability of data inputs of the model. These data are often questionable by States if they are not

collected and refined in a rigorous and transparent manner. For this to occur, it is strictly recommended to use technical assistance, which has extensive experience in the collection and refinement of the data in this type of model, the objective of this assistance is guaranteed to reach a consensus on data and therefore the approval of a new apportionment (Ould Bah, 2011).

According to the World Bank (World Bank, 2005), donors involved in financing different OMVS activities, programs, and projects include: the International Development Association (IDA), the CaisseFrancaise de développment (CFD, France) which is now the Agence Francaise de Développment (AFD, France), the KreditanstaltfürWiederaufbau (KfW, Germany), the Canadian International Development Agency (CIDA, Canada), the European Union, the European Investment Bank (EIB), the Islamic Development Bank (IDB), the African Development Bank (AfDB), the Arab Fund for Economic and Social Development (FADES), the West African Development Bank (BOAD), and the Nordic Development Bank (NDB). The World Bank was active in the area already since the1960s with its 'Regional hydropower development project'. But it backed out of the Manantali and Diama dam project because of expected, but unpredictable negative influences on the environment and the livelihood (Hirji and Panella, 2003). USAID as well declined to support the construction of the dams but provided financial and technical assistance for environmental assessment and resettlement (Bosshard, 1999). Today the World Bank and the USAID are involved in projects in the Senegal River basin again. Other financing organizations include the Global Environment Facility (GEF) and the United Nations Development Program (UNDP).

### 3.3 Cooperation in Integrated Water Resources Management

With the drought that has developed since 1972/1973, the leaders of three riparian States of the Senegal River decided in 1972 to join efforts within the Organization for the Development of the Senegal River (OMVS). In addition to the agreements on OMVS establishment and on the legal status of the Senegal River, a Convention on the legal status of common infrastructures was signed on 21 December 1978 by the Heads of State and Government of Mali, Mauritania and Senegal, who decided in 1974 that installations of common interest on the Senegal River would jointly belong to the Member States of the OMVS. The Convention on the financing arrangements for common infrastructures was signed on 12 May 1982 in Bamako.

Due to potential conflicts between power generation and the other uses of the Senegal River, the governments have embarked through OMVS on the implementation of an environmental impact alleviation and follow-up program (PASIE, Plan d'Atténuation et deSuivi des Impacts surl'Environnement). It is an environmental program specifically designed to address, monitor and mitigate the environmental issues raised by, and related to, the development and distribution of power from the Manantali power plant. PASIE was finalized by 2002, and was succeeded by the Environmental Observatory (SOE). The May 2002 effective date of the Senegal River Water Charter and the start-up of environmental monitoring by the SOE represented golden opportunities for increasing the involvement of representatives of the various stakeholders in the resource management and decision making process. This participatory approach has been reinforced by the launching of the Master Plan the following year (GWP and INBO, 2012).

In March 2002, the OMVS began drafting a Master Plan for Development and Water Management (SDAGE, Schéma Directeur d'Aménagementet de Gestion des Eaux) of the Senegal River basin. This procedure enables progress to be made in the following areas:

- education, by favoring collaboration between stakeholders;
- technology, by reassessing the situation (diagnosis of the entire basin) and defining the strategic orientations and measures required to establish sustainable resource management practices;
- legislation, by ensuring that regulatory actions carried out in all of the member states are coherent; and
- finances by focusing funding on future OMVS programmes.

The formulation of the Master Plan for Water Development and Management (SDAGE) of the Organization for the Development of the Senegal River (OMVS) was conducted in a participatory manner. The characterization validated in 2009, a true knowledge base shared by all stakeholders, is firstly based on a rich bibliography of studies, and secondly on meetings organized in each country with the water stakeholders. The participatory approach implemented by the OMVS helped involving people (often illiterate)in developing the SDAGE, a complex and technical document. An extension guide ("image box") has been developed especially to facilitate the appropriation and development of the SDAGE. Radio programs were also used and strong support was provided by local facilitator's trained by the project team (GWP and INBO, 2012).

The OMVS's fundamental conventions of 1972 and the Senegal River Water Charter signed in May 2002, which establish its legal and regulatory framework; clearly state that river water must be allocated to the various use sectors. The resource is not allocated to riparian states in terms of volumes of water to be withdrawn, but rather to uses as a function of possibilities. The various uses can before agriculture, inland fishing, livestock rising, fish farming, tree farming, fauna and flora, hydroelectric energy production, drinking water supply, health, industry, navigation and the environment.

The principles and procedures for the allocation of water wiredrawn up and a Permanent Water Commission (PWC) was set up to serve as an advisory body to the OMVS's Council of Ministers that makes decisions and asks the High Commission to oversee their application. The OMVS's process for managing needs has four steps.

- First, an inventory of needs is taken by the OMVS National Committees under the Ministries in charge of water in each country. The 'state of needs' is then sent to the OMVS High Commission.
- The High Commission centralizes all of the needs, writes a synthesis report and convenes a meeting of the Permanent Water Commission to vote on recommendations. It then draws up a record of the proceedings with precise recommendations for the Council of Ministers.
- The Council of Ministers makes decisions based on the information provided by the Permanent Water Commission, either in a formal meeting or by informal telephone consultation. The High Commission receives instructions from the Council of Ministers and transmits to member states and other actors the procedures for carrying out the measures adopted by consensus by the member states in the Council of Ministers.
- The work of the Permanent Water Commission and the criteria used by the ministers for decision-making are based on the following general principles:
    - Reasonable and fair use of the river water;
    - Obligation to preserve the basin's environment;
    - Obligation to negotiate in cases of water use disagreement/conflict; and
    - Obligation of each riparian state to inform the others before undertaking any action or project that could affect water availability.

The objective of the OMVS method of water allocation is to ensure that local populations benefit fully from the resource, while ensuring the safety of people and structures, respecting the fundamental human right to clean water and working towards the sustainable development of the Senegal River basin.

The Diama (anti-salt dam) and Manantali Dams (hydropower and regulating dam) were respectively built in 1988 and 1990. They are works of the so-called "first generation". Operation and maintenance are carried out by the Diama Dam Management and Exploitation Company (SOGED) and the Manantali Energy Management Company (SOGEM), the OMVS's Council of Ministers being the highest supervising body. The payment of the incurred debt to donors is distributed between the OMVS Member States in proportion to the benefits provided by the programme, especially regarding energy production but also navigation and irrigation. The construction of the Diama anti-salt dam and the Manantali multipurpose hydroelectric dam marked the partial conclusion of a major phase, based on a development approach. The location of the two dams is shown in Figure (3). Today, the OMVS is attempting to redefine medium-

and long-term development strategy for the entire basin, associating development with integrated and sustainable management.

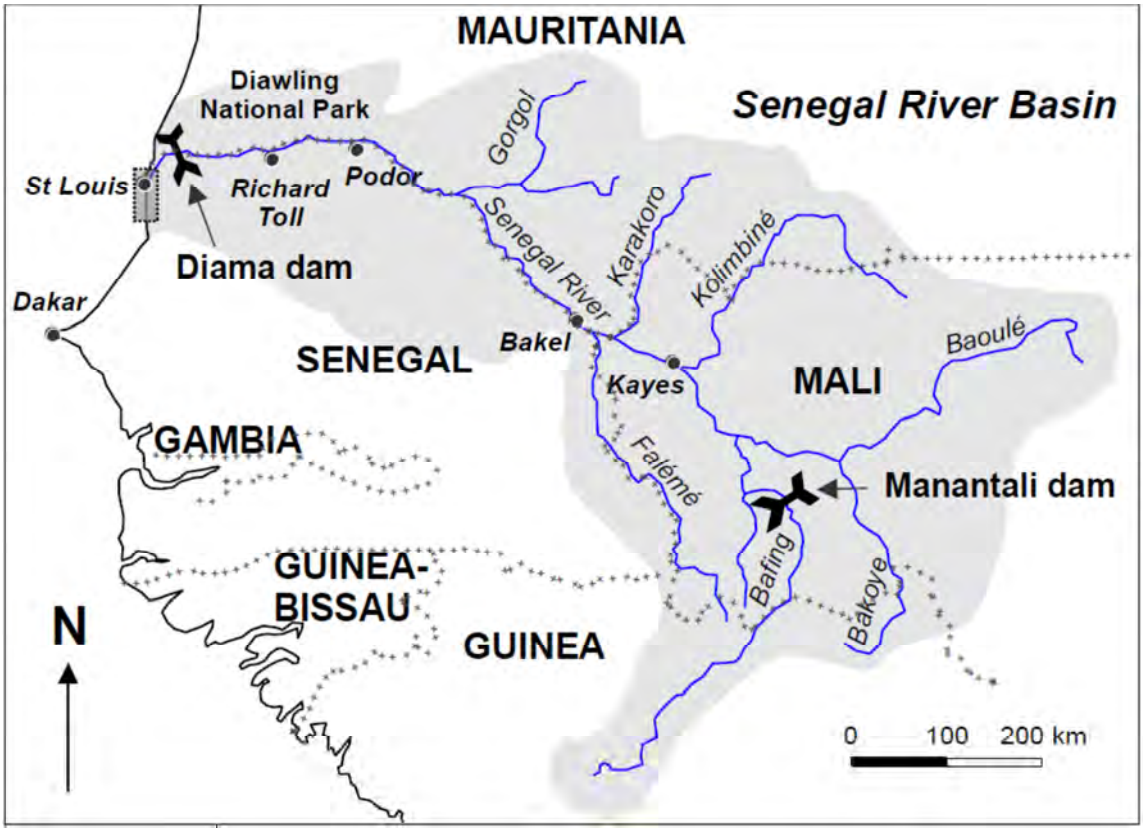


**Figure 3. Location of the Diama and Manantali dams, Senegal River Basin (Dumas et al., 2010)**

OMVS efforts are continuing today, including the following achievements (GWP and INBO, 2012):

- Increasing hydropower generation to create an enabling environment for lower production costs with the completion of the Félou and Gouina installations on the river (ongoing, second generation);
- Controlling, regulating, securing and diversifying water resources to meet the enormous needs. Efforts will focus on the implementation of baseline studies and work for the Gourbassi dam (third generation);
- The Organization for the Development of the Senegal River (OMVS) has had strong political support for more than thirty years at the highest level (the supreme governing body of the organization is the Conference of Heads of State and Government). This political support is based on a benefit-sharing system between riparian states and the implementation of concrete activities in favor of regional development (GWP and INBO, 2009).

The OMVS has conducted a number of basin-wide studies and development programs (Diawara, 2005):

- Integrated Regional Infrastructure and Water Management Plan of Senegal River Basin
- Regional Environment Code and Environmental Actions Plan

- Regional Health Program
- Observatory of Environment (control panel for environment and water quality & balance)
- Water saving and Regional Program for more effective irrigation systems
- Environmental impacts mitigation and environmental management program
- Early warning and disaster preparedness system
- GEF environmental program, extension to Guinea, public participation, sustainability of the mitigation program beyond the Regional Energy Program
- Cooperation in the Senegal River basin through OMVS has resulted in the many achievements (Dione, 2013):
- 1972-80: OMVS development program (irrigation; hydropower; navigation);
- 1984: Joint loan from 12 donors to build dams: Manantali (in Mali) and the Diama (Senegal/Mauritania border).The total cost of the Manantali dam, its associated hydropower plant, the deforestation of the future reservoir, studies and "complementary measures" was 1.02bn Euro. The construction cost of the related Diama dam further downstream was an additional 50m Euro;
- 1986: Diama dam operational (blocking salt water intrusion) with an ambitious irrigation program (375 000 ha);
- 1997: Manantali hydropower dam completed (800 GWH);
- 2000: Joint dams management bodies established (SOGED-SOGEM)
- 2002: Jointly owned Power transmission lines connecting the three countries: The jointly-owned Manantali dam and its network of transmission lines covering 1,300 kilometers finally came online in 2002, and has been working at full capacity since May 2003. In connecting Manantali to the three national grids, dual-purpose fiber optic technology was used for the transmission lines, which the telecommunication sector can also use, thus lowering communication costs;
- 2002: Private operator (ESKOM, SA) contracted to dispatch the energy produced to national power grids;
- 2004: First basin wide environmental project (four riparian countries included)
- Some benefits to the OMVS countries due to river flow regulation at 300 m3/s all over the year are (Dione, 2013):
- An irrigation potential of 375,000 ha from Manantali dam;
- Long term solution for Dakar critical water supply need (1.3 million people in Dakar are now supplied from the Senegal River);

- Adequate response to Nouakchott water supply shortage. The city of Nouakchott is currently supplied with water from the Senegal River;
- Groundwater recharge and ecosystems restoration;
- River navigation over 900 km from St-Louis (Atlantic Ocean) to Kayes (Mali).

Additional benefits (Dione, 2013) are the jointly owned 1500 km power transmission lines connecting the three riparian countries power grids from Manantali dam. This power is shared based on critical needs: Mali (104 MW or 52%), Mauritania (30 MW or 15%, and Senegal (66 MW or 33%). An optic fiber combined with the transmission lines enables increased telecommunications capacity (30,200 connections and 48 TV channels), making Senegal telecommunication network entirely digital, and linking Mali and Mauritania to the international network.

OMVS can be considered as an example and a catalyst for Peace and Regional Stability where (Dione, 2013):

- Jointly owned infrastructures act as catalyst for peace: Diama dam contributed to diffuse the 1989 tension between Senegal and Mauritania;
- Regional stability enhanced through cooperative framework: Though in 1989 diplomatic ties were broken, OMVS still functioning as the only viable link between Senegal and Mauritania;
- Mutual confidence and broad bundled benefits foster regional integration by opening new development opportunities (inter-countries road segments, joint privatization of the Dakar-Bamako railroads, lift of trade barriers, and joint environmental actions.

### 3.4 Monitoring and Evaluation

According to the World Bank Water and Environmental Management project brief (World Bank, 2001), time series data on hydrology in the Senegal river basin did exist for the valley from Bakel to Saint-Louis in the delta. The data has been used for basin water resources planning and management. However, the changing patterns of rainfall and its implication on runoff and the governing processes were not yet fully understood. This problem originates from a lack of data in the catchment areas above Bakel, especially in the Guinean territory. This problem was exacerbated by the weakness of ecological monitoring in almost the entire basin, and especially in the upper basin. Geomorphologic processes, dynamic ecological phenomena and associated modification of flow regimes have been totally ignored. Ecological, economic and social water demand was unknown, as well as water-flows and especially the extreme events such as floods and droughts. Corrective measures were being taken by OMVS within the Regional Hydropower Project and the related program, PASIE.

On the other hand, the Senegal River basin case study (UNESCO, 2003) indicated that OMVS had abundant quantitative data thanks to a discharge monitoring network set up in 1904, with updated records stored in a database of the OMVS High Commission. Major studies carried out by the French Research Institute for Development (IRD, Institut de Recherche pour le Développement) and the OMVS have also made it possible to estimate withdrawal and losses during low flow stages. These studies have also made it possible to develop suitable resource management tools based on analysis of the hydrological behavior of the river in relation to needs. Software (SIMULSEN) has been developed to evaluate the effects of the various Manantali dam management practices on the degree of satisfaction of demands such as hydroelectric production, flow regulation, flow at Bakel as a function of needs downstream. Specific studies have also been carried out on how flooding is related to the functioning of basins, providing important information concerning their filling and emptying, and the volumes of water potentially available during this period.

Data on water quality, health, livestock-raising, agriculture, fishing, climate and the environment did exist, but were dispersed in various government services, laboratories, universities and research institutes, or even in cooperation institutions, such as the IRD, the United States Agency for International Development (USAID), the United Nations Development Programme (UNDP), and the World Bank. Data have been collected for many projects, but the resulting databases were incompatible or have simply been lost or abandoned upon completion of projects. The most acute need was in the upper basin, including Guinea, where the lack of data was a concern not only for the government of Guinea but for the whole basin (UNESCO, 2003).

Agencies that report to the OMVS are in charge of the operation of the Manantali and Diama dams, which are jointly owned by the three member countries Mali, Mauritania, and Senegal. Flow data from the Senegal have been recorded since 1904, and the large quantities of hydrological data that have been collected are stored in a database operated by the OMVS' technical department. The department publishes a monthly information sheet for member-country hydrological services as well as for other actors. The changes in the Senegal's flow regime that set in once the dams were completed have had numerous negative impacts on environment, health, and traditional water uses. In response to this situation, the French Institut de Recherche pour le Développement (IRD) and the OMVS conducted a series of comprehensive analyses of the river's hydrological behavior in relation to abstraction and regulation, and the findings were used as a basis to improve dam regulation. In this context, a water

management model was developed to assess the effects of different regulation practices. Whilst some data had been regularly collected on water quality, population, health, livestock, agriculture, fishery, climate, and the environment, the data are dispersed across a number of different institutions (e. g. government agencies, universities, research institutes or projects). Comprehensive datasets have been collected for numerous projects, but the databases are incompatible (Scheumann and Neubert, 2006).

Lack of information on the impacts of constructed dams long posed an obstacle to the OMVS' work. The insufficiency or total lack of time- and space-related data for many water-relevant areas has stood in the way of a systematic analysis of improved water availability, the environmental and health problems caused by the projects, and their direct and indirect impacts on the living conditions of the affected population. The OMVS was reorganized in response to these problems, with new indicators defined and strategies worked out to compile the data required by the OMVS to continuously monitor the impacts of its water projects on water availability, health, the state of the environment, and socioeconomic development - and if need be to adjust its management strategy.

As a result, the High Commission set up an Observatory of the Environment in November 2000 to create a network of all of the producers/possessors of thematic data and hook them up to a general database that would be managed by the Observatory's Coordination Bureau. Agreement protocols were drawn up by these organizations and the OMVS to formally define the roles and responsibilities of each of the actors in the data collection, processing and storage procedures on the one hand, and data development, dissemination and sharing on the other. Data collected by the Observatory can be divided into four major classes (Ndiaye, 2011):

- Water resources and physical environment: Climatology, Surface water (quantity), Groundwater (quantity), and Soil science - Soil Degradation.
- Biodiversity and the natural environment combining the themes: Wetlands Vegetation cover, Invasive plants, Fish and Wildlife, banks degradation.
- Economy and population: Human waterborne diseases and animals, Fishing activity, irrigated agriculture activities, farming activities.
- Water Quality: Surface water quality, Groundwater quality, Fertilizers and pesticides, Mining and quarrying.
- It is not easy to access information in Africa and there is no organized, common information management system. The African Water Documentation and Information System (AWIS),created by partners from developed and developing countries, was launched in April 2007 to promote and facilitate the provision of information and knowledge on water in Africa via a Pan-African web portal(GWP and INBO, 2009).AWIS is led by the OMVS and it is taking a two-step approach:

    i. Developing and providing a mechanism for knowledge and information exchange, and
    ii. Building stakeholder capacity through the creation of an African network gathering together organizations that produce information (basin organizations, resource management centers, documentation centers, non-governmental organizations, etc.).

Faced with a changing environment with multiple determinants, OMVS decided to develop another monitoring tool, the Water resources Dashboard of the Senegal River (Tableau de Bord de la Resources eau, TBR) (Ndiaye and Trouvat, 2010). The TBR is a tool jointly constructed with OMVS under agreement partnership with the financial support of the French Development AFD (Agence Francaise de Development). The TBR is intended to monitor and understand the basin, understand hydrological phenomena, help decision, and evaluate actions.

In 2007, Senegal River basin hydrology and meteorological networks have been rehabilitated and were fully operational consisting of 19 hydrological stations (3 updated stations in Mali, 3 in Mauritania and 5 in Senegal and 8 fully rehabilitated stations in Guinea) and 24 meteorological stations through the Senegal River Basin Water and Environmental Management Project (World Bank, 2009). On the other hand, the monthly hydrological bulletin (available at the OMVS Portal: http://www.portail-omvs.org/hydrologie) usually reports only 9 main rainfall stations (Dakka Saidou, Bafing Makana, Manantali, Diangola, Oualia, Gourbassi, Kidir , Kayes, and Bakel) and 6 main flow (level and discharge) stations (Bafing Makana, Manantali, Oualia, Gourbassi, Bakel, and Diama). Figure (4) shows the location of the hydrologic stations in the Senegal River basin.

Further details of hydrologic stations can be found in the OMVS baseline Study (OMVS, 2006). Currently, data collection is based on a network of hydrological stations of the Member States. Water level data in 15 stations are automatically transmitted twice a day (8 hours and 12 hours, called the shift) with SSB radios. These stations are monitored by the departments in charge of hydrology in each country through three companies that process the reported data, compare them with normals, and ensure the soundness of the data from a statistical point of view. The OMVS collects data from countries in a data sharing meeting that is held once a year. In the data sharing meeting, each country's focal point reports his country data in the following fields: climate, surface water, groundwater, human health, fish, animal health, agriculture, and energy. These data are the basis for the Environmental Status Reports that are issued by the OMVS. Currently, no surface water quality data is collected, only flow data from the dams (OMVS, 2013). On the other hand, Mauritania had given some information on the quality of groundwater in part of the basin.

There is also an ongoing GEF groundwater monitoring project covering 32 wells (6 in Senegal, 20 in Mauretania, and 6 in Mali), where conductivity, salinity, pH, and piezometric head are measured. Automatic sensors and data acquisition system are used, which can be a base for any communication protocol between the basin countries. There are some data transmission difficulties, resulting in the additional use of computers/data loggers at each site to store the data. Till now, groundwater abstraction in the basin has not been assessed, and groundwater modeling has not been performed yet (OMVS, 2013).

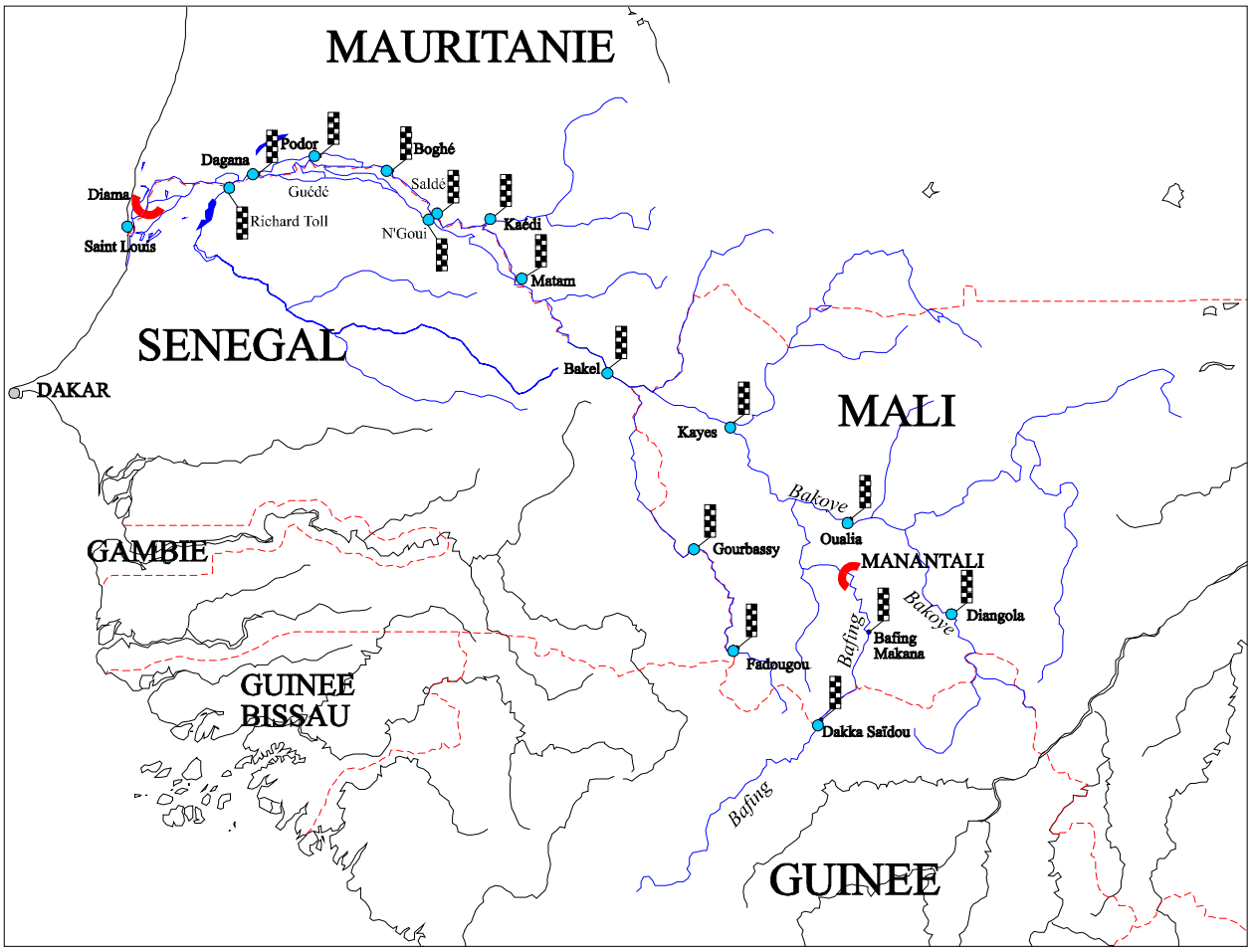


**Figure 4.** Hydrologic Stations in the Senegal River Basin (OMVS, 2013)

### 3.5 Water Indicators

To address the constraints of insufficient information control, and to better understand the evolution of development in the basin, the OMVS has been reorganized so that it can collect, process, and store all the data needed to monitor development project performance indicators from the upper basin to the delta of the river. The Environmental Observatory was created by the High Commission in November 2000 for this purpose. Between November 2000 and December2001, indicators were defined and strategies set up together, process, and store data that would enable OMVS to correlate water availability, public health, the state of the environment and socio-economic development. These indicators concern (UNESCO, 2003):

- The productivity of activity sectors (agriculture, livestock raising, fishing, mining);
- The market rate of crops grown in the basin;
- The percentage of participation of women in economic activities;
- The impact of the involvement of women by activity sector;
- The quality and the quantity of domestic water use;
- The rate of access to drinking water of the populations living along the river;
- The prevalence of water-borne diseases (human and animal);
- The state of the environment (degradation of soil, forests, water bodies);
- The quantitative estimation of the degradation of ecosystems by sector of activity;
- The quantitative estimation of the health situation in each sector of activity;
- The rate of immigration and emigration in the zone; and
- The quantitative estimation of the corrective measures taken to eliminate the negative impact of developments.

An initial list of indicators and domains chosen by the stakeholders in order of priority has been prepared by the OMVS (OMVS, 2007):

***Priority No. 1***: (urgent, immediate action)

- Hydrological regime;
- State of the flooding of the valley;
- Monitoring the quality of surface waters;
- Invasion by aquatic vegetation;
- Actions against aquatic vegetation;

- Improving water quality;
- Irrigation schemes;
- Prevalence of human waterborne diseases;
- Fight against water-borne diseases;
- Fisheries production;
- Inventory of birds;
- Epidemiological surveillance.

***Priority No. 2*** (relatively urgent action between 1 and 3 years)

- Basin Climatology;
- Monitoring of groundwater quality;
- Extension of recession crops;
- Spreading of fertilizers and pesticides;
- Control of the use of pesticides;
- Waterborne diseases of livestock;
- Inventory of wild wildlife;
- Inventory and monitoring of wetland habitats;
- Fisheries resources;
- Reforestation and agroforestry;
- Monitoring of erosion;
- Monitoring of water erosion on slopes;
- Monitoring of wind erosion;
- Erosion control actions;
- Demographic trends;
- Monitoring of land degradation.

**Priority No. 3**

- Socio-economic development;
- Inventory of livestock;
- Pastoral Resources.

The level of feasibility of monitoring these indicators based on the capacities of data producers (Technical Services of States) was assessed as follows (OMVS, 2007):

| Level 1 | Level 2 | Level 3 |
|---|---|---|
| • Water characteristics of surface waters and groundwater<br>• Flood<br>• Prevalence of water-borne diseases (human and animal)<br>• Climatology<br>• Related activities irrigated agriculture | • Fish resources<br>• Wildlife and aquatic life<br>• Wetlands<br>• Fertilizers, pesticides and chemicals<br>• Mining | • Socioeconomic status and demography<br>• Plant Resources<br>• Degradation (water erosion, wind erosion, salinization, etc.).<br>• Aquatic plants invasive |

To simplify the approach to environmental issues and in order to optimize means and methods to assess the operation of networks, the original 13 thematic targets (surface water, water disease, wetlands, fishery resources, climate, wildlife and Aquatic life, socio-economic situation, invasive plants, plant cover, soil science, fertilizers and pesticides, groundwater, quarrying and mines) identified in the Environmental Baseline report (OMVS, 2003)were later reorganized into four related classes (OMVS, 2006):

- Class 1: Water resources and physical environment combining the themes:
    - Climatology (1.1)
    - Surface water (quantity) (1.2)
    - Groundwater (quantity) (1.3)
    - Soil Science - Soil Degradation (1.4)
- Class 2: Biodiversity and the natural environment combining the themes:
    - Wetlands (2.1)
    - Vegetation (2.2)
    - Invasive Plants (2.3)
    - Fish and Wildlife (2.4)
    - Soil Science - degradation of banks - (2.5)
- Class 3: Economy and population
    - Human (3.1) and animal (3.2)waterborne diseases
    - Fishing activity (3.3)
    - Hydro-agricultural Activities - irrigated (3.4)

- Hydro-agricultural activities - farming (3.5)

- Class 4: Water Quality
  - Surface water - quality appearance - (4.1)
  - Groundwater - quality appearance - (4.2)
  - Fertilizers and pesticides (4.3)
  - Mining and quarrying (4.4)

These four classes can be effectively interpreted in terms of the objectives of the Observatory, with two major fundamental issues (A, B) and their consequences (C, D):

A - The risk of over-exploitation of water resources (class 1);

B - The risk of degradation of water resources (class 4);

C - The risk of environmental degradation (class 2);

D - The risk of deterioration of the living conditions of populations (class 3).

A comprehensive set of detailed indicators have been suggested by the OMVS in their first annual report on the State of the Environment and Natural Resources (OMVS, 2006) based on the four thematic target classes mentioned above and classified according to the Pressures/State/Response (Pressions/Etat /Réponses, PER) model. According to this model State Indicators describe the quality of the environment, the quality and quantity of natural resources; Pressure Indicators describe pressures from human activities carried on the environment (sampling, pollution); and Response Indicators demonstrate corrective measures, efforts to improve the environment and reduce its degradation (regulatory actions, improvement of knowledge management measures).

Details of the selected indicators including definition and calculation methods are given in a technical report (OMVS, 2005). Indicators were considered in two levels of precision: target indicators and temporary indicators. Target indicators are indicators approaching the best ideal indicators defined by scientific experts, given the available data, their quality, their homogeneity across the basin, their time of acquisition by the Observatory. In the absence of certain data to calculate these targeted indicators, similar temporary indicators are proposed. Temporary indicators should move rapidly towards the target indicators as missing data are collected/supplied by the relevant authorities in the countries concerned. Table (5) presents a categorized list of these indicators used, relevant data, their availability, and temporary indicators if needed.

**Table 5. List of Water Indicators**

| Target Area | Class | Category | Target Indicator(s) | Relevant data | Availability of data | Temporary Indicator(s) |
|---|---|---|---|---|---|---|
| Climatology 1-1 | Sate | Rainfall | Index of decadal or monthly cumulative average gross rainfall by zone of catchment area | - Daily precipitation depth (mm)<br>- Breakdown of watershed area in terms of climatic zone | Yes<br>No | Average total monthly gross rainfall by region or administrative Wilaya |
| | | | Index of the average annual total gross rainfall by zone of catchment area | - Daily precipitation depth (mm)<br>- Breakdown of watershed area in terms of climatic zone | Yes<br>No | Average total annual gross rainfall by region or administrative Wilaya |
| Surface Water (Quantity) 1-2 | State | Flow | Flow variation | Daily flow at Bakel | Yes | |
| | | | Monthly index level of the Manantali dam | Monthly rated storage of Manantali Dam | yes | |
| | | | Monthly index level of the Diama dam | Monthly rated storage of Diama Dam | yes | |
| | | Flooding | Index of area of flooded zones | Area of flooded zones on satellite photos during winter | No | |
| | | | Duration and dates of flooding | Satellite photos of the flooded areas during winter | No | Residence time of the flood |

Table (5) (continued): List of Water Indicators.

| Target Area | Class | Category | Target Indicator(s) | Relevant data | Availability of data | Temporary Indicator(s) |
|---|---|---|---|---|---|---|
| Surface Water (Quantity) 1-2 | Pressure | Consumption | Monthly intensity of use of water resources of the river | -Monthly volume of surface water withdrawals<br>-Total monthly volume of surface water resources | No | Monthly volume consumed on the stretch of Bakel- Diama |
| | | | Monthly satisfaction of needs of surface water by department | -Monthly volume of surface water needs by department<br>-Volume of surface water samples by department | No | |
| | | | Departmental monthly rate of population using surface water as drinking water | - Average daily volume of surface water samples for drinking water by department<br>- Average daily consumption of drinking water per person by department<br>- Population by department as number of individuals | No | |
| | Response | Prevention | Departmental index of information and user awareness of management of structures | - Number of People present at seminars by department<br>- Number of individuals by department | No | Departmental monthly frequency of information and awareness seminars on dam management |
| | | Dam management (Usages) | Index of satisfaction of reference support of domestic flow retained | - Flow released at Manantali<br>- Domestic water retained at Manantali | yes | |

Table (5) (continued): List of Water Indicators.

| Target Area | Class | Category | Target Indicator(s) | Relevant data | Availability of data | Temporary Indicator(s) |
|---|---|---|---|---|---|---|
| Surface Water (Quantity) 1-2 | Response | Dam management (Usages) | Index of satisfaction of reference support of low flow | - Minimum Daily Flow at Bakel<br>- Daily low flow hydrograph goal in Bakel | yes | |
| | | | Index of satisfaction of reference support of flood | - Mean daily flow at Bakel<br>- Daily flood hydrograph goal a Bakel | Yes | |
| | | | Index of satisfaction of reference flood routing | - Maximum daily flow at Bakel<br>- Maximum allowed flow at Bakel | Yes | |
| Human waterborne diseases 3-1 | State | Endemic Diseases<br>1 - Malaria<br>2 - Intestinal Schistosomiasis,<br>3. Urinary schistosomiasis,<br>4 - Diarrhea | Quarterly evolution of disease by disease and region | - Year n, quarter 1,2,3 or 4<br>- Number of cases by disease and by department<br>- Effective population by region for the year in question | Yes<br>Yes<br>No | Quarterly change in the number of cases by disease and region |
| | | | Quarterly change in mortality by disease and region | - Year n, quarter 1,2,3 or 4<br>- Number of deaths by disease and department<br>- Effective population by region for the year in question | Yes<br>Yes<br>No | Quarterly change in the number of deaths by disease and region |
| | | | Evolution of the prevalence by disease and region | - Date of survey<br>- Number of old and new cases, by disease and by department<br>- Effective population by region for the year in question | Yes<br>Yes<br>No | Evolution of the prevalence by disease and region |

Table (5) (continued): List of Water Indicators.

| Target Area | Class | Category | Target Indicator(s) | Relevant data | Availability of data | Temporary Indicator(s) |
|---|---|---|---|---|---|---|
| Human waterborne diseases 3-1 | State | Epidemic-prone Diseases<br>5 - Yellow fever<br>6 - Cholera<br>7 - Poliomyelitis<br>8 - shigellosis | Quarterly evolution of outbreak by region | - Date or period of the epidemic<br>- Number of epidemic outbreaks by region<br>- Total number of cases by region<br>- List of households<br>- Number of cases per household<br>- Effective population by region for the year in question | Yes<br>Yes<br>Yes<br>Yes<br>Yes<br>No | Quarterly evolution of outbreak by region |
| Human waterborne diseases 3-1 | Response | Endemic Diseases<br>1 - Malaria<br>2 - Intestinal Schistosomiasis,<br>3. Urinary schistosomiasis,<br>4 - Diarrhea | Annual Trend of awareness by region | - year n<br>- Number campaigns, by department<br>- List of campaigns<br>- Size of population affected by campaign<br>- Effective population by region for the year in question | Yes<br>Yes<br>Yes<br>No<br>No | Annual change in the number of campaigns by region |
| | | Epidemic-prone Diseases<br>5 - Yellow fever<br>6 - Cholera<br>7 - Poliomyelitis<br>8 - shigellosis | Annual Trend of awareness by region | - year n<br>- Number campaigns, by department<br>- List of campaigns<br>- Size of population affected by campaign<br>- Effective population by region for the year in question | Yes<br>Yes<br>Yes<br>No<br>No | Annual change in the number of campaigns by region |
| | | | Annual change in vaccination rates of the population by disease and region | - year n<br>- Number campaigns, by department<br>- List of campaigns<br>- Effective population vaccinated by country<br>- Effective population vaccinated by department<br>- Effective population by region for the year in question | Yes<br>Yes<br>Yes<br>Yes<br>No<br>No | Annual change in the number of vaccination campaigns by region |

Table (5) (continued): List of Water Indicators.

| Target Area | Class | Category | Target Indicator(s) | Relevant data | Availability of data | Temporary Indicator(s) |
|---|---|---|---|---|---|---|
| Hydro-agricultural activities (irrigated Agriculture) 3-4 | State | Land productivity<br>1-Rice<br>2-Corn<br>3-Sorghum<br>4-Sugarcane<br>5-Tomato<br>6 - Onion | Performance of major types of irrigated agriculture by department | - Agricultural production (in tonnes or quintals), by department and agricultural year<br>- Cultivated area (ha) by crop and by department and agricultural year | Yes<br>Yes | |
| | Pressure | Land use | Proportion of cultivated areas by department and agricultural year | - Total cultivated area (ha) per year per agricultural department<br>- Total area of the department | Yes<br>Yes | |
| | | | Irrigation rates by department and agricultural year | - Total irrigated cultivated area (ha) by department and agricultural year<br>- Total agricultural area (ha) by department and agricultural year | Yes<br>Yes | |
| | | Water consumption | Demand for irrigation water by department and agricultural year | - Average water withdrawals by irrigation department and agricultural year<br>- Total cultivated area irrigated by department and agricultural year<br>-Theoretical withdrawals for irrigation by crop type and crop year<br>-Irrigated area by crop type, by department and agricultural year | No<br>Yes<br>Yes<br>Yes | Estimated consumption of irrigation water |

Table (5) (continued): List of Water Indicators.

| Target Area | Class | Category | Target Indicator(s) | Relevant data | Availability of data | Temporary Indicator(s) |
|---|---|---|---|---|---|---|
| Hydro-agricultural activities (irrigated Agriculture) 3-4 | Response | cultivation techniques | Cropping intensity of irrigated areas by department and agricultural year | -Irrigated area in winter by department<br>- Irrigated area in double cropping by department<br>- Area equipped for irrigation by department | Yes<br>Yes<br>Yes | |
| | | | Rate of practice of double cropping by department and agricultural year | - Irrigated area in double cropping by department<br>- Total cultivated area irrigated by department and agricultural year | Yes<br>Yes | |
| | | | Share of water-saving irrigation techniques by department and agricultural year | - Irrigated area affected by water-saving techniques, by department<br>- Area suitable for irrigation | Yes<br>Yes | |
| | | | Share of varieties requiring less water, all crops combined by department and agricultural year | - Area of less water consuming varieties by crop<br>- Total cultivated area by crop | ?<br>Yes | |
| | | Capacity Building | Frequency of campaigns to better farming techniques | Number of awareness campaigns by department and agricultural year | Yes | |

Table (5) (continued): List of Water Indicators.

| Target Area | Class | Category | Target Indicator(s) | Relevant data | Availability of data | Temporary Indicator(s) |
|---|---|---|---|---|---|---|
| Hydro-agricultural activities (Livestock) 3-5 | state | Area of grazing lands | Capacity by department and agricultural year | - Biomass index<br>- Daily consumption per UBT<br>- Cumulative effective of all species combined (converted to UBT) | ?<br>Yes<br>Yes | |
| | | Access to water points | Satisfaction with water, by department and agricultural year | - Available volume by species<br>- Daily consumption by species<br>- Number of livestock (number of heads) by species and by department | Yes<br>Yes<br>Yes | |
| | Pressure | Grazing intensity<br>1. cattle<br>2. sheep<br>3. goats<br>4. camels<br>5. donkeys<br>6. Horses | Load by species, by department and agricultural year | - Potential-grazing area (ha) by species and by department<br>- Number of livestock (number of heads) by species and by department<br>- Number of days of grazing by species | Yes<br>Yes<br>? | Animal densities by species and by department, by crop year |
| | Response | Measures of compensation of the deficit | Use of agricultural and agro-industrial by-products in animal feed | - Amounts of by-products used by department and agricultural year<br>- Culture production (kg), by department and agricultural year<br>- Residue production coefficients by crop | ?<br>Yes<br>Yes | Agricultural by-products of rice, maize, and sorghum |
| | | | Establishment of forage crops | - Area of forage crops by department and agricultural year | Yes | |

Full definitions and methods of calculation of different indicators can be found in the original report (OMVS, 2005), and is reproduced in Appendix 1.

### 3.6 Information Management and Reporting

The establishment of the Environment Observatory in the Senegal River Valley started in 2000 with support from the French Global Environment Facility (FFEM). The Environmental Observatory was set up as part of the Program for the Mitigation and Monitoring of Impacts on the Environment (Programmed'Atténuationet de Suivi des Impacts surl'Environnement). The Environmental Observatory (Service de l'Observatoire de l'Environnement, SOE) is a network of governmental and non-governmental organizations designed to bring together organizations and individuals that provide environmental information. The Observatory has a central database designed to make data available and to publish them on a periodic basis (Scheumann and Neubert, 2006). The project has resulted in the development of a computerized tool labeled SOE-OMVS database, allowing each thematic network to manage the stakeholders, the handled information, the information flows between the stakeholders, and information processing resulting in actions (GWP and INBO, 2012).

The SOE-OMVS is a strategic tool for monitoring the state of Environment Basin (OMVS, 2004). The first phase of the project covered 13 areas: surface water, groundwater, waterborne diseases, Wetlands, fishery resources, climatology, terrestrial and aquatic wildlife, the socio-economic situation, invasive plants, the canopy, soil science, fertilizers and pesticides, quarries and mines.

Tools for monitoring and evaluation in place are:

- Relational Database: currently covering the following topics:
    - Locations
    - Surface Water
    - Groundwater
    - Waterborne Animal Diseases
    - Waterborne Human Diseases
    - Climate
    - Hydro Agricultural Activities
- Metabase
- MapInfo software to generate maps
- A website (publication of SOE products online)

SOE-OMVS is a relational database-type customer-oriented server developed using Microsoft Access and VB scripts, with a very user-friendly interface. It is easy to use in the world of personal computing as it derives its strength from its search engine built on the Windows OS of Microsoft.

The OMVS Metabase application was developed to manage different entities of significant monitoring useful data and existing Observatory environmental indicators which enable the evaluation of these networks under information flow and data processing. The Metabase is a product developed in Microsoft Access2000 for the database and interfaces with DELPHI. The software under MapInfo is able to produce thematic maps, synthesis, and associated graphics.

The Water resources Dashboard of the Senegal River (Tableau de Bord de la Ressourceen eau, TBR, see Figure (5) below) is another tool that centralizes and structures information on water resources and their

use in the basin. It offers decision support to the management strategy with an operational approach based on forecasting to determine water allocations compatible with the current availability and anticipated availability for coming seasons, balancing between water use for irrigation and hydropower generation. The efficient operation of the TBR relies on collecting information by operational structures, data producers themes, and constituting focal points, formalized by technical and administrative protocols, and involving all actors of the 4 countries in the basin in a participatory and collaborative approach. Once collected and validated, information are published in the TBR and are accessible by data producers, partners and clients via internet connection.

The TBR is an open tool, the heart of the adaptive management of water resources. To cope with changing hydrological context, OMVS uses TBR as a tracking tool that affect the management of water resources of the basin. TBR is a technically advanced development tool with IT support, databases, and remote access. The compilation of basic information and validated indicators development is used as a basis for decision support and consultation initiated by the CPE. All partners of the four countries of the basin share common information in a participatory approach. Data sharing mechanism adopted is involving all actors in different national institutions dealing with river basin resources. Focal points are collaborating with OMVS national water units as driving actors for the data sharing process. The tool is open and adaptive with prospects: description of prospective situations, coherence with other databases (SOE-OMVS), and creation of new specific indicators.

The Technical Department of the High Commission also publishes a monthly hydrological bulletin (http://www.portail-omvs.org/hydrologie) for the technical services of the member states and other actors (producers, development partners, NGOs, industrial projects) carrying out activities in the basin.

Currently, OMVS has a set of tools for data management of the Senegal River which are(OMVS, 2013):

- The HYDRACCESS database;
- Software for simulation of Manantali dam: Simulsen;
- Software for management of Manantali dam in real time: Progeman;
- Software for management of Diama dam in real time: Gesdiam;
- Software for calculating Diama dam backwater curve: Corediam

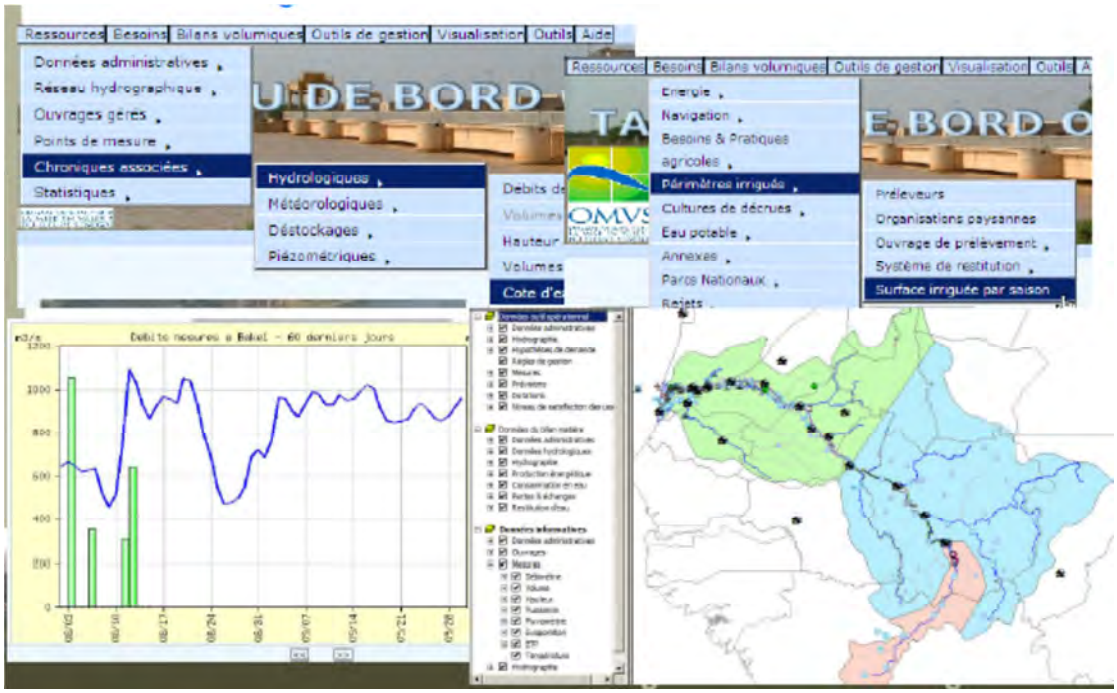


**Figure 5. Water resources dashboard - TBR**

*HYDRACCESS* database allows, among others, entry and storage of water level data collected at different stations, capturing and storage of recorded rainfall depths at rain stations, calculation of the rates and daily average sat each station, processing of a single station or multiple stations simultaneously, importing diagrams, and different types of statistical analysis of data. The interface of the *HYDRACCESS* database is shown in Figure (6) below. The central database resides in Senegal, but it cannot be accessed by the transboundary countries - only by focal points. They typically share their data by e-mails and Excel sheets (OMVS, 2013).

*Simulsen* is a software package for strategic management of Manantali dam storage. It allows, based on the available water resources in the reservoir, to calculate the average annual energy yield for several management scenarios. It also allows determining the average change in the level of the reservoir for a given energy yield, and thus predict the final low water level (late June of the same year). *Progemane* is a software package for real-time management of Manantali dam. It allows, based on the flow of the tributaries of Falémé and Bakoye, to calculate releases from Manantali dam to obtain a target flow set at Bakel. *Gesdiam* is a management software package in real time for Diama dam. It calculates the openings of Diamagates based on inflows recorded at Bakel. *Corediam* is a software package for calculating the backwater of Diama dam. It can, based on the incoming flow at Bakel and Diamadam storage, calculate the level at intermediate stations and the time of propagation of a flood wave recorded at Bakel. There are several other models in use, including an Early Warning System (EWS). It is to be noted, however, that no flow forecasting models are currently used by the OMVS (OMVS, 2013).

Information collected by the SOE was used to issue a baseline report on the status of the environment in 2003 (OMVS 2003). Although the status of the environment report was intended to be an annual report (as indicated by its title in 2006), only two other reports have since been issued. The 2006 report (OMVS 2006) covered the period between the baseline report in 2003 and 2005, while another report issued in

2011 covered the period between 2006 and 2010, consisting of a final report (OMVS 2011a) and a synthesis report (OMVS, 2011b).

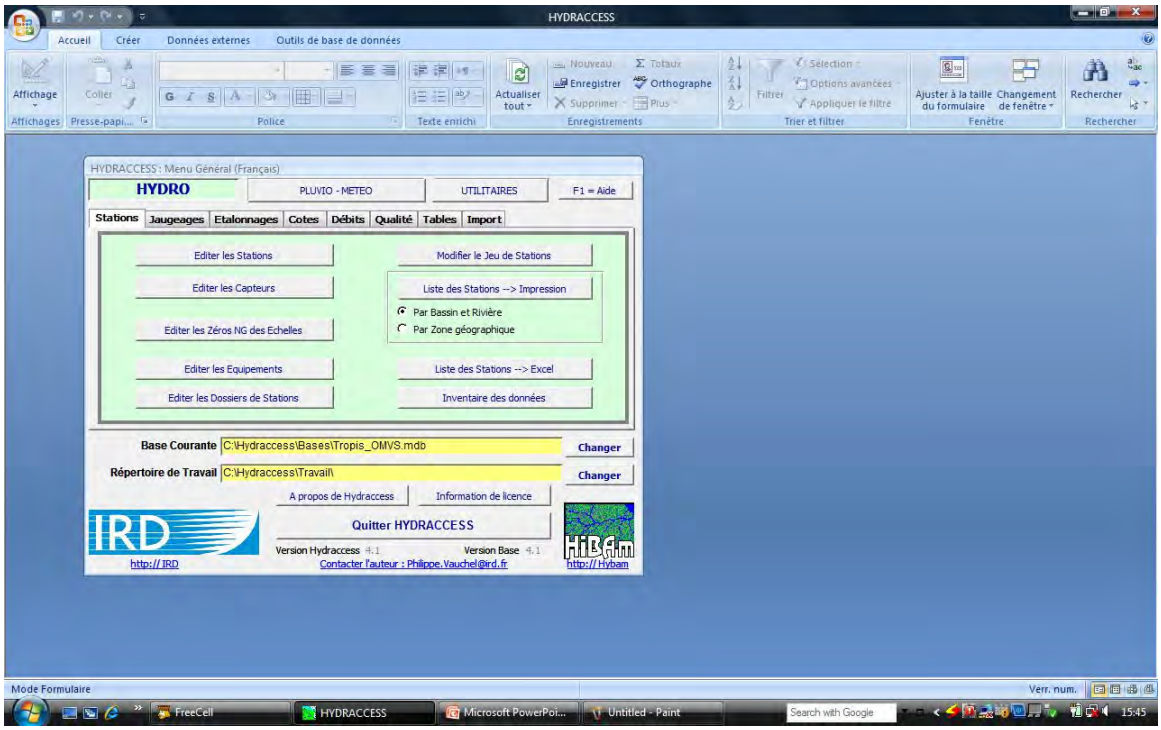


**Figure 6.** The user interface of the HYDRACCESS database

The most recent report on the state of the environment of the Senegal River Basin (OMVS, 2011a) adheres to the following steps: based on factual observations, the factors explaining the findings of the evolution of each topic studied are sought in order to make recommendations to policy makers with the aim of improving environmental conditions in the basin. The topics are divided into 3 major groups, namely: natural resources, the socio-economic situation of the people, and water quality and human health. Finally, a summary table at the end of each chapter summarizes the issues according to the Pressure-State- Response (PSR) model. The above-mentioned table also shows the interactions between environmental issues in the basin.

The OMVS, through its various programs, supports the achievement of the Millennium Development Goals (MDGs). The Master Plan for Development (Schéma Directeur d'Aménagementet de Gestion des Eaux, SDAGE) (OMVS, 2009) gives details of the efforts by the OMVS to achieve the MDGs. To improve access to water and sanitation for the achievement of the MDGs, significant efforts have been made by the countries of the OMVS through several projects to improve the conditions of living for their populations. Examples of several such projects are given in the SADGE final report (OMVS 2009).

### 3.7 Assessment and SWOT Analysis

The OMVS was once called by observers "the first international river basin authority with an executive capability" (Parnall and Utton 1976: p. 248).The OMVS is an example for cooperation with a strong international competence center in charge of organizing cooperation with national authorities. It is an experienced river basin organization with a clear mandate, vision with innovative tools (Dione, 2013). It is decentralized at national levels, associated with technical bodies (Permanent Water Commission, Regional Steering Committee, and Environment Observatory), and coupled with autonomous management entities, familiar with private sector involvement, and open to stakeholder participation. To date, management of the Senegal River suffers from two on-going issues: conflicts of interest between regional/international, national and local actors; and between some farmers who prefer recession agriculture and the state's interest in irrigation (Ndiayeet al., 2007). Nevertheless, the example of the OMVS shows overall that regional cooperation provides benefits and advantages over unilateral action. Problems were caused not by the decision to engage in basin-wide hydropower cooperation, but by the lack of efficient and effective implementation, especially with regard to environmental and social mitigation measures (GIZ, 2012).

The OMVS is responsible for the operational regulation of jointly run infrastructure, and as such it also operates hydrological measuring networks. Inadequate monitoring of socioeconomic developments and the environment long stood in the way of any systematic analysis of the impacts of the dams on health and environment as well as on the living conditions of the local population (Scheumann and Neubert, 2006).The OMVS Observatory (SOE-OMVS) is an institution with an increasing importance to monitor the status of the Senegal River Basin and the environmental impact of the projects being carried out within its boundaries. A study by the African Water Facility (AWF, 2010) indicated the need to strengthen the OMVS Observatory. In practice, significant disparities exist between countries and between ministries within member states that impede the collection and subsequent dissemination of relevant data. While each CNC (Centre Nationale de Collecte) receives some capacity building support from the OMVS to improve their data collection and storage systems, this does not solve the problem of weak data collection mechanisms in certain sectors, such as waterborne diseases, due to the nature of the data itself. Addressing these deficiencies remains a work in progress (AWF, 2010).

The recent rehabilitation and expansion of surface water monitoring network and the establishment of a groundwater monitoring network is a good achievement, but continual maintenance of the network and updating of devices and software should be considered. Financial as well as human resources should be secured to ensure sustainability of the network. On the other hand, additional parameters, including water quality parameters, need to be collected in order to better report the environmental status of the basin. It is also important to boost the use of automatic data gauging and acquisition (OMVS, 2013). This could be achieved through the Senegal-HYCOS project (OMVS, 2013). The purpose of the Senegal-HYCOS is to implement a device, based in part on the update of the observation network and telecommunications, and secondly on strengthening national (National Hydrological Services) and regional (OMVS) capacities to use the data and translate it into information that can improve the management capacity of water resources in the basin (WHYCOS, 2007). A web-based database system accessible to all stakeholders may also be helpful (OMVS, 2013). Additional improvement can be achieved by development of monitoring, modeling, and forecasting facilities, for planning purposes, which take

climate change into consideration. This can ultimately be promoted to a full Decision Support System (DSS) for the whole basin.

### 3.7.1 Strengths

- Strong legal status of the OMVS and high spirit of cooperation between basin countries in water resources development despite some political tensions.
- Strong political support for more than thirty years at the highest level.
- The recent accession of Guinea to the OMVS. Guinea is in the process of being fully aligned with the OMVS's Water Charter (superseding national legislation).
- Recently rehabilitated and expanded surface water monitoring network increase the M&E capacity of the OMVS.
- Knowledge gaps on the upstream portion of the Senegal River Basin have been filled, and Guinea's hydrology network has been fully integrated into the existing OMVS network.
- Newly-established groundwater monitoring network is an added asset.
- OMVS Observatory (SOE) is gaining importance as an institution with capabilities to monitor the status of the basin, and possibly become a regional center.
- Mechanism of data sharing is implemented within the basin.
- Additional tools and programs such as TBR and HYCOS add more strength to the M&E capabilities within the basin.
- A group of water resources staff have been gaining experience through different projects and programs of the OMVS, including capacity building programs.
- A set of analysis tools are in place (Simulsen, Progeman, Gesdiam, Corediam), albeit not in an integrated manner.

### 3.7.2 Weaknesses

- Monitoring needs to include additional parameters, including water quality ones.
- Lack of sufficient automatic measuring and data acquisition and telecommunication systems.
- Lack of a web-based database system. As a result, data sharing is not yet at full basin scale. Only focal points can access information. Others receive information either indirectly or through the status reports issued by the OMVS.
- Problems in communication and collection of information from different focal points. Significant disparities exist between countries and between ministries within member states that sometimes impede the collection and subsequent dissemination of relevant data.

- Lack of forecasting and integrated planning tools and/or DSS for the entire basin.

### 3.7.3 Opportunities

- OMVS is a promising framework to enhance cooperation in the important areas of poverty alleviation and water supply towards achieving the MDG's.
- The international community and different donors are willing to support such a successful and effective organization.
- OMVS has partnership with several international river basin networks (ANBO, INBO) and other international institutions (UNESCO, GWP, GEF, GIZ, … etc.). This provides opportunities for experience exchange and financial stability.
- Increasing awareness, capacity building programs, and well trained staff ensure the sustainability and advancement of the OMVS.
- Existence of experienced research institutions such as the University of Dakar and Gaston Berger University.

### 3.7.4 Threats

- Possibility of lack of sufficient resources for operation and maintenance of monitoring networks needed to ensure sustainability.
- Political conditions or other disparities in communication that might interfere with data collection or data sharing and dissemination.
- Possible adverse effects of climate change, which may force unilateral actions by countries in order to secure water resources for their people.

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