This paper presents the main deliverables of the EDF – WWF framework: “multipurpose water uses of hydropower reservoirs”. Multipurpose hydropower reservoirs are designed and/or operated to provide services beyond electricity generation, such as water supply, flood and drought management, irrigation, navigation, fisheries, environmental services and recreational activities, etc. These reservoir purposes can conflict at times but are also often complementary: a major challenge with multi-purpose reservoirs is sharing water amongst competing users. This framework provides tools to avoid/minimize tensions among users, governance issues for all stages and financial/economical models to develop and operate such multipurpose reservoirs. The SHARE concept was developed as a solution of these challenges. It is based on international case studies to find guidance on particular issues of multipurpose water reservoirs.

By Emmanuel BRANCHE
The author wish to thank in particular the people and organisations that participated in the discussions of the Steering Committee and those who provided comments on the draft main report:

- EDF - Electricité de France (Jean Comby)
- ICOLD - International Commission on Large Dams (Alessandro Palmieri)
- IEA Hydro - International Energy Agency Hydro (Niels Nielsen)
- IHA - International Hydropower Association (Richard Taylor and Tracy Lane)
- IUCN - International Union for Conservation of Nature (James Dalton)
- IWMI - International Water Management Institute (Jeremy Bird and Matthew McCartney)
- OECD - Organisation for Economic Co-operation and Development (Delphine Clavreul)
- PFE/FWP - French Water Partnership (Philippe Guettier)
- WB - The World Bank (Rikard Liden and Kimberly Lyon)
- WBCSD - World Business Council for Sustainable Development (Joppe Cramwinckel)
- WWF (Jian-hua Meng)

The author wish to thank the people who provided information or comments to case studies:

- Hélène Xhaard (EP Loire) for the Villerest project in France;
- Rikard Liden (WB - World Bank) for the Kandadji project in Niger;
- Lise Breuil and Nicolas Fornage (AFD - Agence Française de Développement) for the Lom Pangar project in Cameroun;
- Judy | Dan ZHU (China Three Gorges Corporation) for the Three Gorges project in China;
- Helen Locher and Greg Carson (HydroTasmania) for the Arthurs Lake project and Bronte Lagoon project in Australia;

A special thank to Niels Nielsen (IEA Hydro) for reviewing all the case studies is to be acknowledged.

The author wish also to thank the World Water Council team involved in this Framework for their engagement and support: Danielle Gaillard-Picher, Kata Molnar and Allelign Zeru.

« Sharing the water uses of multipurpose hydropower reservoirs: the SHARE concept »

Author and contact for additional information:

Emmanuel BRANCHE
EDF - Sustainable Development Department
EDF-CIH Savoie Technolac
73373 Le Bourget du Lac Cedex – France
Phone: +33 (0)4 79 60 64 26
Mobile: +33 (0)6 47 86 35 65
Email: emmanuel.branche@edf.fr or emmanuel.branche@gmail.com
EDF-WWC FRAMEWORK

“MULTIPURPOSE WATER USES OF HYDROPOWER RESERVOIRS”

SHARING THE WATER USES OF MULTIPURPOSE HYDROPOWER RESERVOIRS: THE SHARE CONCEPT - MAIN DOCUMENT
# TABLE OF CONTENTS

1 CONTEXT .......................................................................................................................... 6

2 EXECUTIVE SUMMARY ................................................................................................. 8

3 INTRODUCTION TO MULTIPURPOSE HYDROPOWER RESERVOIRS .......... 12

4 THE SHARE CONCEPT .................................................................................................. 16

  4.1 | Sustainability approach for all users .......................................................................... 16
  4.2 | Higher efficiency and equity among sectors ................................................................. 19
  4.3 | Adaptability for all solutions ....................................................................................... 24
  4.4 | River basin perspectives for all ................................................................................... 28
  4.5 | Engaging all stakeholders .......................................................................................... 31

5 THE WAY FORWARD ..................................................................................................... 36

6 REFERENCES .................................................................................................................. 39

7 APPENDIXES ................................................................................................................. 40

  7.1 | Overview of case studies ............................................................................................ 40
  7.2 | Arenal (Costa Rica, Latin America) ............................................................................. 42
    7.2.1 | Project description .................................................................................................. 42
    7.2.2 | A participative approach for resettlement in the 1970s .......................................... 44
    7.2.3 | Establishment of a Commission for a better integrated vision of the water .......... 45
    7.2.4 | The Arenal Lake is classified as a Ramsar site since 2000 ................................... 46
    7.2.5 | Main lessons learnt ............................................................................................... 46
    7.2.6 | References ............................................................................................................ 47
Consensus is building in the international business and development community that water scarcity and water quality issues will increase dramatically in many parts of the world over the next decades. These trends will have profound social, economic and political consequences, with impacts on food, energy, trade, the environment and potentially international relations, as water scarce nations search for ways to ensure their long-term growth and sustainability. Over the past years, the concepts of integrated water resource management, water-use efficiency and water footprint have been introduced to water, agricultural and energy policy discussions. In this context, trans-boundary rivers are a very important issue. Much effort is needed to support riparian countries to improve their dialogue on shared rivers, and to build intra-riparian trust.

The production and use of energy and the storage and use of water are vital to the health and welfare of all nations, and the wise stewardship of these resources is essential to the protection of the environment. Energy and water are inextricably linked and the provision of clean and abundant sources of water depends on the availability of clean, affordable, and sustainable energy. However, energy and water resources are often planned for and managed separately, and their production and use are often at the expense of the environment. It is important to move away from ad hoc or laissez-faire planning and management towards long-term, integrated processes, in which these resources are recognised as being interconnected. This will be especially important in harmonising water use between energy production, food production and other uses so that these needs complement each other rather than compete against each other. This is especially true considering the potential impacts of climate change in the future. Water and energy are two key components for the development of a country, and hydropower is at the crossroads of these two components. The Bonn2011 nexus conference’s background document (Bonn, 2011) presents initial evidence for how a nexus approach can enhance water, energy and food security by increasing efficiency, reducing trade-offs, building synergies and improving governance across sectors. The World Commission on Dams report (WCD, 2000) provided a framework for planning water and energy projects to ensure that the benefits from dams are equitably distributed, and protect dam-affected people and the environment.

In addition to electricity, the development of hydropower with reservoirs often contributes to other services (the most important ones being: water supply, flood and drought management, irrigation, navigation, fisheries, environmental services and recreational activities). These objectives (power services, water quantity management, ecosystem services economic growth and local livelihoods) can conflict at times, but are also often complementary.

After the 6th World Water Forum in Marseille (France, 2012), Electricité de France (EDF) and the World Water Council (WWC) agreed to work on “the multipurpose water uses of hydropower reservoirs”. This framework bridges between the 6th Forum in Marseille and the 7th Forum in Daegu/Gyeongbuk in Republic of Korea and addresses the following issues: (i) How to minimize contradictions/competition among multipurpose water uses of hydropower reservoirs? and (ii) How to set an appropriate governance structure to allow coordinated/integrated water use management (in terms of strategy, planning, decision-making and operation)?

This initiative is closely linked with the ICOLD Committee on “Multipurpose Water Storage Dams” and the IEA Hydro Annex on “Hydropower Services”. Several other organisations and institutions also support this framework. A kick-off workshop was initiated in Paris (France) on 6 December 2013 to present and launch this WWC-EDF Framework, and to share information with other on-going initiatives, and other contributing organisations (AFD, EDF, ICOLD, IDDRI, IEA, IHA, IUCN, IWA, IWMI, MEDDE, MRC, OECD, PFE/FWP, World Bank, WBCSD, Wetlands International, WWC, and WWF). This framework and interim results were presented to several international events as presented in the figure below. This Framework will be presented in session 2.2.4 “Multipurpose uses and benefits of hydropower reservoirs” during the 7th World Water Forum in Republic of Korea.
An international multi-disciplinary Steering Committee was set to guide the project and validate the enclosed messages, using consultative and participative measures.

This framework addresses reservoirs with hydropower as one of the main drivers for their development.

This paper “Sharing the water uses of multipurpose hydropower reservoirs: the SHARE concept” contains the main results and key messages of this EDF-WWC Framework “Multipurpose water uses of hydropower reservoirs”. It is organised in four main parts, the first one highlights the main messages, the second part provides an overview of multipurpose hydropower reservoirs, the third one presents a broader description of the SHARE concept supported by boxes presenting case studies, and the fourth part proposes the way forward for this multipurpose water uses of hydropower reservoir Framework.

Appendixes present the 12 detailed case studies.
2 EXECUTIVE SUMMARY

Multipurpose hydropower reservoirs are designed and/or operated to provide services beyond electricity generation, such as water supply, flood and drought management, irrigation, navigation, fisheries, environmental services and recreational activities, etc. While these objectives (renewable and power services, water quantity management, ecosystem services, economic growth and local livelihoods) can conflict at times, they are also often complementary.

A major challenge with multi-purpose reservoirs is sharing water amongst competing users. Although there are no universal solutions, there are principles that can be shared and adapted to local contexts. Indeed the development and/or operation of such multipurpose hydropower reservoirs to reach sustainable water management should rely on the following principles:

» Shared vision, Shared resource, Shared responsibilities, Shared rights and risks, Shared costs and benefits «
Sustainable development requires attention to a wide range of economical, social and environmental objectives. Energy and water for sustainable development depends not only on supply choices, but also on how these choices are implemented. The intent for multipurpose water uses of hydropower reservoirs is to ensure that positive aspects are maximised and negative impacts avoided, minimised, mitigated or compensated.

Addressing sustainability of multipurpose hydropower reservoirs could be categorised in five value propositions:

1 – **Sustainability approach for all users:** The degree to which multipurpose hydropower reservoirs can advance sustainable development objectives depends on careful planning, construction, operation, management and governance. It is important to implement an adequate governance model that fosters equity across water reservoir users and ecosystems in line with agreed sustainability objectives. There are no one-size-fits-all solutions as each project is site specific and as water governance is place-based and context-dependent. It is therefore essential to customise the governance model to local conditions. The Hydropower Sustainability Assessment Protocol for those multipurpose reservoirs creates a common language among stakeholders and provides a measurement of the sustainable profile of the project and guidance for continuous improvement. In addition governance mechanisms are vital tools for achieving equitable access to, and provision of, ecosystem services.

2 – **Higher efficiency and equity among all sectors:** Economic data and innovative financial mechanisms are crucial for equitable and efficient sharing of benefits among water users. A major challenge is that many of the additional benefits around hydropower reservoirs are currently not recognised or monetised. Putting a value for all benefits is necessary to allow discussions and negotiations between different water users to find optimal and efficient solutions. In addition it is essential to have such values to bridge the gap between financial and economical viability. Many additional purposes of hydropower reservoirs may not be financially motivated in the short-term, but would give more equitable long-term benefits that are not reflected in the financial analysis. Trying to assess the economic value of all services is important for investors this is also a good way to bring stakeholders around the table to put a value collectively for water but also energy. Innovative financial mechanisms will be essential to address this gap between financial and economic feasibility, especially since hydropower reservoirs comprise such large up-front capital intensive infrastructure. The challenge is to find ways of framing long-term strategies, securing long-term finance sources and shielding them as effectively as possible from short-term exigencies. In the developing world, funding and guarantees from bi-lateral or multilateral development banks are important financing instruments that can provide low-cost financing over long repayment periods, and function as a catalyst for other investors. Pension funds are another example of financing with long time perspectives, which may unlock private sector capital to invest in long-term sustainable infrastructure, such as multipurpose hydropower dams.

3 – **Adaptability for all solutions:** It is essential to provide greater flexibility and adaptability in the way water is allocated among users during the entire lifetime of the reservoir. History has clearly shown that multipurpose reservoir developments are long-term investments that can benefit various generations, and new purposes, demands or preferences may appear during this long lifetime due to the evolution of social and environmental values and requirements. In recognition of the significant uncertainty associated with future changes in climate, economies and demographics, there is a need for the physical design and governance systems of hydro reservoirs to be able to respond to these changes. The multiple dimensions of projects as they emerge over time should be more explicitly addressed in the institutional management and operation arrangements. Hydropower as a renewable energy plays a key role in climate change mitigation. In addition the stored water in the reservoir could help adapt to climate change; hydropower is climate-sensitive and it is also very important for the energy security and economic development of countries. River flows are vital for healthy ecosystems and their services. The mitigation of reservoir sedimentation should be addressed with a multi-stakeholder approach from the early stages of project planning through to operation.

4 – **River basin perspectives for all:** An integrated approach is essential to reach a holistic view of the river basin. An important over-arching framework for sustainable hydropower reservoir development is Integrated Water Resource Management (IWRM) and basin development planning. Many hydropower projects are evaluated in isolation of an overall basin planning framework, and issues arise due to competing or conflicting needs and uses of the basin resources. The creation and effective functioning of transboundary river commissions (e.g. the Danube, Rhine, Mekong, Senegal rivers, etc.) with the purpose of enabling information exchange and better transboundary cooperation with water infrastructure development and operation is essential for upstream and downstream countries or those that have the same river as a national border. However some river commissions are not operating as intended. River basin organisations need political commitment to address the very sensitive discussions around dam/ reservoir projects, a broad representation of stakeholders and should also be equipped with capacities related to staff, finance, expertise, skills, know-how, infrastructure etc. in order to carry out their duties effectively. Cross-sector coordination should be foreseen for greater policy coherence and consistency of...
multipurpose reservoirs uses. Water allocation in river-basin planning is a very important step forward to achieve sustainable use of stored water among users. In addition, stakeholder initiatives may also provide interesting opportunities for better integration of the different reservoir water users.

5 – Engaging all stakeholders: Stakeholder engagement is critical for success in multipurpose reservoir management in terms of sustainability and efficiency. It is very necessary to identify all stakeholders likely to influence or be impacted by decisions on the reservoirs, and engage them in the early stages to participate on a voluntary basis in the dialogue. It is important that the groups need to see there is a reason for them to engage, i.e. that they can influence decisions and outcomes that would be better than if they had not participated. It is crucial to understand early in the process stakeholder interests and power relations between these stakeholders. Most of them may not know or understand the perspective of the other stakeholders involved; it is therefore important to raise awareness among them. Leadership within the community and across stakeholders is key for success. Equity, transparency and accountability should drive the solutions. Different viewpoints generate alternative priorities and highlight different challenges among stakeholders. Coordination and capacity improvements are required to manage multipurpose water uses issues between different stakeholders. Policy makers should increase their engagement with all stakeholders to improve their understanding of issues and better communicate their impacts. Communication and diplomacy will be essential. Policy makers should also provide the enabling environment for result-oriented stakeholder engagement, and strive to include the inputs of engagement processes towards improved decision making. The quality of the data sources and availability of information vary considerably at the local and state levels; making this information accessible, timely, understandable, usable and useful is the challenge. Strengthening partnerships and mobilizing resources remain essential to achieve effective multipurpose reservoir management.

The SHARE concept

Therefore a sustainable development and operation of multipurpose hydropower reservoirs should rely on “shared vision, shared resource, shared responsibilities, shared rights & risks, shared costs & benefits” principles. These principles and acknowledgement of joint sharing among all the stakeholders are key to successful development and management of multipurpose hydropower reservoirs, and should frame all phases from early stage to operation.

The SHARE concept also gives guidance through being an acronym for: Sustainability approach for all users, Higher efficiency & equity among sectors, Adaptability for all solutions, River basin perspectives for all, and Engaging all stakeholders, which correspond to the above five value propositions. Using the SHARE concept for multipurpose water uses of hydropower reservoirs both as an overarching principle and as a reminder of the five value propositions can help in making these reservoirs more sustainable and equitable.

As each project is always site specific in terms of technical, economical, social, environmental and other regulation issues, this SHARE concept provides basic principles that should be adapted to local conditions. Good practices presented in this report and annexes may help addressing this issue.
The multipurpose water uses of hydropower reservoirs

Shared vision, Shared resource,
Shared responsibilities, Shared rights and risks,
Shared costs and benefits

Future investments in and operation of hydropower projects should embrace the SHARE concept and take a multipurpose approach where appropriate together with the co-financing necessary to make it work. In the coming decades it is important that there is sustained and steady focus on utilization of multi-purpose opportunities for investment and operation, firstly on existing infrastructures in multipurpose hydropower reservoirs with dams. The way forward for each developer/sponsor is to work out a reasonable decision making process that meets these objectives with a duration that is predictable and compatible with the urgency of the needs to be met.
3 INTRODUCTION TO MULTIPURPOSE HYDROPOWER RESERVOIRS

This chapter initially presents key attributes of hydropower, followed by highlights of the main services provided by multipurpose water reservoirs, and concludes with an overview of the main positive and negative aspects of hydropower reservoir/dam projects.

**Hydropower is the first renewable electricity source**

Hydropower is the generation of power by harnessing energy from water. Electricity is generated through the transformation of hydraulic energy into mechanical energy to activate a turbine connected to a generator. Hydropower is currently the largest renewable power generation source (1085 GW installed, 3200 TWh/year). It accounts for 16% of the total electricity generated worldwide (IEA, 2013), or 76% of all electricity renewables. The potential for additional hydropower remains considerable, especially in Africa, Asia and Latin America. According to the International Energy Agency (IEA, 2012), the most important drivers for hydropower development will continue to be:

- long and productive local generation capability and low life-cycle costs;
- proven reliability of electricity production, with few service interruptions;
- safe operation, with minimum risks to hydropower staff and the general public;
- environmental and socially sustainable development, providing climate change mitigation;
- flexible operations, energy services enhancing grid stability and enabling use of variable renewables;
- large-scale energy storage for seasonal load balancing;
- provision of many non-energy services such as flood control, water supply and irrigation, especially in the context of growing freshwater needs and adaptation to climate change;
- upgrades, redevelopments and improvements to existing hydropower plants;
- addition of hydropower facilities, where feasible, to existing dams originally built to provide flood control, irrigation, water supply and other non-energy purposes; and
- energy security with local generation.

The contribution of hydropower to decarbonising the energy mix is twofold: the primary benefit is its clean, renewable electricity, and the secondary benefit is as an enabler to allow a greater contribution from variable renewables on the grid as hydropower helps stabilise fluctuations between demand and supply (i.e. hydro is an enabler of variable renewable energy sources).

The need for affordable and clean energy, for water in adequate quantity and quality, and for food security will increasingly be the central challenges for humanity: these needs are strongly linked. **Hydropower is at the heart of the water-energy nexus.** Hydropower has a special role to play in economic development, social justice and environment caution which represent the basic pillars of sustainable development. Hydropower is at the cross road of two basic human needs which are energy and water supply.

Hydropower plants can be constructed in a variety of sizes and with different characteristics. Hydropower facilities installed today range in size from less than 100 kW to
greater than 22 GW. In addition to the importance of the head and flow rate, hydropower schemes can be put into the three main categories (IPCC, 2011):

- **Run-of-river (RoR)** hydropower projects have no, or very little, storage capacity behind their dams and generation is dependent on the timing and size of river flows.

- **Reservoir** (storage) hydropower schemes have the ability to store water behind the dam in order to de-couple power generation from river inflows. Reservoir capacities can be small or very large, depending on the characteristics of the site and the economics of dam construction.

- **Pumped storage hydropower** schemes use off-peak electricity to pump water from a lower to a higher reservoir, so that the pumped storage water can be used for generation at peak period times; they provide grid stability and flexibility services.

For the remainder of this document, only storage hydropower will be considered, i.e. hydro with reservoirs that have multipurpose water uses.

### The different purposes of hydropower reservoirs

Hydropower reservoir projects are also used for freshwater management and they provide a variety of value-added uses. The reservoir provides the opportunity to release water when it is most advantageous and provides a constant flow of water via penstocks through turbines to generate electricity. Storage hydropower can therefore be used for both base and peak power load. The multipurpose uses of hydropower reservoir usually imply “multi-users”. Hydropower reservoirs can also regulate water flows for freshwater supply, flood control, drought mitigation, irrigation, navigation services and recreation. Regulation of water flow may be important to climate change adaptation (IEA, 2012).

According to ICOLD’s Register (status March 2015) there are 38,452 large dams in the world with their purposes described, among which 26% are multipurpose large dams/reservoirs. Only 9,568 (or 25%) of large dams in the world have hydropower as one of their purposes (single or multipurpose reservoirs). The figure below presents these purposes for single and multi-purpose dams/reservoirs.

---

**Use of dams / reservoirs by purpose according to ICOLD database**  
Emmanuel BRANCHE’s analysis, March 2015

**Single purpose dams**  
<table>
<thead>
<tr>
<th>Purpose</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydropower</td>
<td>5706</td>
</tr>
<tr>
<td>Water supply</td>
<td>3650</td>
</tr>
<tr>
<td>Flood control</td>
<td>2460</td>
</tr>
<tr>
<td>Recreation</td>
<td>1352</td>
</tr>
<tr>
<td>Navigation &amp; fish breeding</td>
<td>138</td>
</tr>
<tr>
<td>Others</td>
<td>1322</td>
</tr>
</tbody>
</table>

**Multi-purpose dams**  
<table>
<thead>
<tr>
<th>Purpose</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydropower</td>
<td>3862</td>
</tr>
<tr>
<td>Water supply</td>
<td>4334</td>
</tr>
<tr>
<td>Flood control</td>
<td>4783</td>
</tr>
<tr>
<td>Irrigation</td>
<td>5977</td>
</tr>
<tr>
<td>Recreation</td>
<td>2879</td>
</tr>
<tr>
<td>Navigation &amp; fish breeding</td>
<td>1850</td>
</tr>
<tr>
<td>Others</td>
<td>1173</td>
</tr>
</tbody>
</table>
In addition to hydropower, the other main purposes are briefly described below:

- **Irrigation**: It is the artificial application of water to the land or soil. It is used to assist in the growing of agricultural crops, maintenance of landscapes, and re-vegetation of disturbed soils in dry areas and during periods of inadequate rainfall. In addition, irrigation has a few other uses in crop production, which include protecting plants against frost, suppressing weed growth, and delaying soil consolidation. Most of large dams (ICOLD, 2014) in the world have been built for irrigation purposes (intert or by-product). It is very important for the water-energy-food nexus.

- **Drinking water supply**: Water storage for safe and available supply of drinking water was behind the early development of dams. Nowadays, the provision of fresh water by public utilities, commercial organizations, community endeavours or by individuals, is usually provided from the reservoir through a system of pumps and pipes. This is an increasing important issue in the world (water scarcity and quality). Water storage systems designed with the primary purpose of providing bulk water supply can be assessed and evaluated according to their ability to meet pre-determined targets of water delivery. It is also very important for the water-energy-food nexus. There are also possible concerns over water quality.

- **Navigational conditions**: The construction of a dam across a river forms a reservoir that both raises the water level upstream (i.e. stores the water) and slows down its rate of flow. There can be improvements in navigation conditions upstream of the dam for shipping, such as submergence of dangerous areas of rocks, sandbanks and rapids (flooding of such habitats can have an adverse effect on fisheries and other ecosystem services). In addition, water from the reservoir can be released into the river downstream during the drier seasons of the year to ensure that it is deep enough for navigation all the year round. However, a dam also forms a barrier to navigable passage past the dam. To enable safe navigable passage past the barrier in both directions some form of boat passage needs to be provided. This can take the form of ship locks, lifts, ramps or other such means. Reservoirs and boat passage play an important role for this economy both upstream and downstream of the reservoir.

- **Flood control**: Ambitions to control river flows for improved agriculture and industry and in particular to protect living populations and property from flooding are a fundamental aspect of water storage. These storage reservoirs regulate river flows and operate by storing varied volumes of flood waters in reservoirs and then controlling the timing of water discharge over time. Similarly, there is competition in setting reservoir rule curves that balance the drawdown levels prior to the flood season, to prevent or minimize spill, with the need to maintain maximum hydraulic head for hydro generation.

- **Drought mitigation**: Many dams and their associated reservoirs supply additional water in times of drought that can have a substantial impact on the ecosystem and agriculture of the affected region.

- **Recreational activities**: The water bodies provided by many reservoirs often allow some recreational uses such as fishing, sailing (canoe, kayak, water-skiing, swimming or even use small sailboats), and other activities. These activities (generally by-product) are increasingly coming as a priority for the people living close to the reservoirs, and therefore attract tourists in this lake area. A distinction may be relevant between developed and developing economies. For example in developed economies, fishing is normally a recreation activity, whereas in developing economies it is normally about providing a food supply to maintain livelihoods.

- **Commercial fisheries**: In addition to recreational fishing some reservoirs support commercial fisheries. These can be in the form of fishing from boats, trapping at the dams and artificially enhancing the stocks. The development of commercial fish farming (generally by-product) has recently increased in many areas.

Although hydropower does not directly consume water, hydro generation may be in competition with other uses, because its release schedule does not always correspond to the timing of water use by other activities but it may involve river diversions negatively affecting downstream uses. Those conflicts between water users are increasing, making evident the lack of a judicious, balanced and transparent procedure for water allocation or governance. The question of water allocation between sectors in general and between hydropower and other activities in particular, is thus crucial. This situation is particularly apparent in regions where multipurpose demand comes from users with a wide range of needs and different levels of power, and where human appropriation of water is reaching unsustainable levels. This is increasingly challenging where the rivers cross borders (i.e. the transboundary issue).
Hydropower & dams: advantages and disadvantages

Hydropower dams have both positive and negative impacts which are well documented in the 2000 report of the World Commission on Dams (WCD, 2000). After several decades of experience, hydropower reservoir’s strengths and weaknesses are thus well known and understood. Whilst not all negative impacts of hydropower reservoir can be avoided, many of them can be minimised, mitigated or compensated. The figure below presents an overview of advantages and disadvantages of hydropower & dam reservoirs regarding their sustainable aspects (i.e. in terms of economic, environmental and social issues).

The degree to which multipurpose hydropower reservoirs can advance sustainable development objectives depends on careful planning, construction and management, as well as particular attention to maximising the positive and minimising the negative aspects in project development, implementation and operation.
4 THE SHARE CONCEPT

The main hydropower reservoir issue to be addressed is sharing water amongst competing users. Although there are no universal solutions, there are principles that can be shared and adapted to local contexts. Indeed the development and/or operation of such multipurpose hydropower reservoirs should rely on the following principles:

**Shared vision, Shared resource, Shared responsibilities, Shared rights and risks, Shared costs and benefits**

This chapter provides a description of the SHARE concept along its five main components:

- **Sustainability approach for all users**, which ensures a common language among stakeholders and provides a measurement of the sustainable development of the project.
- **Higher efficiency and equity among sectors**, which allows for better resource allocation.
- **Adaptability for all solutions**, which ensures flexibility in the governance model.
- **River basin perspectives for all, and**, which promotes a holistic approach to sustainability.
- **Engaging all stakeholders.**

Boxes are presented to support a special statement based on case studies or reference initiatives. Readers interested in a particular case study could refer to Annexes document for detailed analysis.

4.1 | Sustainability approach for all users

The degree to which multipurpose hydropower reservoirs can advance sustainable development objectives depends on careful planning, construction, operation, management and governance. It is important to implement an adequate governance model that fosters equity across water reservoir users and ecosystems in line with agreed sustainability objectives. There are no one-size-fits-all solutions as each project is site specific and as water governance is place-based and context-dependent. It is therefore essential to customise the governance model to local conditions.

The Hydropower Sustainability Assessment Protocol for those multipurpose reservoirs creates a common language among stakeholders and provides a measurement of the sustainable profile of the project and guidance for continuous improvement. In addition governance mechanisms are vital tools for achieving equitable access to, and provision of, ecosystem services.

The subject of the hydropower development sustainability has been debated extensively over the last few decades. Multipurpose hydropower reservoir projects can make a significant contribution to sustainable development when they are developed and operated in an economically viable, environmentally sound and socially responsible manner. The history of hydropower development includes periods of intense controversy over the need for large dams, the practices involved in developing hydropower and the impact of development for local communities and the environment. The benefits and challenges of developing hydropower reservoirs are well understood and negative impacts well identified. Though some impacts cannot be eliminated, much can be done to mitigate or compensate for them in a sustainable manner, covering environmental, economic and also socio-political aspects (Locher et al, 2012). Increasingly through the 1990s, attention at a global level was directed at the sustainability issues relating to dam development broadly and hydropower specifically. One of the first international level initiatives to better define these issues and develop mitigation measures to address them was through the International Energy Agency’s (IEA) Implementing Agreement on Hydropower Technologies (cf. IEA Hydro Annex III on Hydropower and the Environment, 1995-2000). A major and intensive focus was cast on the dams sector globally through the World Commission on Dams (WCD) between 1998 and 2000, and its follow-up the UNEP Dams and Development Project (DDP) lasted from 2001 to 2007; in two phases. In the last decade, an interesting and participative initiative addressing sustainability in the hydropower sector has been driven by the International Hydropower Association (IHA) to develop the Hydropower Sustainability Assessment Protocol. Box 1 presents an overview of this protocol.

The section below is focusing more on Governance; it is an enabling strategy that cuts across all the five shared approaches.
The Hydropower Sustainability Assessment Protocol is a tool that promotes and improves the sustainable use of hydropower. It provides a common language that allows governments, civil society, financial institutions and the hydropower sector to talk about issues of sustainability. It offers a way of assessing the performance of hydropower over more than 20 sustainability topics.

Assessments are based on objective evidence and the results are presented in a standardised way, making it easy to see how existing facilities are performing and how new projects are being developed. It is based on five core values and seven strategic priorities of the 2000 World Commission on Dams (WCD) report. It is the result of intensive review from 2008 to 2010 by the Hydropower Sustainability Assessment Forum (Forum). The Forum’s members came from social and environmental NGOs, governments, commercial and development banks and the hydropower sector. Many of these organizations are now represented in the Hydropower Sustainability Assessment Council (Council). This Council includes representatives from social and community organisations, environmental organisations, governments from around the world, banks and investors, and the hydropower sector and works to ensure that all voices are heard with regard to the use of this protocol and its future development.

It can be used at any stage of hydropower development, from the very earliest planning stages, right through to operation. It has also been designed to work on projects and facilities anywhere in the world. To assess the sustainability of hydropower projects at all stages of development, the HSAP comprises five documents – a background document and four assessment tools (Early Stage, Preparation, Implementation and Operation) for the different stages of the project life cycle.

More information available at: http://www.hydrosustainability.org/

---

OECD underlines the extent to which the current water crisis is largely a governance crisis. It also stresses that often, the technical, financial and even institutional “solutions” to the crisis are well-known. The main challenges concern their implementation on the ground – overcoming the governance gaps hindering water policy, monitoring social, environmental and economic outcomes and engaging stakeholders at all level to design and implement place-based policies, tailored to local contexts (OECD, 2011). The OECD Water Governance Initiative (OECD-WGI, http://www.oecd.org/gov/regional-policy/water-governance-initiative.htm) is an international network that convenes key stakeholders within and outside the water sector in order to share experiences and lessons learnt in support of better governance in the water sector. The OECD-WGI has an open membership and a wide geographic, economic and institutional representation of key water governance players at local, basin, national and global levels. Regarding the multipurpose reservoirs, such a governance issue is essential to have sustainable use of the water among users. The governance model for multipurpose reservoirs should rely on best practises requirements, but need to be adapted to local context. There is no one size
fits all solutions, but good practises could be found in different case studies. For instance the Box 2 presents the French experience on that matter based on the Villerest dam example.

Governance mechanisms can create an enabling environment for implementing ecosystem service management and securing the equitable distribution of service benefits. The provision of ecosystem services and the benefits that people derive from them are influenced by the rules, practices and institutions that govern the management and use of those natural resources. It should be noted that interventions can be made at all governance levels (sub-basin, basin, local, regional, national and international) to improve the long-term sustainability of ecosystem services. The equitable access to those services and their benefits could be foreseen by encouraging, facilitating or enforcing changes to ecosystem service use and management.

Consultative Group on International Agricultural Research (CGIAR) framework highlights the importance of ecosystem service and resilience concepts (CGIAR, 2014). Conservation of important ecosystems should be considered in the decision making process. Box 3 presents the Arenal case study.

---

**BOX 2 – THE WATER GOVERNANCE IN FRANCE FOR MULTIPURPOSE RESERVOIR: A PARTICIPATIVE APPROACH WITH EXAMPLE OF THE VILLEREST DAM/RESERVOIR AND THE BASIN TERRITORIAL PUBLIC INSTITUTION**

Villerest purposes: hydropower, flood control and water management

There are several discussion forums and tools to promote policies integration in France and in Europe. The River Basin Management Plan is a detailed account of how the objectives set for the river basin (ecological status, quantitative status, chemical status and protected area objectives) are to be reached within the timescale required by the European Union Water Framework Directive. Among the main discussion forums, the most important ones are:

- The **Basin Committee** brings together stakeholders (elected representatives, users and administrations) to deliberate and to take decisions in the interest of all in water resource matters (but this is not the case everywhere in Europe),

- The **EPTB (Établissement Public Territorial de Bassin)**, i.e. basin territorial public institution): regions, departments and areas bordering a common waterway, logic upstream-downstream reasoning; arbitration and processing of the various requests on a hierarchical basis. **EP Loire** is responsible for the operation of Villerest dam.

Several tools are available:

- The **SDAGE (Schéma Directeur d’Aménagement et de Gestion des Eaux)**, River Basin Management Plans, RBMPs) and the associated Programmes of Measures (PoM): prioritised objectives and measures at catchment level;

- The **SAGE (Schéma d’Aménagement et de Gestion des Eaux)** is adapted to the sub-basin level to Development and Water Management Plans;

- Other types of forward planning documents: river contracts (drinking water, water treatment, environment), management plan of low water levels (resources/needs balance), territorial project for the creation of new dams, etc.

More information can be found in the Annex document, where this Villerest case study is presented in detail (number 6).
Arenal purposes: hydropower, irrigation and recreation

This case study presents the Costa-Rica attempt to make the most effective dual use (energy and agriculture) of the water resources of Lake Arenal Rica, the country’s largest water reservoir, and an increasingly important tourist destination. Arenal Lake was declared Ramsar site on 16 March 2000.

The concerns about the lake, such as the stability of its watershed, problems of deforestation, and possible premature sedimentation, led the Government to create a Lake Arenal Watershed Management and Development Plan in 1996, and a Commission to implement the plan in 1997. The intent was to involve all the interested parties and institutions to make the best use of all resources. The environmental outcomes have been mixed, i.e. negative from disruptions caused by construction of the dam and irrigation project and positive as the project attracted the attention of government authorities who has done a good job at protecting the forests and introducing a vision of sustainable development.

The Commission for the Implementation of the Development and Management Plan of the Arenal Reservoir Watershed, when operated, create a platform for dialogue with all stakeholders and was established in part to bring different stakeholders together.

The Costa Rican government has financed the establishment of the ACAT (Area de Conservación Arenal Tempisque) including payments of more than US$ 11 million in land purchases for conservation. Furthermore, several local NGOs have also invested in conservation measures, including forest protection and environmental education with grant funds obtained from foreign aid agencies and NGOs. Planning and land use zoning, including the Basin Plan cost an estimated US$ 1 million. ACAT holds special value for one or more endemic species or communities of flora and fauna in each of seven protected areas and contains 1,131 species of flora.

The wetland provides benefits related to hydropower generation, irrigation, tourism (water sports), recreational fishing and consumption, grazing, domestic agriculture and irrigation, agriculture and aquaculture. Approximately 80% of the existing legislation is being enforced to regulate activities in the wetland and other protected areas. Environmental education programs are being implemented to involve organized groups, farmers, community leaders, teachers and schoolchildren in the search for better opportunities for the wise use of natural resources.

More information can be found in the Annex document, where this Arenal case study is presented in detail (number 1).

4.2 | Higher efficiency and equity among sectors

Economic data and innovative financial mechanisms are crucial for equitable and efficient sharing of benefits among water users. A major challenge is that many of the additional benefits around hydropower reservoirs are currently not recognised or monetised. Putting a value for all benefits is necessary to allow discussions and negotiations between different water users to find optimal and efficient solutions. In addition it is essential to have such values to bridge the gap between financial and economical viability. Many additional purposes of hydropower reservoirs may not be financially motivated in the short-term, but would give more equitable long-term benefits that are not reflected in the financial analysis. Trying to assess the economic value of all services is important for investors this is also a good way to bring stakeholders around the table to put a value collectively for water but also energy. Innovative financial mechanisms will be essential to address this gap between financial and economic feasibility, especially since hydropower reservoirs comprise such large up-front capital intensive infrastructure. The challenge is to find ways of framing long-term strategies, securing long-term finance sources and shielding them as effectively as possible from short-term exigencies. In the developing world, funding and guarantees from bi-lateral or multilateral development banks are important financing instruments that can provide low-cost financing over long repayment periods, and function as a catalyst for other investors. Pension funds are another example of financing with long time perspectives, which may unlock private sector capital to invest in long-term sustainable infrastructure, such as multipurpose hydropower dams.
Multipurpose water infrastructure projects are capital-intensive operations and most of the financial resources have to be available upfront, increasing the cost of capital. Making the duration of the decision making process reasonably predictable is therefore essential to the bankability of a project. Bankability is the combination of considerations pertaining to risk management and to financial viability.

Investment in hydropower reservoirs has traditionally been the realm of the public sector, as hydropower projects are major infrastructure investments. More recently, private players have entered the sector that includes public–private partnerships (PPP), where risks are allocated to the party best able to manage it. With increasing multi-purpose use of freshwater reservoirs and the growing role of the private sector, it is important to analyse both economic and financial performance of hydropower developments. Some innovative models were developed to overcome these financial and economical challenges. Box 4 presents the Olmos case study in Peru with an innovative PPP model.

Other models exist that allow developing multipurpose reservoirs in a sustainable way. This is particularly interesting regarding cascades projects. Indeed the regulating dam/reservoir (i.e. largest storing capacity upstream of the river) allows water flow regulation for all downstream assets. This water management capacity is very important to develop and manage the whole basin in an efficient and effective way, for hydropower development but also for all other water users (water allocation among users) and the environment (minimum flows for instance). Innovative water fees may be used to pay back for this initial investment as well as for the operation of this reservoir (see Box 5 with the Lom Pangar example in Cameroon).

Hydropower reservoir projects are also used for freshwater management to provide a variety of value-added uses. In such projects, hydropower typically brings a financial justification for investment in public benefit such as flood protection, drought management, navigation, irrigation and recreation. Given the major investment required for hydropower, and the potential impact on local environments, politicians and the general public are likely to support projects that offer multiple benefits beyond electricity. This also highlights the need for a holistic approach, thorough and wide consultation process and proper management of the project to deliver optimal benefits to all involved. These multiple services and benefits have reinvigorated interest in hydropower and have altered perceptions of its importance. Significant advancements in sustainable development practices have also improved acceptance and willingness to engage among the stakeholder community, including policy-makers and the financial sector (see §4.1 - Sustainability approach for all users). However there is today a lack of recognizing and quantifying all benefits of hydropower reservoirs.

### Box 4 – Olmos project in Peru: A PPP model to address the investment challenge

**Olmos purposes: hydropower and irrigation**

Olmos project consists of 3 main elements, (i) diversion of water from Huancabamba River (Atlantic basin) to Olmos River (Pacific basin), including the construction of the Limon Dam and diversion of regulated water through 20 km long tunnel, (ii) development of a new irrigation area of 38,000 ha, using water transferred by the diversion system and (iii) the construction and operation of 2 hydropower plants. This project is under implementation. It should be noted that the first hydropower plant is also registered as a CDM project of the UNFCCC.

For each of the project’s elements a different approach was applied for making it viable and for distributing correctly the corresponding costs and benefits between public and private sectors.

The concession is a Build-Own-Operate-Transfer (BOOT)/Public Private Partnership (PPP) where the Government of Peru auctions the land to be irrigated, the proceeds of such sale finance the construction of the irrigation infrastructure, and the private partner develops the necessary works to operate adequate irrigation services. The Private partner then manages and charges for irrigation services for 20 years. Peruvian pension funds took part in the financing roundtable and may boost infrastructure investments in Peru.

The concessionaire grants lot buyers individual Water License Certificates that are transferable among irrigators. This is a real opportunity for increasing the flexibility for water users allowing an optimal use of the water by reallocation of water amongst water users.

More information can be found in the Annex document, where this Olmos case study is presented in detail (number 2).
and quantifying all benefits of hydropower reservoirs for all users). However, there is also improved acceptance and willingness to engage among advancements in sustainable development practices. Significant externalities have reinvigorated interest in hydropower and have altered perceptions of its importance. Significant benefits beyond electricity are likely to support projects that offer multiple uses and have altered perceptions of its importance.

For instance, the non-power services benefits that hydropower reservoirs can bring to a country or region often cannot be clearly quantified on a return on investment basis. For example, many hydropower projects offer an element of flood protection for the local region and the economic value lies in the value preservation and avoidance of damages. Although it is a highly valued benefit, there is no specific contribution to return on investment for this service. Other multi-purpose benefits include drought management, drinking water supply, irrigation, navigation and tourism, all which typically do not offer clear and direct revenue streams to reservoir developers. When considering a multi-criteria analysis, to give an economic value to all services is sometimes difficult and may be controversial (flood control, sediment management, etc.). A comparison of the cost of benefits of a project should always be compared to the situation in a non-project situation; it is also important to know how benefits and costs are distributed between users and the trade-offs mitigations they imply. Trying to assess the economic value of all services is needed because at the end, investors (public or private ones) will take their decision based on the financial/economical analysis of the project. It should be noted that this is also a good way to bring stakeholders around the table to put a value collectively for water but also energy, and thus put externalities into financial valuation.

Dam projects generate numerous impacts both on the region where they are located, as well as at an inter-regional, national and even global level (socioeconomic, health, institutional, environmental, ecological and cultural impacts). The World Commission on Dams (WCD, 2000) and numerous other studies have discussed the importance and difficulties of evaluating a number of these impacts. One of the issues raised by these studies is the need to extend consideration to indirect benefits and costs of dam projects. According to the WCD’s Final Report (WCD, 2000) “a simple accounting for the direct benefits provided by large dams—the provision of irrigation water, electricity, municipal and industrial water supply, and flood control—often fails to capture the full set of social benefits associated with these services. It also misses a set of ancillary benefits and indirect economic (or multiplier) benefits of dam projects”. Indirect impacts are called multiplier impacts, and result from both inter-industry linkage impacts (increase in the demand for an increase in outputs of other sectors) and consumption-induced impacts (increase in incomes and wages generated by the direct outputs). Multipliers are summary measures expressed as a ratio of the total effects (direct and indirect) of a project to its direct effects. A multi-country study on multiplier effects of large hydropower projects was performed by the World Bank (World Bank, 2005), which estimates that the multiplier values for large-scale hydropower reservoir projects vary from 1.4 to 2.0, meaning that for every dollar
of value generated by the sectors directly involved in dam-related activities, another 40 to 100 cents could be generated indirectly in the region. Though these multiplier benefits are not unique to hydropower projects, but accompany—to varying degrees—any energy project, they nonetheless represent benefits that might be considered by communities considering hydropower reservoir development. There are several initiatives that are willing to identify and evaluate those different benefits.

New methodologies are currently developing which can be applied to quantify the value created at hydropower reservoirs. Box 6 presents a new methodology developed by EDF to identify and evaluate created benefits and to take them into consideration for operation and planning.

**BOX 6 - THE EDF VALUE CREATION METHODOLOGY: A SYSTEMATIC ASSESSMENT AND BENEFIT SHARING APPROACH FOR HYDROPOWER PROJECTS**

**Durance-Verdon purposes: hydropower, flood control, water supply, irrigation, fisheries, recreation, navigation, water flow management**

An important step in developing Cameroon's largely unexploited hydropower potential is the construction of a Existing and planned hydropower projects present multiple opportunities to create environmental and socio-economic value for their host communities and regions. EDF is developing a methodology to identify and evaluate created benefits and to take them into consideration for operation and planning. The project objectives are:

- Identification of socio-economic and environmental values created by hydropower installations as well as their spatial and temporal distribution,
- Analysis of the contribution of the operator to the value creation in a given region,
- Evaluation in qualitative, quantitative and, if possible, monetary terms of the created values, including non-power considerations around drinking water supply, employment creation, irrigation, tourism, navigation and flood protection,
- Development of didactic ways to present values and to facilitate stakeholder engagement around the created values.

Five categories for assessment were identified and applied on a number of test cases: i) Electricity services (electricity, tax payments, system services, etc.); ii) Socio-economic values (employment creation, drinking water, irrigation, etc.); iii) Societal values (health services, education, social cohesion, etc.); iv) Environmental values (biodiversity protection, rehabilitation of aquatic or terrestrial environments, fish farming etc.), and v) Risk management (flood and drought protection, etc.).

2 full methodology applications were undertaken at the Durance-Verdon valleys in France and at Nam Theun 2 in Lao PDR. Figures below present the main results of the French case (spatial & temporal distributions):

**More information can be found in the Annex document, where this Durance-Verdon case study is presented in detail (number 5).**
In addition to regulation and legislative framework, direct initiatives between stakeholders based on an economical approach to foster a win-win situation can be appropriate. Such initiatives may appear to solve a crisis, but can also be proactive in sharing costs and benefits in an efficient way. Box 7 presents the water saving conventions that have been developed between EDF and irrigators in France.

**BOX 7 - INNOVATIVE WATER SAVING CONVENTIONS BETWEEN EDF AND IRRIGATORS FOR A WIN-WIN SITUATION: THE ENERGY LOSS METHODOLOGY FOR DURANCE-VERDON VALLEYS**

**Durance-Verdon purposes:** hydropower, flood control, water supply, irrigation, fisheries, recreation, navigation, water flow management

EDF is required to deliver 200 Mm³ to irrigators between 1st July and 30th September annually (as Ministry of Agriculture financed part of the Serre-Ponçon dam construction), and an information bulletin is sent each week to farmers about irrigation flows.

EDF encourages farmers to **save water by financing modern systems** for water use reduction. This specific agreement leads EDF to pay back a part of the savings if the targeted objectives are reached. The evaluation of energy loss is based on a method developed jointly by EDF and the Rhône-Méditerranée-Corse Water Agency, who provides part of the financing. It is a simplified method worked out to provide the reference, in negotiations between EDF and other users, on the cost to hydropower generation of new external constraints or uses. It consists in evaluating losses due to lost or shifted energy, with respect to a year divided into specific periods, and then to evaluate them on the basis of a representative price of electricity market futures. Given the multipurpose water uses of Serre-Ponçon hydropower reservoir, requirements and constraints, EDF wanted to use water valuation to help manage the allocation of regional water resources and optimize water use not only for itself, but also for other stakeholders. The application of water valuation based on energy loss evaluation method was used to take into account a combination of purposes. These included helping to: improve operations and management (through option appraisal and water use efficiency); enhance overall environmental and social considerations; and assess how much EDF should compensate the irrigators for reducing their water consumption.

Thanks to this convention significant water savings were reached (**a 30% reduction of water by the irrigators**), and this is a **win-win solution** for: i) Irrigators (they have an attractive annual compensation, and a better control of the Serre-Ponçon reservoir); ii) Energy (there is a better seasonal use with the saved water volume stored (which could be generated during peak hours) but a limited energy gain (as those savings are located at the downstream end of the chain ; the valuation is recovered 20% on the energy side and 80% regarding appropriate time generation); iii) Environment (it benefits from water savings that were used by EDF); and iv) Tourism (it contributes to minimize variations in the Serre-Ponçon reservoir water levels).

More information can be found in the Annex document, where this Durance-Verdon case study is presented in detail (number 5).
4.3 Adaptable for all solutions

It is essential to provide greater flexibility and adaptability in the way water is allocated among users during the entire lifetime of the reservoir. History has clearly shown that multipurpose reservoir developments are long-term investments that can benefit various generations, and new purposes, demands or preferences may appear during this long lifetime due to the evolution of social and environmental values and requirements. In recognition of the significant uncertainty associated with future changes in climate, economies and demographics, there is a need for the physical design and governance systems of hydro reservoirs to be able to respond to these changes. The multiple dimensions of projects as they emerge over time should be more explicitly addressed in the institutional management and operation arrangements. Hydropower as a renewable energy plays a key role in climate change mitigation. In addition the stored water in the reservoir could help adapt to climate change; hydropower is climate-sensitive and it is also very important for the energy security and economic development of countries. River flows are vital for healthy ecosystems and their services. The mitigation of reservoir sedimentation should be addressed with a multi-stakeholder approach from the early stages of project planning through to operation.

Hydropower reservoirs can make a powerful case as a long-term investment, by delivering sustainable energy and water services for multiple generations. Hydropower projects do have high upfront outlays during the construction phase, but they have very low running costs and operate for many decades. There are many projects older than 100 years and still under operation, having additional purposes since their origins. It is therefore important to keep in mind the dynamic dimension of those reservoirs, where activities which were not initially expected may appear on the reservoir or expected ones may never occur due to changing society, climate change, etc. Any solution or mechanism to address these multipurpose water uses of hydropower reservoirs should be flexible. Box 8 presents the new operating rules between HydroTasmania and irrigators in Australia.

Management of multipurpose freshwater reservoirs is especially important in the context of climate change. As a renewable energy source, hydropower offers a contribution to climate change mitigation. As water management infrastructure, it is also expected to play an increasingly important role in climate change adaptation, where it will be called upon to help respond to expected increases in extreme weather events, including more intense and frequent flood incidents and longer periods of drought. Considering the evolution of the water resource and the water demand under climate stress and depending on demographic and socio-economic territories, adaptation strategies may evolve or be developed. Water savings are the most obvious lever, plus crop and development choices that ensure long-term effectiveness of a model that has proven to serve the general interest and which finds answers to reduce water use conflicts that could arise if nothing is done. Access

BOX 8 - THE ARTHURS LAKE: NEW OPERATION RULES RESPONDING TO IRRIGATION AS A NEW PURPOSE

Arthurs Lake purposes: hydropower, irrigation, fisheries and recreation

Arthurs Lake is a very good example of multipurpose water uses of reservoirs in Tasmania, Australia. The multiple purposes that Arthurs Lake can deliver are hydropower, recreation, a fishery and irrigation.

Irrigation is a new purpose, with the commissioning of the Midlands Water Scheme in August 2014. Water for the Midlands irrigation district is sourced from Arthurs Lake. Farm Water Access Plans are all in place and will ensure the environmental sustainability of the scheme. Water price and supply in the irrigation district is underpinned by a water supply agreement between Tasmanian Irrigation and Hydro Tasmania. The agreement recognises that water taken from Arthurs Lake would have otherwise been used to generate electricity at Hydro Tasmania's Poatina and Trevallyn Power Stations.

Considering the economic and financial benefits (and costs) was a key step when considering changes to the storage operating rules of Arthur Lake. With respect to accommodating irrigation needs, Hydro Tasmania evaluated the implications on electricity generation and revenues. The water pricing principle developed by Hydro Tasmania in a transparent way is an effective means to consider water sharing among users.

More information can be found in the Annex document, where this Arthurs Lake case study is presented in detail (number 11).
to water is in this context a major strategic challenge for all stakeholders. The good structural design of such multipurpose water infrastructure give all water users time to set governance to find and to implement solutions to preserve the future. This is the collective challenge of tomorrow! Uncertainty exists. It is up to all stakeholders to collectively manage and prepare for tomorrow’s developments with less water, less money and more risks. The answer to those challenges is not unique and should be addressed on a case by case approach. There is also a need to have flexible and adaptable multipurpose management schemes to be able to adapt to the effects of climate change as it might affect some users more than others, as presented in Box 9.

While hydropower reservoirs are recognised for their contribution to energy and water services, global relative water storage capacity is diminishing (existing storage is decreasing mainly due to sedimentation, at a rate faster than new storage is being created better develop run-of-river projects, etc.). This is due in particular to the more challenging conditions for developing projects with storage reservoirs, thus favouring run-of-river projects (i.e. with no reservoir and storage capability). Indeed opposition to large reservoirs can come in the form of both environmental and social concerns. These concerns could be appropriately addressed in consultation with all stakeholders (especially those most impacted by the development) and by planners as they can consider the broader strategic needs for water storage along with the electricity. This is especially true in the context of climate change where water storage infrastructure will be increasingly called upon to help manage the effects of extreme weather events (floods and droughts). Strategic planning of hydropower at a national and river basin level can help to address this issue, by ensuring sufficient storage is integrated at the system level, rather than on a project-by-project basis. In markets relying on private sector development, additional services are often considered unfunded obligations placed on the developer, with no recognition of the value they contribute. The Box 10

---

**BOX 9 - THE R2D2,2050 PROJECT: AN INTEGRATED AND MULTIDISCIPLINARY APPROACH TO ASSESS IMPACTS OF CLIMATE CHANGE ON THE DURANCE-VERDON WATER SYSTEM**

**Durance-Verdon purposes: hydropower, flood control, water supply, irrigation, fisheries, recreation, navigation, water flow management**

The R2D2,2050 project is partnership project aimed at assessing the possible impacts of climate change on the quantity and quality of water resources, biodiversity and the changing demand and uses till 2050. The goal is to inform the communities and public authorities about the measures required in order to adapt to one of the 21st centuries’ greatest challenges.

This research program will in particular provide insights on:

- Changes in the hydrological regime of the major rivers of the watershed and the water supply;
- Applications in current and future water uses (hydropower, agriculture, tourism, etc.), including the main aquatic ecosystems, local or external, which put pressure on the hydro plants of the Durance-Verdon system;
- Potential future imbalances resulting from the confrontation between supply and demand under scenarios of climate change and socio-economic development;
- Leeway and management alternatives to ensure a “balanced and sustainable” management of water resources in line with the objectives and challenges of planning;
- Uncertainties attached to the main results obtained, as well as the relative importance of potential sources of uncertainty.

This project is based on 3 principles of innovative search: (i) the development of an integrated, multi-disciplinary approach to build an operationally accurate representation of how the river system works, taking into account the main biophysical and decision-making processes, their interactions and their spatial distribution; (ii) the simultaneous application of different hydrological models on the same watersheds and methods for assessing future water demand to reduce uncertainties resulting from methodological choices; and (iii) the mobilization of local players.

This research project can thus allow 1) co-constructing territorial socio-economic scenarios, 2) sharing the assumptions and results, and 3) assessing their operational relevance in the context of policy initiatives.

More information can be found in the Annex document, where this Durance-Verdon case study is presented in detail (number 5).
Hydropower has long been the cornerstone of the power sector in Brazil, but there remains significant potential to expand. In 2012, installed hydropower capacity was 83 GW, around one-third of the estimated 245 GW of hydro potential in Brazil. Hydropower continues to be central to the operation of Brazil’s power system in the future projections according to IEA projections (IEA, 2013), but this is not only the volume of hydropower capacity added, but also the type of capacity. Most of the additions over the period to 2035 are run-of-river (RoR) hydropower, not involving the expansive reservoirs of many existing hydropower projects in Brazil, as RoR hydro projects are considered to have less environmental and social impacts. The volume of water stored in hydropower reservoirs is at present a key (and closely watched) indicator for the Brazilian power and water sectors, as it represents a massive amount of stored water-energy, to be used as needed by the system. The volume of stored water/energy has been declining in relation to the overall size of the Brazilian power sector since the mid-1980s and the addition of run-of-river hydropower would continue this trend.

The relative storage capacity of Brazil’s hydropower system is expected to continue to decline from about half of total generation in 2011 to less than one-third of total generation in 2035, as domestic demand increases but hydro storage does not expand to match it as described in the figure below highlighting the Brazil energy storage potential from hydropower reservoirs in compared with total generation in the IEA New Policies Scenario.

Brazil energy storage potential from hydropower reservoirs in compared with total generation in IEA New Policies Scenario
(adapted from World Energy Outlook 2013)

The addition of mainly RoR hydropower has significant impacts on the evolution of the power system in Brazil by making the system more subject to variations in rainfall and river flows over the course of the year. It will also have an impact on water management and potentially increasing conflicts among water users of hydropower reservoirs (governance, water allocation, etc.).

Brazil has the world’s biggest reserves of fresh water. However in 2014 several cities, including Sao Paulo (one-fifth of Brazil’s population and one-third of its economic activity) faced severe drought events due to a record dry season and ever-increasing demand for water. The main reservoir system that feeds this immense city was dangerously low, and it would take months of intense, heavy rainfall for water levels to return to anything like normal according to experts.
Policies should endorse a holistic approach between different sectors in order to avoid decision potentially banning multipurpose water reservoirs, and decisions that may be counter-effective/contradictory with the reservoir’s purposes.

The installation of a dam will impact the rate of sediment transport in a river, in many cases leading to sediments becoming trapped behind the dam rather than flowing downstream. This can have a direct effect on the operating life and the electricity generation of multipurpose reservoir projects, as well as affecting the distribution of sediments and nutrients downstream (ecosystems). Sedimentation has a number of effects on the operation and lifecycle of multipurpose reservoirs (reduced reservoir and flood management capacity due to the loss of storage capacity, a shortened power generation cycle, higher maintenance costs, impact on recreational activities, etc.). These challenges are increasing as more sediment accumulates over the lifecycle of those multipurpose reservoirs. One of the solutions to mitigate the sedimentation issue is to adapt the operation. Box 11 presents the Three Gorges Project in China where operation conditions have been adapted.

### BOX 11 - THE THREE GORGES PROJECT: DESIGNED TO FOSTER EFFICIENT MULTIPURPOSE WATER USES OF THE RESERVOIR

**Three Gorges purposes: hydropower, flood control, irrigation, navigation and water flow management**

The Three Gorges Project was designed for multipurpose uses from its original design concept. Its major benefits are flood control, power generation and navigation. The various uses have certain priorities depending on the time of the year.

<table>
<thead>
<tr>
<th>Three Gorges project – Priority for Water uses according to the season</th>
<th>Dry season (December to 10th June of the following year)</th>
<th>Flood season (10th June to 30th September)</th>
<th>Water storage period (10th September to December)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st priority</td>
<td>Navigation</td>
<td>Flood control</td>
<td>Navigation</td>
</tr>
<tr>
<td>2nd priority</td>
<td>Power generation</td>
<td>Navigation</td>
<td>Flood control</td>
</tr>
<tr>
<td>3rd priority</td>
<td>Flood control</td>
<td>Power generation</td>
<td>Power generation</td>
</tr>
</tbody>
</table>

Even though the Three Gorges Project is the world largest hydropower plant (in terms of maximum installed capacity 22.5 GW, and annual energy generation 98.8 TWh/year in 2014), whatever the season of the year, the power generation is never the first priority!

During the operation phase, measures are taken to reduce the amount of sediment in a sustainable manner so as to extend the service life of the reservoir. The operational modes and objectives derived during the design phase are adapted according to changes in the operation conditions such as the amounts of water and sediment entering the reservoir and the efficiency of water conservancy projects. For example, to utilize floodwaters as resources, regulation for small and medium floods is managed during the flood season, and water is impounded ahead of schedule to be at a higher level at the end of the flood season so as to increase the likelihood of the reservoir being filled.

Efforts are continuously being sought to extract more potential from the reservoir to match economic development and meet the needs of the society and people. The operational modes of the reservoir are optimized under scientific guidance to achieve a higher standard of management and facilitate the fulfillment of the reservoir’s objective.

More information can be found in the Annex document, where this Three Gorges Project case study is presented in more detail (number 10).
4.4 | River basin perspectives for all

An integrated approach is essential to reach a holistic view of the river basin. An important over-arching framework for sustainable hydropower reservoir development is Integrated Water Resource Management (IWRM) and basin development planning. Many hydropower projects are evaluated in isolation of an overall basin planning framework, and issues arise due to competing or conflicting needs and uses of the basin resources. The creation and effective functioning of transboundary river commissions (e.g. the Danube, Rhine, Mekong, Senegal rivers, etc.) with the purpose of enabling information exchange and better transboundary cooperation with water infrastructure development and operation is essential for upstream and downstream countries or those that have the same river as a national border. However some river commissions are not operating as intended. River basin organisations need political commitment to address the very sensitive discussions around dam/reservoir projects, a broad representation of stakeholders and should also be equipped with capacities related to staff, finance, expertise, skills, know-how, infrastructure etc. in order to carry out their duties effectively. Cross-sector coordination should be foreseen for greater policy coherence and consistency of multipurpose reservoirs uses. Water allocation in river-basin planning is a very important step forward to achieve sustainable use of stored water among users. In addition stakeholder initiatives may also provide interesting opportunities for better integration of the different reservoir water users.

An important over-arching framework for sustainable multipurpose hydropower reservoir development is Integrated Water Resource Management (IWRM) and basin development planning. For instance River Basin Management Plans (RBMPs) are a requirement of the EU Water Framework Directive (WFD) and a means of achieving the protection, improvement and sustainable use of the water environment across Europe. This includes surface freshwaters (including lakes, streams and rivers), groundwater, ecosystems such as some wetlands that depend on groundwater, estuaries and coastal waters out to one nautical mile. There are also International River Basin Management Plans that were developed in Europe for a number of international River Basin Districts (Danube, Rhine, Elbe, etc.).

**BOX 12 ‑ THE CUMBERLAND RIVER DEVELOPMENT: A ROBUST RIVER BASIN MANAGEMENT SYSTEM IN THE USA**

**Cumberland river purposes: hydropower, flood control, water supply, recreation, navigation, water flow management**

The Cumberland River plays a vital role in support of commerce, energy, recreation, and quality of life for all its stakeholders. The US Army Corps of Engineers (USACE) operate a system of eight projects. These include four tributary storage projects (flood damage reduction and hydropower), three main-stream navigation projects (navigation and hydropower) and one hybrid project (flood damage reduction, navigation, and hydropower). Together, they have the ability to moderate flows to support regional objectives such as flood damage reduction and commercial navigation.


Cumberland River projects play a critical role in the regional system, including the Ohio and Mississippi Rivers. The Nashville District Water Management has a multidisciplinary staff of engineers and scientists who perform complete system analysis daily. The mission of the Water Management Section is to sustainably manage the rich natural resources of the Cumberland River and to provide flood risk management, commercial navigation, hydropower production, water supply, environmental stewardship and recreational opportunities to the people and businesses of the Cumberland Basin.

In July 2014 the USACE Nashville District went live with the mobile website “River Status”. Anyone with a smart device and Internet access can view real-time water information within the Cumberland River watershed.

More information can be found in the Annex document, where this Cumberland case study is presented in detail (number 3).
To function properly, a basin organisation needs broad representation of stakeholders (with adequate capacity building) and a sound financial base (i.e. providing for appropriate funding mechanisms whenever creating a basin commission or authority. Legislation that creates these bodies should also consider the source and the financial resources necessary to run them). Cross-sector coordination should be foreseen for greater policy coherence and consistency of multipurpose reservoirs water users. In addition it is important that basin institutions are effective in achieving their duties and IWRM objectives for result-oriented stakeholder engagement (i.e. enhancing the capacity for implementing decisions). The French system described in Box 2 is one of these examples among this Framework case study analyses. Others could be found in the USA for instance, and Box 12 presents the Cumberland system.

Basin water allocation planning is typically undertaken to achieve a series of overarching policy objectives (Speed et al, 2013). In many jurisdictions, these now include:

i) Equity (allocating water in a way that is fair and equitable amongst different regions and user groups. This can include equity between different administrative regions and between upstream and downstream areas);

ii) Environmental protection (allocating water in a way that recognizes the needs of freshwater-dependent ecosystems and protects key freshwater services such as sediment transport, groundwater recharge, waste assimilation and estuarine functioning);

---

**BOX 13 - THE KANDADJI PROJECT IN NIGER: AN ADAPTIVE BASIN-WIDE, MULTI-SECTORAL APPROACH UNDER THE AUSPICE OF THE NIGER BASIN AUTHORITY**

**Kandadji purposes: hydropower, water supply and irrigation**

The Kandadji Project is located on the main Niger River in Niger. This project is under preparation.

The Kandadji project combines large-scale hydropower with livelihoods development and irrigation in a vulnerable and insecure part of the Sahel region. One of the major challenges is to leverage sufficient concessional financing (hydropower aside, many of the benefits such as irrigation mostly do not generate sufficiently attractive returns for the private sector). The World Bank finances 25% of the total Kandadji Program cost with the remaining costs financed through a combination of co-financing from 10 different development partners and counterpart financing from the Government of Niger. The need to effectively coordinate a large number of financiers adds an extra layer of complexity to an already challenging project.

The importance of adequate coordination among all riparians – 9 countries in the case of Kandadji – has been repeatedly identified as a critical component for success in complex, multi-sector projects in trans-boundary river basins. For over a decade, the Niger Basin Authority (NBA) has been engaged in an extensive shared visioning process with riparian countries to optimize the construction of major water infrastructure in the basin. This culminated with the Niger Basin Sustainable Development Action Plan and Investment Program, where the Kandadji project was endorsed by the 9 Heads of State as one of 3 priority multipurpose projects in the Basin. Through this basin-wide lens, the design of Kandadji dam was revised, reducing reservoir size to minimize upstream and downstream impacts, while maximizing national level non-hydropower benefits.

**Concerns from downstream countries** (notably Nigeria) were partially overcome through continued basin level dialogue under the auspices of the NBA. New institutional frameworks are being established under the auspices of the NBA, including the Niger Basin Water Charter endorsed in 2010 (with its Annex 2 regarding the coordinated management of dams currently under preparation) as an essential part of this necessarily adaptive basin-wide, multi-sectoral approach.

At the national level, the Government of Niger established the High Commission for the Development of the Niger Valley (HCDNV) in 2002 with the mandate to implement the Kandadji Program. The institutional framework post-dam construction (including the operation and maintenance of the dam and power plant, and the mechanisms for overseeing water allocations for multi-purpose benefits at the national and basin level) have however yet to be defined.

More information on the Kandadji case study can be found in the Annexes document (number 7).
iii) Development priorities (allocating water in a way that supports and promotes economic and social development. This can include supporting strategic priorities and protecting existing dependencies);

iv) Balancing supply and demand (water allocation plans need to balance water supplies with demands, particularly to manage the natural variability of water availability, and to avoid frequent or unexpected water shortfalls); and

v) Promoting the efficient use of water (allocating water in a way that promotes the most efficient use of available water).

Regional collaboration would be required to combine power systems development with sound integrated water resources management, as was observed, for example, in the Danube or Rhine Commissions in Europe, Senegal rivers in Africa and the Mekong River Commission in Asia. Such basin initiatives provide riparian countries with the only all-inclusive regional platform for multi stakeholder dialogue, information sharing as well as joint planning and management of water and related resources in the basin. They provide effective support for sustainable management and development of water and related resources. However some river commissions are not operating as intended. The regional cooperation and basin-wide planning are at the heart of their operation: their purpose is the promotion of cooperation among member countries to ensure integrated development of resources. Box 13 presents the Kandadji project in Niger.

Most of the time international treaties were signed to set the scene among riparian countries … which could be the first step towards stability in the region. Other examples of regional collaboration may be used for bi-national projects which enhance better regional cooperation, integration and economic development. Itaipu, the second largest hydropower plant in the world, is an example between Brazil and Paraguay. A bi-national treaty was signed between those 2 countries in 1973. This bi-national partnership has brought stability and economic development to the border territory since it has been in place, and the station is forecast to operate for at least 60 more years. Another project is under development in Nepal/India: Pancheshwar multipurpose project (see Box 14).

In addition to these legal initiatives, various stakeholders (river basin commission, NGOs, banks, etc.) engage voluntarily to foster sustainable development of multipurpose reservoirs and they are developing tools to address the issues. For example, the Rapid Basin-wide Sustainability Assessment Tool (RSAT), is an initiative co-developed by the Mekong River Commission (MRC), WWF and Asian Development Bank (ADB). Box 15 provides an overview of this tool.

BOX 14 - THE PANCHESHWAR BI-NATIONAL PROJECT: AN OPPORTUNITY FOR MEANING NEPAL/INDIA COOPERATION

Pancheshwar purposes: hydropower, flood control and irrigation

The Pancheshwar Multipurpose Project (PMP) is a bi-national project to be developed in Mahakali River bordering Nepal and India. This project is under development (preparation phase). In addition to hydropower, it also offer benefit of regulated water providing irrigation flows to a vast area of agricultural land both in Nepal and India along with benefit of flood control at downstream.

The Mahakali Treaty, which emphasizes an integrated approach to the development of water resources, was signed in 1996. Very little action took place for nearly two decades. Political decisions by two Prime Ministers enhanced the continuation of the project in August 2014. Implementation of the Pancheshwar Multipurpose Project is the centre piece of this Treaty. This binational project is seen as a landmark development in Nepal-India cooperation in hydropower sector.

At the end of 2014, The governing body of seven members from each country will be co-chaired by the energy secretary of Nepal and the water resource secretary of India. A CEO will head the executive committee of the Pancheshwar Development Authority (PDA). An Indian consultant was nominated to upgrade data for the integration of detailed project reports prepared separately by Nepal and India. All water uses and environment concerns are expected to be involved within the process. The PDA is the appropriate body to foster this multipurpose reservoir development.

More information can be found in the Annex document, where this Pancheshwar case study is presented in detail (number 9).
4.5 Engaging all stakeholders

Stakeholder engagement is critical for success in multipurpose reservoir management in terms of sustainability and efficiency. It is very necessary to identify all stakeholders likely to influence or be impacted by decisions on the reservoirs, and engage them in the early stages to participate on a voluntary basis to the dialogue. It is important that the groups need to see there is a reason for them to engage, i.e. that they can influence decisions and outcomes that would be better than if they had not participated. It is crucial to understand early in the process stakeholder interests and power relations between these stakeholders. Most of them may not know or understand the perspective of the other stakeholders involved; it is therefore important to raise awareness among them. Leadership within the community and across stakeholders is key for success. Equity, transparency and accountability should drive the solutions. Different viewpoints generate alternative priorities and highlight different challenges among stakeholders. Coordination and capacity improvements are required to manage multipurpose water uses issues between different stakeholders. Policy makers should increase their engagement with all stakeholders to improve their understanding of issues and better communicate their impacts. Communication and diplomacy will be essential. Policy makers should also provide the enabling environment for result-oriented stakeholder engagement, and strive to include the inputs of engagement processes towards improved decision making. The quality of the data sources and availability of information vary considerably at the local and state levels; making this information accessible, timely, understandable, usable and useful is the challenge. Strengthening partnerships and mobilizing resources remain essential to achieve effective multipurpose reservoir management.

**BOX 15 - THE RAPID BASIN‑WIDE SUSTAINABILITY ASSESSMENT TOOL: A MULTI‑STAKEHOLDER DIALOGUE AND ASSESSMENT TOOL DESIGNED TO CONSIDER HYDROPOWER SUSTAINABILITY ISSUES IN A RIVER BASIN CONTEXT**

The Rapid Basin-wide Sustainability Assessment Tool (RSAT) is a multi-stakeholder dialogue and assessment tool designed to consider hydropower sustainability issues in a river basin context. Placing hydropower in a basin-wide context requires looking beyond individual projects to take a broader integrated approach to planning and management. The application of tools such as the RSAT can assist to identify development strategies, institutional responses and management measures that can be deployed to optimise and reduce the risks.

MRC, WWF and ADB formed a partnership since 2006 to provide interested stakeholders in the Mekong region with information, knowledge and tools to better manage hydropower. The aim of the partnership is to ensure that the ecological functions of rivers, the natural resources they provide to other economic sectors and the livelihoods of people that depend on them are maintained acceptably and appropriately as hydropower resources are developed. The RSAT was developed to assess hydropower in a basin wide context based on IWRM principles. It has been under development since 2010 including a series of trials and national and regional consultations in the Lower Mekong region including government, industry and civil society groups. RSAT assessments have been completed or are currently in progress in nine hydropower sub-basins in the Lower Mekong region.

The core principles of the RSAT are: Co-operation in international river basins; Integrating river basin planning and hydropower regulatory and management framework; Ensuring robust governance for sustainability at all levels; Evidence based planning and decision making; Using collaborative and multi-disciplinary approaches to options assessment, hydropower siting and design; Consulting stakeholders and protecting rights and entitlements; Equitably sharing costs and benefits of development; Addressing poverty and food security in hydropower basins; Maintaining basin wide ecosystem integrity.

The last version of the full RSAT report can be downloaded at:

It is nowadays established practice to involve stakeholders from the earliest stages of the decision making process. Multi-stakeholder process is an investment, but it is one of the most effective governance instruments to inform decisions on complex and potentially controversial operations and can improve policy decisions within a shared vision. Moreover, overlooking such procedures may cost more eventually if the project is thereafter delayed or halted due to stakeholder opposition. So the question: “how to make such processes more effective and efficient?” First of all, a multi-stakeholder process cannot initiate without a needs assessment exercise which is critical to clearly define the objectives of the engagement process. Second, entities having interests as well as those likely to be impacted in the way those needs are going to be satisfied must be identified. The multi-stakeholder group should, ideally, be a self-regulating body in which rights, risks, and responsibilities are balanced and regularly assessed during the process (Palmieri, 2004). Following this rule provides a transparent way to facilitate negotiated agreements. As a matter of facts, with very few exceptions, it is highly unreasonable to expect “consensus” when so important stakes are under discussion. It should be stressed that the decision making process should not necessarily end up with a water storage project; the process could identify alternative options to satisfy the needs. The process could even identify non-structural solutions to that end. In all cases it is essential that environmental and social impacts of the no-project option are carefully assessed upfront and compared to the project-related impacts. Experience-sharing at all levels (local, national or regional) to draw lessons from success stories and common challenges should be foreseen to have an efficient use of water for multipurpose reservoirs. It is essential to foster transparency and regular information sharing for greater accountability and trust among stakeholders. Box 16 presents the Tennessee Valley Authority (TVA) example in the USA.

One of the major shortcomings in the development and management of multi-purpose reservoirs is the complete or partial lack-of- knowledge of other sectors. The creation of a dedicated platform for dialogue between sectors and stakeholders is an excellent way to share information and bring understanding among sectors. Most of the conflicts that are appearing around multipurpose reservoirs lie in non understanding of the needs of other water users. Stakeholder engagement should be ongoing throughout the decision-making process and include all sectors of society, including those that are typically

---

**BOX 16 - THE TENNESSEE VALLEY AUTHORITY (TVA): A MODEL CASE FOR MULTIPURPOSE RESERVOIRS**

**TVA purposes: hydropower, flood control, water supply, irrigation, fisheries, recreation, navigation, water flow management**

The Tennessee Valley Authority is the USA’s largest public power provider and a corporation of the U.S. government. TVA was established by Congress in 1933 to address a wide range of environmental, economic, and technological issues, including the delivery of low-cost electricity and the management of natural resources. The TVA main purposes are: power system, navigation on the Tennessee River, flood damage reduction, water quality, water supply, reducing the impact of droughts, and recreation.

TVA periodically updates its power generation strategy. The purpose of the Integrated Resource Plan (IRP) is to identify the portfolio most likely to help TVA lead the region and the nation toward a cleaner and more secure energy future. TVA asks the general public, its customers, and partners and regulators about their concerns regarding the sources it uses to generate power (fossil fuels, renewables, nuclear, etc.), how it reduces demand (energy efficiency programs, time-of-use pricing, environmental impact, etc.) and how it delivers power (transmission, environmental impact, pricing, etc). TVA holds public meetings to gather input on the scope of the planning process and associated environmental impact statement. In the meantime, TVA is working with the IRP Working Group (IRPWG), stakeholders who represent broad perspectives such as customers, businesses, activists, elected officials and economic development experts. This group will accompany TVA on nearly two year journeys to create and test this 20-30 year vision to meet TVA's power needs for the Valley. TVA will meet frequently with other stakeholders to get their feedback, insights and challenges as scenarios, strategies and plan measurements are developed along the way. Specific meetings are also organised.

It should be noted that many data are available to the public for other purposes.

More information can be found in the Annex document, where this Tennessee Valley Authority case study is presented in detail (number 4).
BOX 17 - NEXUS DIALOGUE ON WATER INFRASTRUCTURE SOLUTIONS: BUILDING PARTNERSHIPS TO OPTIMISE INFRASTRUCTURE AND TECHNOLOGY FOR WATER, ENERGY AND FOOD SECURITY

Since 2012, IUCN and IWA have collaborated on a joint initiative to address competing demands on water resources across the water, energy, and food sectors, with the objective being to identify how solutions are being provided through infrastructure and other means including technologies. The ‘Nexus Dialogue on Water Infrastructure Solutions’ is a call to action to those leading transformations in water infrastructure planning, financing and operation. With a continued increase in water abstractions and use from growing populations, and more irregular patterns of water availability due to climate change, the pressure on water supplies is rising. This Dialogue is an outcome of the Bonn Nexus Conference back in 2011, and the call to action that the conference requested, specifically on initiatives that could mobilise stakeholders around particular issues. At the Bonn Conference there was increased interest in investing in water infrastructure in different parts of the world because of concerns around water storage, water supply and flood protection, as well as securing water for food production and the need to better cope with increasing hydrological variability. This Dialogue has therefore focussed on infrastructure and technology because of the increasing demand for solutions adopting technological innovation, and the interest in dams and large scale water storage and built infrastructure solutions.

Since 2012, the Dialogue has successfully organized a series of regional anchor workshops in Africa, Latin America, South-East Asia, Central Asia and Symposium in China. Each event brought together innovators and thought leaders from the water, food and energy sectors and emphasized how their interactions with the water cycle are increasing in complexity. In all workshops participants from water, energy and food sectors across the various regions, countries and river basins were asked to identify their particular nexus problems, the proposed solutions and how these can be implemented.

Regarding the main recommendations, the nexus is a strong communication tool. By highlighting the interdependencies across the water, energy, and food domains sectoral dialogue becomes cross-sectorial. The key is to identify joint opportunities through identifying and negotiating any trade-offs. There is a rich array of existing practical knowledge and technologies across professional fields that can be shared and applied cross-sectorially, including farming, energy-production, natural resource management, and engineering. The nexus is not a one-way discussion. Rather, it challenges beliefs within the tribal nature of disciplinary silos. It challenges the application of knowledge, and it highlights the need for greater integration on core elements such as data collection, sharing, and interpretation. Through dialogue opportunities can be created to bring together people with a variety of experiences from across sectors, to brainstorm, and exchange knowledge, with the ultimate aim being to move to practical actions. The nexus is also solution-oriented. It appears that water shortages, through climate variability, over-use, pollution, or a combination of these creates pinch-points in water resource availability, or challenges over allocation and use between and within sectors. Forming partnerships to solve these problems appears, across all the workshops, to be key. However, practically, there is no need to always have complete integration between sectors. Relevant stakeholders may come together to identify and solve a problem (problem holders), and then continue to implement the agreed solution(s) as separate entities. Where there is confidence in solving the problem, the links between sectors (the nexus in practice) provides a natural, non-pecuniary incentive – joint problem identification, joint risk sharing, leading to collective action.

More information available at: http://www.waternexussolutions.org/
It is better to have inclusive decision-making which lead to better acceptability of decisions on water management for multipurpose reservoirs. Such participative approach, on a voluntary basis, allows also a greater sense of ownership across the different actors affected. However, stakeholder engagement does not come without difficulties: to achieve a consensus is unlikely most of the time; striking compromises among those divergent interests are often used to facilitate progress. Box 18 presents the Bronte Lagoon example in Australia.

**BOX 18 - THE BRONTE LAKE: DATA SHARING AND STAKEHOLDER ENGAGEMENT**

**Bronte Lagoon purposes: hydropower and recreation**

Bronte Lagoon is a lake that was created by Hydro Tasmania in the 1950s, along with Bradys Lake, Lake Binney and Tungatinah Lagoon as the head water storages for the Tungatinah Power Station on the Nive River.

Sharing the information is important, so Hydro Tasmania provides water level and flow data to other stakeholders. It also publishes river and lake levels, where available in near real-time, on their website.

Hydro Tasmania has developed many agreements and/or tools to set-up participative and constructive models around multiple uses of its waterways. Important tools include Memorandums of Understanding between key agencies, water supply agreements, and storage operating rules. For instance the Tasmanian Inland Recreational Fishery Management Plan establishes a 10 year-vision (2008-2018) for the State’s inland recreational fishery (the Fishery) with the goals of nurturing, developing and managing the inland recreational fisheries in harmony with the natural environment and realising its full potential for the Tasmanian community and future generations.

More information can be found in the Annex document, where this Bronte Lagoon case study is presented in detail (number 12).
5 THE WAY FORWARD

This Framework is bringing the considerations around multi-purpose projects together in one document which has identified the issues and the principles that should guide decision making (SHARE concept). However as it is always case specific, it is impossible to have reply to the question “how to do it?” in general terms. Adapting some of the experiences presented as case studies can certainly assist developers in conceiving and implementing a reasonable decision making process.

<table>
<thead>
<tr>
<th>S</th>
<th>Sustainability approach for all users</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Ensure the 3 aspects of sustainable development (economy, social &amp; environment) are included in any river development from the beginning and continue through all stages of project development</td>
</tr>
<tr>
<td></td>
<td>• Customise the governance model to local context according to strong and best practices requirements (e.g. OECD water governance initiative)</td>
</tr>
<tr>
<td></td>
<td>• Promote sustainable assessment with the Hydropower Sustainability Assessment Protocol (<a href="http://www.hydrosustainability.org">www.hydrosustainability.org</a>)</td>
</tr>
<tr>
<td></td>
<td>• Use an ecosystems based approach for the reservoir design and operation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>H</th>
<th>Higher efficiency and equity among sectors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Ensure water use is balanced between all water users and ecosystems in the most efficient and effective ways for existing &amp; future uses inc. water quality</td>
</tr>
<tr>
<td></td>
<td>• Put economic analysis at the very centre throughout the process (strategy, planning, decision-making and operation) for better cross-sectoral collaboration</td>
</tr>
<tr>
<td></td>
<td>• Use best practices &amp; innovative economical/financial approaches (public, private, PPP)</td>
</tr>
<tr>
<td></td>
<td>• Recognize, quantify and optimize all benefits and value created at reservoirs for all multi-purpose water users (e.g. using EDF value creation methodology)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>A</th>
<th>Adaptability for all solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Incorporate flexibility options for design and operation of reservoir to be able to adapt to the evolution of social &amp; environmental requirements, climate change, etc.</td>
</tr>
<tr>
<td></td>
<td>• Require stable local and state regulations covering development (dams and hydro are long term investments and highly capitalistic)</td>
</tr>
<tr>
<td></td>
<td>• Highlight the role of hydro storage for climate mitigation &amp; adaptation</td>
</tr>
<tr>
<td></td>
<td>• Address mitigation of sedimentation issue on a multi-stakeholder approach</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>R</th>
<th>River basin perspectives for all</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Map and understand all the river basin implications for any prospective development to enhance regional cooperation in a sustainable way</td>
</tr>
<tr>
<td></td>
<td>• Negotiate and set priorities/water allocation among water uses and environmental sector at basin, cascade and reservoir levels</td>
</tr>
<tr>
<td></td>
<td>• Ensure adequate and effective governance among water users</td>
</tr>
<tr>
<td></td>
<td>• Enable better transboundary cooperation for water infrastructure development and operation, and use proven river-basin development approaches (e.g. RSAT in Mekong)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>E</th>
<th>Engaging all stakeholders</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Map all stakeholders and identify/nominate a leader</td>
</tr>
<tr>
<td></td>
<td>• Initiate the dialogue and foster participative approach for co-construction since early stages (i.e. non-coercive participation) in an efficient &amp; effective way (learn, adjust, improve) based on appropriate and equitable share of resources</td>
</tr>
<tr>
<td></td>
<td>• Build understanding between stakeholders and sectors</td>
</tr>
<tr>
<td></td>
<td>• Make the information accessible, timely, understandable, usable and useful</td>
</tr>
<tr>
<td></td>
<td>• Create platforms/ fora (formal and informal) for all stakeholders with equity, transparency, accountability and trust as principles (e.g. Hydro Sustainability Protocol forum; water-energy food nexus dialogue IUCN/IWA <a href="http://www.waternexussolutions.org">www.waternexussolutions.org</a>)</td>
</tr>
<tr>
<td></td>
<td>• Ensure stakeholder support, acceptance and agreement is reached before proceeding with appropriate consultation</td>
</tr>
</tbody>
</table>

The SHARE concept, developed within this international multi-stakeholder initiative, is a useful framework to address the potential conflicts that will or may appear around multipurpose water uses of hydropower reservoirs. There are no one-size-fits-all solutions. However thanks to these case studies, it is possible to find guidance to address particular issues of multipurpose water reservoirs. These examples offer the readers/users the possibility to find case studies matching their needs.
<table>
<thead>
<tr>
<th>Case studies overview “multipurpose water uses of hydropower reservoirs”</th>
<th>Area</th>
<th>Country</th>
<th>Phase</th>
<th>Brief description of the case study and associated key points</th>
<th>Reservoir Purposes</th>
<th>SHARE topics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arenal</td>
<td>Latin America</td>
<td>Costa Rica</td>
<td>X</td>
<td>• Successful resettlement in the 1970s thanks to stakeholder engagement and IFIs participation  • Creation of a Commission to enhance effective participation and Ramsar site</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Olmos</td>
<td>Latin America</td>
<td>Peru</td>
<td>X</td>
<td>• CDM project for hydro  • Innovative DBO/PPP model  • Peruvian pension funds to boost infrastructure development  • Individual water tradable certificates</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cumberland</td>
<td>North America</td>
<td>USA</td>
<td>X</td>
<td>• Strong stakeholder engagement  • Information/ data sharing at the basin level  • Strong infrastructures which can adapt to evolving conditions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tennessee Valley Authority</td>
<td>North America</td>
<td>USA</td>
<td>X</td>
<td>• Long-term experience multipurpose water management  • Effective tools and data sharing  • Participative approach for the integrated resource plan</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Durance - Verdon</td>
<td>Europe</td>
<td>France</td>
<td>X</td>
<td>• Stakeholder engagement for co-construction, coordination and dialogue for win-win situation  • Innovative bilateral economical conventions to save water  • EDF value creation methodology</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Villerest</td>
<td>Europe</td>
<td>France</td>
<td>X</td>
<td>• Governance model with EP Loire  • Strong French regulation within RBMPs allowing participative approach  • Flexible model with clear roles set among water users</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kandadji</td>
<td>Africa</td>
<td>Niger</td>
<td>X</td>
<td>• Design optimized at basin level to maximize multi-sector benefits while minimizing downstream impacts  • Large numbers of donors to secure sufficient concessional financing  • Ambitious large scale resettlement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lom Pangar</td>
<td>Africa</td>
<td>Cameroon</td>
<td>X</td>
<td>• IFIs and public to develop this regulating dam to attract downstream private projects  • Innovative payment of water fees by downstream water users  • Creation of River Basin Commission</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pancheshwar</td>
<td>Asia</td>
<td>Nepal/ India</td>
<td>X</td>
<td>• A bi-national treaty to enhance cooperation of hydro development  • To set an appropriate governing body to finalize the studies  • Cost/benefit analysis for 2 countries</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Three Gorges project</td>
<td>Asia</td>
<td>China</td>
<td>X</td>
<td>• Hydro is not the first purpose  • Changing operating conditions (water &amp; sediment) requires new modes  • New economic opportunities around the reservoir</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arthurs Lake</td>
<td>Oceania</td>
<td>Australia</td>
<td>X</td>
<td>• Many agreements and tools to set-up participative approach  • Water pricing principle for energy losses among water users with new purposes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bronte Lagoon</td>
<td>Oceania</td>
<td>Australia</td>
<td>X</td>
<td>• Strong Australian water framework  • Many agreements develop for new purposes  • Flexible operation of reservoirs</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
This SHARE concept should now be shared within all multipurpose reservoir stakeholders; it should be implemented by multipurpose reservoir planners, developers, operators, decision-makers and other stakeholders to foster a sustainable water management of such reservoirs. Using these main principles is essential for multipurpose reservoirs: shared vision, shared resource, shared responsibilities, shared rights & risks, shared costs & benefits.

The multipurpose water uses of hydropower reservoirs

- **S**ustainability approach for all users
- **H**igher efficiency, equity among sectors
- **A**daptability for all solutions
- **R**iver basin perspectives for all
- **E**ngaging all stakeholders

It is also important to continue collaboration with research initiatives on this multipurpose issue (the economic value, new financial mechanisms, and adaptive design), in particular with ICOLD and IEA Hydro. ORNL/DOE is also working on economic benefits of multipurpose hydropower projects in the USA (e.g. developing methodology). It is also of huge interest that those researches, methodologies and modelling approaches be connected to policy making.

Future investments in hydropower projects should embrace the SHARE concept and take a multipurpose approach where appropriate together with the co-financing necessary to make it work. In the coming decades it is important that there is sustained and steady focus on utilization of multi-purpose opportunities for investment and operation, firstly on existing infrastructures in multipurpose hydropower reservoirs with dams. The way forward for each developer/sponsor is to work out a reasonable decision making process that meets these objectives with a duration that is predictable and compatible with the urgency of the needs to be met.
6 REFERENCES


CGIAR, 2014 “Ecosystem Services and Resilience Framework”, CGIAR Research Program on Water, Land and Ecosystems led by IWMI


IHA, 2011 Hydropower Sustainability Assessment Protocol (HSAP), International Hydropower Association (IHA)


Locher H., Scanlon A., 2012 “Sustainable Hydropower - Issues and Approaches”


World Bank, 2005 “Shaping the Future of Water for Agriculture- A sourcebook for investment in agricultural water management”
7 APPENDIXES

This part provides twelve case studies that were analysed for this "Multipurpose water uses of hydropower reservoirs". For each case study, a project overview is first presented, after that the key issues of this example related to the SHARE concept, then main lesson learnt, and finally references.

7.1 | Overview of case studies

Each project is site specific, but those cases represent a wide range of situations worldwide in terms of geography, size, type, purposes and topics: 2 in Latin America (Peru, Costa Rica), 2 in North America (United States of America), 2 in Europe (France), 2 in Africa (Cameroon, Niger), 2 in Asia (Nepal-India, China) and 2 in Oceania (Australia). The figure below presents those case studies.
The table below presents an overview of the different case studies in terms of reservoir purposes and SHARE topics (Sustainability approach for all users, Higher efficiency and equity among sectors, Adaptability for all solutions, River basin perspectives for all, Engaging all stakeholders).

<table>
<thead>
<tr>
<th>Case studies overview</th>
<th>Arenal</th>
<th>Olmns</th>
<th>Cumberland</th>
<th>Tennessee Valley Authority</th>
<th>Durance - Verdon</th>
<th>Villerest</th>
<th>Kandadji</th>
<th>Lom Pangong</th>
<th>Pancheshwar</th>
<th>Three Gorges project</th>
<th>Arthurs Lake</th>
<th>Bronte Lagoon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>Latin America</td>
<td>Latin America</td>
<td>North America</td>
<td>North America</td>
<td>Europe</td>
<td>Europe</td>
<td>Africa</td>
<td>Africa</td>
<td>Asia</td>
<td>Asia</td>
<td>Oceania</td>
<td>Oceania</td>
</tr>
<tr>
<td>Hydropower</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Flood control</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Water supply</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Irrigation</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Fisheries</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Recreation</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Navigation</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Water flow management</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Sustainability approach</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Higher efficiency</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Adaptability for solutions</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>River basin perspectives</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Engaging stakeholders</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
7.2 | Arenal (Costa Rica, Latin America)

Arenal project case study was provided by EDF. All data is issued from public information; this was compiled by Emmanuel BRANCHE (EDF).

7.2.1 | Project description

The Lake Arenal (or the Sangregado Dam) is administered by the I.C.E (Instituto Costarricense de Electricidad, Costa Rica’s National Electric Power Company). Lake Arenal is situated in the Canton of Tilaran, in the tropical highlands of the provinces of Guanacaste and Alajuela, in Costa Rica. It is located in the Arenal Tilaran Conservation Area, and is close to the Arenal Volcano and Monteverde cloud forest. This natural depression caused by local geological faults formerly contained a small lake that emptied into the Arenal River which flowed into the Caribbean via the San Carlos and San Juan Rivers. The Arenal project raised the level of existing Lake Arenal by 43 m. The hydroelectric project redirected the flow of its waters towards the Pacific and into the Santa Rosa River. The lake is approximately 30 km long and almost 5 km at its widest point, making it the largest lake in Costa Rica at 85 km². Its depth varies between 30 and 60 meters.

The town of Arenal was relocated to higher ground when the lake was expanded in 1979. The old towns of Arenal and Tonadora now lie abandoned at the bottom of the lake, while the new town of Arenal exists to the northeast of the lake.

The purposes of this project were originally to generate energy (hydropower) and to irrigate agricultural land, i.e. dual use energy & agriculture. Today recreational activities
are also increasing. Indeed the Arenal lake itself is a popular place to fish, boat, and windsurf (this is an increasingly important tourist destination).

The hydroelectric plant has an installed capacity of 157 MW and includes a 70 m high earthen dam located 545 m above the level of the sea, a reservoir of 1,750 m$^3$ and 6,700 m of conduction tunnels leading to its three (3) generating units. Construction of the Arenal project began in 1975 and the powerhouse went on line in December 1978. The last of the transformers commissioned in April 1980. This hydroelectric project is hugely important to Costa Rica, initially generating 70% of the country's electricity, now closer to 17% of green electricity.

The water passes through three turbine-driven generating stations for hydropower purpose, and after that it is channeled into a system of irrigation canals that have substantially increased the agricultural productivity of the lower Tempisque basin in Guanacaste.

The Arenal-Tempisque Irrigation District, which is the largest irrigation project in the country, is nearly totally supplied by surface water, utilizing water from the reservoir Lake Arenal. SENARA is the government agency that runs the Arenal Irrigation District. This irrigation process has increased its surface area from 10,000 ha in 2003 to 28,000 ha today. The irrigation system has increased the reliability of the water supply, which in turn enabled farmers to move from one to two crops per year, resulting in a significant increase in land productivity and contributing to national food security. This project benefits approximately 1,125 families producing mainly sugarcane, fodder, rice, and fish (400 ha of aquaculture), generating income of approximately $163.7 million from this region. The producers in the area pay SENARA a fixed rate fee of $42.5/ha/year for water used in irrigation

As well as its importance for energy and agriculture, Lake Arenal provides excellent recreational opportunities, especially for windsurfing and freshwater fishing. These are new activities that were developed around the lake. The north-western end of the lake is buffeted by strong winds, particularly from December through March, that make for ideal windsurfing conditions. Wakeboarding is gaining popularity in Costa Rica, with Lake Arenal being the center of this activity. Fishing (primarily for rainbow bass) and kayaking are also popular recreational activities on this lake. Fishing for guapote (*Cichlasoma dovii*) is another popular sport on the lake. The fishing season is open year-round (on this lake only in Costa-Rica!). The area surrounding the lake has also good hiking, biking, bird watching, and horseback riding opportunities.

The Arenal project was created with an IWRM vision, with multiple productive uses of water, and related important environmental and natural resource conservation.

Regarding the financial issues, International Financial Institutions (IFIs) have a crucial role to play in supporting the Government in the renewed front role, and to facilitate private participation for project implementation.

For the Arenal project, IFIs plaid a key role for the development of this multipurpose water project. Indeed the IDB (Inter-American Development Bank) was one of the catalysts to address the financing challenge. The total cost historic was USD 171 million. The policy framework for the Arenal project was based on the Costa Rican expropriation law and on IDB project requirements.

**IDB financing** is presented in the table below (source IDB):

<table>
<thead>
<tr>
<th>Financing Type</th>
<th>Loan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fund</td>
<td>Ordinary Capital</td>
</tr>
<tr>
<td>Reporting currency</td>
<td>USD - United States Dollar</td>
</tr>
<tr>
<td>Reporting Date</td>
<td>December 31, 2014</td>
</tr>
<tr>
<td>Estimated Cofinancing – Historic</td>
<td>USD 50,500,000</td>
</tr>
<tr>
<td>Cancelled Amount – Historic</td>
<td>USD 0</td>
</tr>
<tr>
<td>Undisbursed Amount – Historic</td>
<td>USD 0</td>
</tr>
<tr>
<td>Disbursed to Date - Revalued</td>
<td>USD 77,559,316</td>
</tr>
<tr>
<td>Repayments – Revalued</td>
<td>USD 77,559,316</td>
</tr>
<tr>
<td>Principal Debt Relief Amount – Revalued</td>
<td>USD 0</td>
</tr>
<tr>
<td>Income Collected – Revalued</td>
<td>USD 122,322,428</td>
</tr>
</tbody>
</table>
Roles & responsibilities

- Borrower: Instituto Costarricense De Electricidad (ICE)
- Guarantor: Republica De Costa Rica

7.2.2 | A participative approach for resettlement in the 1970s

This information is issued from United Nations Environment Programme, Dams and Development Project (UNEP/DDP). Compensation policy falls within the scope of recognizing entitlements and sharing benefits. Indeed this example addresses monetary compensation for lost assets, livelihood restoration and enhancement (sustainable agricultural employment) and community development.

The resettlement preparation activities began in 1973, two years before multilateral financing of the project was secured and construction of the dam begun. The National Census and Statistics Bureau provided data about the population to be relocated and in the summer of 1973 an ethnographic survey of a sample of 164 families living in the reservoir area was carried out. A pamphlet was distributed to the affected population with answers to the questions they were asking about the project during the ethnographic survey. Information meetings were also held by Instituto Costarricense De Electricidad (ICE) and the Inter-institutional Task Force in Tronadora and Arenal. A socio-economic survey was undertaken in 1973 to count and characterize the affected population and to document their needs and expectations in regards to the resettlement plan. It turns out that the large-scale ranchers and other wealthy families of the area did not plan to move into government planned resettlements but rather into other holdings they had elsewhere. They did not plan to take with them their labourers because they already had employees on their other ranches. This means that the major sources of employment and capital in the communities would disappear. Resettlement planning was thus planned for small farm plots so that intensive crop agriculture and dairying could support the displaced population.

In February 1974, ICE published its resettlement objectives for the project which included improving the level of living conditions in the affected communities. From June to October 1974 the ICE Office of Resettlement identified resettlement sites who were submitted to the affected population for approval by vote. In Tronadora and Arenal, committees of residents were formed to represent the interest of the affected families, including those living in affected ranches. These Defence committees as they called themselves, were originally set up by ranchers to protest the resettlement but it soon became apparent to poorer families that the rancher's main interest was to increase the compensation price they would receive for their land while poorer families were most concerned with resettlement alternatives that could improve their living conditions. The ranchers quickly lost their credibility as leaders of the committees. ICE considered Defence committees a good vehicle for public participation and they were involved in the inspection of alternative sites and in the presentation of those sites and organized popular votes for site selection. Seven alternative sites were presented for New Arenal and four sites were presented for New Tronadora.

The Resettlement Action Plan was subsequently prepared and included in the loan documents submitted to the IDB in October 1974. The agreed resettlement budget was US$ 4 million including US$ 1.25 million for land acquisition.

The land acquisition process began in 1975 when it was clear that the project would go ahead. A survey of properties was carried out for subsequent approval by land owners. Signed survey maps were provided to ICE lawyers who delivered them to the Fiscal Administration Tribunal authorities who inspected the lands and determined the prices to be paid. Checks for land acquisition were issued by ICE and delivered to the owners. In case of disagreement, according to the expropriation law, both ICE and the landowners could follow the normal appeal proceedings in courts.

Tensions ran high during the land acquisition process as ranchers tried to use the Defence committees to pressure the ICE Resettlement Office to pay higher prices for their lands. At this point ICE ceased to work through the Defence committee setting and instead established family files for all families who wanted to be resettled and assigned a case worker to those families. The other families were only paid cash compensation. A total of 1,208 people chose to be resettled.

The planning of the resettlement sites was undertaken by the Resettlement Office between January and June 1975. Lists of characteristics of the new settlements were discussed, modified and approved in meetings with affected families. The new settlements consisted of an urban core surrounded by farm plots ranging from 2 to 10 ha. The central plaza-church-school complex present in the original settlement would be retained and the new settlements were to be provided with a tubed water system, septic tanks, electricity, paved streets and green space and parks among others. Some eighteen different models of houses were available to choose from and public buildings were designed simply in order to be inexpensive to maintain.

The relocated families’ assets were analysed and compared to their expectations in regards to occupations, size of houses and farm plots. These two aspects were reconciled and guidelines were formulated for financing the acquisition of new houses and plots. They included five categories of financing packages. The financing packages ranged from new house and farm plots free of charge for those whose property was less than a certain amount and cash payment...
only to those whose property was worth more than a certain amounts. Between those extremes, families were requested to pay half of their compensation and the rest of the cost of the new holdings was financed for 8 or 20 years according to their financial capacity. Families who owned neither house nor farm plots were eligible to acquire new houses and farm plots through a credit equal to the purchase price financed over a 20 year period. In all cases of credit, a one-year grace period on payment of interest and principal was given and another year grace period was given on payment of interest. Conditions were set up relating to the selling of newly acquired properties.

Meetings were held between resettlement officials and each family. Agreements were reached regarding the value of each family’s assets and the financing package to which they were entitled. Preliminary distribution of houses and plots was carried out with the help of community leaders and was later modified to accommodate the 20% of families who wished to relocate elsewhere.

Construction of the new settlements began in 1975 and was undertaken by ICE. Salvage materials from old houses could be incorporated into new houses. Each family acted as a building inspector for their new home. The construction of public buildings provided training and employment to some 70 young men of the communities. The ICE Office of Resettlement established itself in the new settlements and its social workers and community promoters encouraged and organized cooperative activities such as agricultural extension meetings or courses on topics ranging from construction of fuel-efficient stoves to child psychology. The agricultural specialist of the office of resettlement set up experimental and demonstration gardens.

Families moved to New Tronadora in December 1976 and to New Arenal in December 1977. The administrative responsibilities for the new settlement were then passed on to the state authorities but ICE development assistance continued another three years.

7.2.3 | Establishment of a Commission for a better integrated vision of the water

Environmental studies carried out since inception suggested the importance of protecting the watershed and its forests. As a result, the Ministry of the Environment (MINAE) became involved in the project. It expanded the Arenal National Park and other parks in the catchment and irrigation areas; these areas were merged into a single “Conservation Area” in the 1990s. The project has had a large social payoff. The project attracted the attention of government authorities, and particularly MINAE, who has done well to protect the forests and introduce a vision of sustainable development.

The main institutions (ICE, SENARA, MINAE, NGOs, etc.) have tended to work independently of each other. In a later stage, efforts were made to coordinate actions and reduce tension between institutional stakeholders. The stakeholder participation is difficult when one of the stakeholders is very powerful and has the legal right over water.

Separately, hydroelectricity and irrigation performance outcomes have been good. Both the Arenal energy and irrigation projects need water from the Lake. Conflict over use is not about quantity -- flow from the dam is about 100 m³/s – but about when the water is needed. Both projects need more water in the dry season, although daily and seasonal requirements are not exactly the same for both. Also in the dry season, important wetlands could benefit from additional water to maintain a reasonable water cover, to service among other things, migratory birds as they travel across the country. Additional distributional conflicts have recently arisen. For example, rice farmers need the water during a critical period on the wet season, at the same time as managers seek to fill the Lake to save water for the next dry season. Some irrigators have specific demands at certain times of the day. But most distribution valves are operated manually and that restricts the ability to distribute water to different parts of the system.

In 1996 the Ministry of Energy and Environment (MINAE), through the Arenal Conservation Area, and with support from the Canadian Government, WWF-Canada and the Inter-American Development Bank (IDB) developed the Arenal Lake Watershed Management and Development Plan (Plan de Manejo y Desarrollo de la Cuenca Laguna Arenal). To implement this plan, the “Commission for the Implementation of the Development and Management Plan of the Arenal Reservoir Watershed” was created by Executive Decree in 1997. It was seen as a temporary entity, until a Watershed Agency, proposed in the Plan, could be instituted. The Commission consisted of representatives from MINAE, ICE, SENARA, IAYA (Instituto de Acueductos y Alcantarillados i.e. responsible for urban water supply at national level), the Foundation for the Development of the Arenal Conservation Area, and a local catholic priest.

The spirit behind the Commission was cross-sectorial, seeking to bring together different key stakeholders. However, the legislation was flawed by the absence of producers’ groups or local development associations and the omission of allocation of funding to keep the Commission functioning. Also missing were the identification of mechanisms for discussion such as public forums where all parties could come together.

There has been little coordination between agencies and local stakeholders, environmental concerns have not received adequate considerations from an integrated perspective.

The establishment of the Commission was therefore a good
The law establishing the Commission provided a framework for IWRM.

### 7.2.4 | The Arenal Lake is classified as a Ramsar site since 2000

According to GWP, one partially successful example of stakeholder participation processes can be cited. MINAE and the Canadian Cooperation Agency produced the Land Use Plan that led to formation of the Commission. Unfortunately, this process is stalled right now for lack of funding, or interest from stakeholders. There have been well-funded initiatives. The Costa Rica government has financed the establishment of the ACAT (Area de Conservación Arenal Tempisque) including payments of several US$ million in land purchases for conservation. Furthermore, several local NGOs have also invested in conservation measures, including forest protection and environmental education with grant funds obtained from foreign aid agencies and NGOs. Arenal Lake was declared a Ramsar site on March 16th 2000.

Another Ramsar site present in the ACAT is in the Palo Verde National Park, located in the lower basin of the Rio Tempisque considered an area of vital importance as breeding and food for many species of waterfowl, migratory and resident, as well as endangered species, becoming one of the area's largest nesting country.

Politically part covers 10 counties and 32 districts in the provinces of Guanacaste, Alajuela and Puntarenas; the entire land area of the Area; currently 24.84% consists of protected wildlife areas, 28.81% to biological corridors and the remaining percentage corresponds to the area of influence. Over 70% of the country's hydropower is generated in this Conservation Area, which also contains more than 90% of production of wind and geothermal energy. In this Conservation Area high diversity of environments, ecosystems and species, distributed in eight different life zones ranging from tropical dry forest to lower mountainous rainforest, with equal numbers of ecological transition zones are present. On the altitudinal varied relief (sea level up to 2028 meters altitude), is given a varied climate regime and presence of geological formations of different ages. Its flora and fauna is diverse with numerous species of birds, mammals, amphibians, reptiles and a large number of taxonomic groups of insects and fungi, besides this Conservation Area has endangered animals such as the jaguar (Panthera onca) and tapir (Tapirus bairdii), among others, the 6 species of wild cats of the country being present. ACAT has also identified about 190 plants that are present in the Conservation Area that are endemic to Costa Rica, some of them endemic to the area. Monteverde are represented only 70 of the 103 families of trees reported in the country and 21.23% of species of orchids.

The wetland provides benefits related to hydropower generation, irrigation, tourism (water sports), recreational fishing and consumption, grazing, domestic agriculture and irrigation, agriculture and aquaculture. Approximately 80% of the existing legislation is being enforced to regulate activities in the wetland and other protected areas. Environmental education programs are being implemented to involve organized groups, farmers, community leaders, teachers and schoolchildren in the search for better opportunities for the wise use of natural resources.

### 7.2.5 | Main lessons learnt

The Arenal Lake has allowed the country to harness water, generate power and irrigate agricultural land with a large social payoff. The Costa Rican Government is also promoting sustainable development, and its growing tourism industry, as well as encouraging protected areas. With tourism activities, Lake Arenal has also a new purpose.

Arenal Lake is classified as a Ramsar site since 2000.

The **resettlement was successful and sustainable** as it is based on recognized entitlements and shared benefits. More specifically it is based on the following elements:

- Contribution of suitable social science professionals in project planning and implementation;
- Consultation and participation of affected people in resettlement planning;
- Introduction of new crops and technology only after trying the traditional ones.

The construction of the dam and irrigation structures was financed by an Inter-American Development Bank (IDB) loan. All IDB requirements (environmental, social, etc.) were used for development of this project. As in several other projects, IFI plays a key role for the development of this dam/reservoir in a sustainable way.

The Arenal project was created with an IWRM vision, with multiple productive uses of water, and related important environmental and natural resource conservation. While it functioned, the Basin Commission enabled contact among representatives of all interested parties, providing a forum for dialogue, and creating an awareness of the need for an integrated approach. To function properly the Commission (i.e. the basin organization) needs broad representation and a sound financial base. The organization needs to include all stakeholders: farmer's groups, conservationists, and major water users. These main users of the water should provide, proportionally, the needed funds for such a body to operate. Consultation of all parties involved before initiating the project is very important to achieve the best result.
7.2.6 | References
ACAT, 2015 http://www.sinac.go.cr/AC/ACAT/


Ramsar, 2000 http://www.ramsar.org/cuenca-embalse-arenal

7.3 | Olmos Project (Peru, Latin America)

Olmos project case study was provided by EDF. All data is issued from public information; this was compiled by Emmanuel BRANCHE (EDF).

7.3.1 | Project description

The Olmos project was conceived with the purpose of irrigating farmland located in the Olmos’ valley by diverting water from the Huancabamba River, located on the Eastern basin of the Andes mountain range (Atlantic basin), on to 43,500 hectares of farmland located on the Western basin (Pacific basin). The Olmos project consists of three (3) main elements:

a) Water transfer = derivation of water from Huancabamba River (Atlantic basin) to Olmos River (Pacific basin), including the construction of the Limon Dam and reservoir (storage capacity of 44 million m$^3$) and derivation of regulated water through 20 km long tunnel,

b) Agricultural production = development of a new irrigation area using water transferred by the derivation system and,

c) Energy generation = construction and operation of two (2) hydropower plants with a total installed power several hundred MW.
The figure below illustrates the general Olmos project hydraulic scheme.

In 2004, the Regional Government of Lambayeque issued calls for tenders under the PPP (public-private partnership) system for the construction and operation of water supply and energy generation systems. Odebrecht Peru won the contract for the first component and is responsible for the entire investment required to complete the projects.

The transposition part alone will require huge investments and mainly includes the construction of the Trans-Andes Tunnel and the Limón Dam, which has already been completed, and can store up to 44 million cu.m (m³) of water for use during peak dry seasons. The company responsible for this stage of the project is the Trasvase Olmos concessionaire, the Odebrecht subsidiary that will operate and maintain the facilities for a 20-year period.

7.3.2 | A targeted approach for a better and efficient water use among users

For each of the project’s elements a different approach was applied for make it viable and to distribute correctly the corresponding costs and benefits between public and private sectors, as briefly presented below:

The water transfer project:
The construction of the tunnel is one of the most complex engineering projects underway in the world today, given its depth (as much as 2,000 m below the surface of the mountain) and the geological characteristics of the Andes.

In the case of the derivation system, the government organized an international bidding for the construction of the dam's tunnel and adjacent structures, with the objective that the awarded company will build the whole system, using its own financial resources and will recover the investment through an operation concession. Nevertheless, in order to reduce water costs for final users, the government decided to invest jointly with the developer in order to provide a more attractive real water cost for final users. The criterion to award the concessioner was the lowest cost per m³ of water to be sold by the concessioner to agricultural users, during a 20-year concession period. The lowest offer was US$ 0,066/m³, or taking into consideration that total annual unit volume for each hectare was 10,000 m³/has, such a cost represents a payment to the concessioner of US$ 660/ha/year, which is acceptable for various types of agricultural products, with total annual production costs of over US$ 10,000/ha/year.
The irrigation project for agriculture:

In addition to installing 50 km of pipelines to supply pressurized water, the works include the construction of canals, reservoirs, a tunnel, grit chambers, access roads and power lines. Expectations are that these areas will be used by agribusinesses dedicated to producing a range of high-quality crops with excellent yields that are highly competitive in the international market.

Of the 43,500-hectare irrigated area, 38,000 ha will be sold at public auction. The land, currently owned by the Regional Government of Lambayeque (RGL), is called Tierras Nuevas (New Land), and will be divided into several lots. The main characteristics of the lots to be auctioned were the following:

- Undeveloped seamless flat farm land lots to be sold in single auction process.
- Estimated 41 lots in two sizes: 6 lots of 500 ha and 35 lots of 1000 ha.
- Flat service fee of US$ 0.066/m³ for water supply rights to be paid by the owners of the land under a take or pay contract.
- Lots to be accessible by road network and connected to the national power transmission grid.

The transaction structure of this process is depicted in the figure below.

In the case of the irrigation system, a bidding process also took place, where the government transferred property of 38,000 ha of agricultural land, to the awarded concessioner, in order to sell it and provide funds for project execution. The total construction investment of the irrigation system for 38,000 ha, was US$ 140,000,000 approximately. Therefore, the government decided to transfer property of that land to the awarded concessioner, under its responsibility to organize the land sale to different users and to use this money to build and put in operation the corresponding irrigation system. For the implementation of the above specified scheme, the concessioner was chosen, the 38,000 ha were sold and the irrigation system will operate until the end of year 2014.

The Concessionaire grants lot buyers individual Water License Certificates, thus allowing them to use the water volumes corresponding to their respective lots. Additionally, such certificates will allow users that consume less water to transfer said resources to other users with higher water needs, as considered in the design of the crop portfolio.

The remaining 5,500 ha belong to the peasant communities of Valle Viejo, who will also benefit from this irrigation project (~2000 residents with farming an important source of employment and income).

In both cases, the concessionaire will charge USD 0.066 for each cubic meter of water used.

The energy generation project:

The third bidding was organized for the hydropower development, with the objective that the developer will provide corresponding annual economic support for project
development and operation, as a percentage of produced energy. In view of the fact that the whole system uses around 406,000,000 m$^3$/year, as a result of the derivation of the Huanacabamba water, the total annual amount to be paid by all agricultural users for this volume of water, at a unit price of US$ 0.066/m$^3$ is US$ 26,796,000/year. Taking into consideration the type of use of water by the hydropower plants (secondary, without consumption), as well as much lower annual income/ approximately US$ 20,000,000/ plant/year), compared to the agricultural users, it is obvious that the construction and operation of the hydropower plants could not provide some significant amount of annual payment for the concessioner. Therefore an additional bidding was organized, with the criteria to award the hydropower plants concessioner, with the responsibility to pay a certain percentage from the annual income to the concessioner of the Huanacabamba derivation system.

It is important to note that the Olmos 1 (51 MW) is registered since 20 November 2012 to one of the Kyoto Protocol mechanism: the Clean Development Mechanism (CDM). Indeed the hydropower plant Olmos 1 demonstrated to UNFCCC (United Nations Framework Convention on Climate Change) that this project will contribute to sustainable development by: helping the national power grid system avoid broad use of thermal power plants and reserve them only for stand-by generation, thus displacing expensive generation fired by heavy fuel, diesel, coal and natural gas, while reducing GHG emissions; utilizing domestic and renewable resources, thus contributing to fuel diversification and resource independence for the Peruvian electricity sector; employing local labor in construction and plant management; supporting local development through an annual contribution to benefit local communities; adding revenue to Peru's fiscal accounts through the payment of taxes; and, helping Peru improve its hydrocarbon trade balance through reduction of oil imports in electricity generation. This project is expected to avoid CO$_2$ emissions annually by 199,800 tCO$_2$e/year.

7.3.3 | The financing challenge overcome by an innovative PPP

The concession is a Build-Own-Operate-Transfer where the Government of Peru auctions the land to be irrigated, the proceeds of such sale finance the construction of the irrigation infrastructure, and the private partner develops the necessary works to operate adequate irrigation services. The Private partner then manages and charges for irrigation services. The term of the concession is 25 years (World Bank, 2010).

The 43 m high, 270 m long concrete face, rock filled Limón dam is being constructed on the Huanacabamba River near the village of San Felipe. The dam will form a reservoir from which the water will be diverted into the tunnel, passing under the mountain range and into a natural canal known as Quebrada Lejas. It will then flow into the Olmos River, whose bed is currently dry most of the year. The water will then flow to the Pacific coast of the Lambayeque region, near the city of Chiclayo, and be distributed for irrigation.

The project is being constructed under a design-build-operate (DBO) / public-private partnership (PPP) investment arrangement. La Concesionaria Trasvase Olmos S.A., wholly owned by Brazilian civil contractor S.A. Odebrecht, was awarded the 20 year concession in 2004. The financing includes USD 77 million of Peruvian federal support. The US$ 190 million construction project is being constructed by Odebrecht Peru Ingenieria y Construccion, S.A.C (OPIC).

The Concesion Trasvase Olmos (CTO) is a Regional Government Project. Regional Government of Lambayeque awarded a US$ 242 million technically complex inter basin transfer project to CTO in 2004 as a 25 year concession contract. Based on its contract, CTO as a special purpose company planned to issue US$ 100 M corporate bonds to finance its concession contract, the balance was to be financed by the GoP US$ 77 M, CAF US$ 45 M, and US$ 20 M equity. Private Pension Funds (PPFs) acquired various series in private offerings for a total of about US$ 60 M all during 2006; insurance companies and other public agencies purchased US$ 40 M. The revenue from issuance of bonds has been used to pay infrastructure investments for the project and to pay principal and interest of bridge loans and other financial expenses during construction.
Concesionaria Trasvase Olmos S.A. (CTO) took full design, financing, construction and operation and maintenance risks. PPFs and other lenders took the credit risks. CTO felt comfortable taking its share of risks because it got the construction contract and take or pay contract with a sovereign guarantee. The lenders felt comfortable because of various credit risk mitigations instruments attached to the concession contract, including sovereign guarantee of the Government of Peru (GoP), CAF’s Partial Credit Risk Guarantee, and the creation of a trust fund to ensure payments of debt. The figure below presents this financing PPP model.

The key concession contract information is:
- **Type, cost:** Design, Build, Finance, and Operate contract (DBFO contract), $US 242 million,
- **Awarding criteria:** Lowest Capital Subsidy,
- **Term:** 25 years,
- **Source of debt payment:** Tariff revenue.

The table below presents the main risks associated to this project as well as risk takers and how these risks can be mitigated:

<table>
<thead>
<tr>
<th>Main project risks</th>
<th>Risk taker</th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction</td>
<td>Private Concessionaire</td>
<td>Turn Key Contract awarded to consortia, Equity less than 10%</td>
</tr>
<tr>
<td>Demand</td>
<td>Private Concessionaire</td>
<td>Take of pay, GoP guarantees TP agreement</td>
</tr>
<tr>
<td>Credit or debt default</td>
<td>Local PPFs, Other private investors</td>
<td>Collecting account handled by creditors trust, GoP sovereign guarantee, CAF (Corporacion Andina de Fomento, a subregional development bank) PRC guarantee</td>
</tr>
</tbody>
</table>
Peruvian pension funds investment Concession Trasvase Olmos (CTO). In this case CTO’s main contracts included:

- Take or pay contract between the Regional Government of Lambayeque (RGL) and CTO;
- GoP Sovereign Guarantee in case RGL can not comply with its take or pay contract;
- CAF Partial Credit Risk Guarantee in case GoP does not comply with its sovereign guarantee in favour of RGL;
- GoP Sovereign Guarantee for bonds to be issued by the concessionaire and for CAF’s debt to finance the project;
- Obligation to create a Reserve and Debt Service Account to ensure timely payment to creditors;
- Obligation to create a Creditors’ Public Trust Fund (Fideicomiso) to handle GoP co-financing of the project for US$ 77 million and bond financing for US$ 100 million during construction; the Trust Fund will also handle CTO operational revenues in such a way that the Reserve and Debt service accounts are able to comply with the financial obligations, including those in favour of the lenders.
- Equity contribution of sponsor (Odebrecht) less than 10% (US$ 20 million) of total project cost as equity and issue shares that is maintained as collateral of debts. In CTO's case, payment of debts also depend on the operational performance of the concessionaire; however, the RGL is regarded weakly able to pay for the large amounts of water to be delivered by CTO, therefore the likelihood of the CTO cash revenues even with the take of pay contract are not regarded robust. Thus, had CTO’s contract not included the two GoP sovereign guarantees, the CAF’s partial risks guarantee, and the Creditors Trust Funds to handle debt service, it is unlikely that any investor would have provided financing for this project.

### 7.3.4 | Main lessons learnt

This project was considered as a whole by the Peruvian authorities and stakeholders with an objective of sustainable use of water resource for all users. One of the hydropower plants (Olmos 1) was registered as a CDM project avoiding CO₂ emissions and providing additional revenue to the developer.

The DBO/PPP is an innovative model in Peru to develop such multipurpose projects. Olmos is a successful case of joint public and private investment, which could be useful for project to be developed in other parts of the world. As the share of government investment in infrastructures has declined, the private sector share has increased. Privatisations and public-private partnership models (PPPs) offered further scope for unlocking private sector capital and expertise.

Peruvian pension funds may boost infrastructure investments. Institutional investors such as pension funds may play a more active role in bridging the infrastructure gap, in particular in the context of the financial crisis. It is also important that government support for long-term investments, i.e. designing policy measures that are supportive of long-term investing in infrastructures.

The concessionaire grants lot buyers individual Water License Certificates that are transferable among irrigators. This is a real opportunity for increasing the flexibility for water users allowing an optimal use of the water by reallocation of water amongst water users.

### 7.3.5 | References

Branche, 2014 “The multipurpose water uses of hydropower reservoirs: success stories as good examples”, Hydro2014 paper, Italy, October 2014

IB Partners, 2010 “Olmos irrigation project: Opportunity to Acquire Farmlands with Irrigation Rights in Peru”, October 2010

Zdravkovic, 2014 “Joint public and private investment in hydro projects – Peruvian experience”, Hydro2014 paper, Italy, October 2014
7.4 | Cumberland (United States of America, North America)

Cumberland River system case study was provided by EDF. All data is issued from public information, in particular from the US Army Corp of Engineers and ORNL initiative; this was compiled by Emmanuel BRANCHE (EDF).

7.4.1 | Project description

The Nashville District US Army Corps of Engineers (USACE) began its service to the region in 1888, when Lt. Col. John W. Barlow became the first Nashville District Engineer. His task was to oversee the construction of a series of locks and dams on the Cumberland River. Engineers on the Cumberland eagerly seized upon the idea of locks and dams to facilitate year-round navigation on the river. Over the next 40 years, fifteen locks and dams were built on the Cumberland River and were kept in service until the modern, multi-purpose dams that are now in operation were constructed. Today the Nashville District is responsible for navigable waterways in the Cumberland and Tennessee River Basins; flood risk reduction; hydropower and recreation at nine multipurpose projects in the Cumberland River Basin; and protection, preservation, restoration and improvement of natural resources.

The authorizing legislation of those dams relies on the following:

- Flood Control Act of 1938 (PL 75-761): Wolf Creek (1952), Dale Hollow (1953), Center Hill (1951), and J. Percy Priest (1970);
The Cumberland River is playing a vital role in the support of commerce, energy, recreation, and quality of life for all. It begins in the foothills of the Appalachian Mountains at Harlan, Kentucky, then winds its way 694 miles where it joins the Ohio River in Smithland, Kentucky. Along the way, the Cumberland River dips into Tennessee and is fed by countless tributaries where it serves as a drainage conduit for a watershed that covers 17,913 square miles.

Eight (8) projects are operated as a system. Indeed four (4) tributary storage projects (flood damage reduction and hydropower), three (3) main-steam navigation projects (navigation and hydropower) and one (1) hybrid project (flood damage reduction, navigation, and hydropower). Those have the ability to moderate flows to support regional objectives such as flood damage reduction and commercial navigation.
The Cumberland River Basin Interim Operating Plan dated back May 2007. It is based on Drought Contingency Plan dated November 1994. There are system-wide over-riding considerations for dam safety and flood damage reduction. During low flow system-wide, priorities were set as follows:

1. Water Supply,
2. Water Quality,
3. Navigation,
4. Hydropower,
5. Recreation.

The Cumberland River Basin Reservoir System consists of 10 multi-purpose projects operating for 5 main purposes (all figures year 2013):

- Flood Damage Reduction: 5.3 M acre-feet of flood storage; > $2.8 B in flood damages prevented ($115 M/yr); 77% of drainage area above Nashville is controlled;
- Hydropower: 9 out of the 10 projects have hydropower; total installed capacity of 914 MW from 28 hydropower turbines;
- Recreation: 380 miles of navigable waterway and 4 locks;
- Navigation: 5 Nashville District projects in top 25; 31.3 M visitors last year (> $700 M economic impact);
- Environmental Stewardship: Environmental restoration projects; Tremendous mussel and fish diversity; Home to two world record fish.

### 7.4.2 | Operation is flexible to address changing societal values or expectations

Planning periods of large multipurpose projects last rarely less than a decade. During those long periods, the needs to be fulfilled by the planned project evolve and change, and it is also the case during operation. Indeed as society demands evolve, together with their welfare, water storage becomes more and more strategic for its capacity to adapt to society’s needs. No alternative to water storage can fulfil such a critical function. The Cumberland water system is a pertinent example.

The table above (source USACE) presents the different reservoir purposes of the Cumberland river system and presents if they were primarily designed (green) for this purpose or not designed for this purpose (red).

<table>
<thead>
<tr>
<th>Cumberland river system projects and purposes</th>
<th>Flood damage reduction</th>
<th>Water Quality</th>
<th>Commercial navigation</th>
<th>Hydropower</th>
<th>Recreation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Martins Fork Dam</td>
<td>green</td>
<td>red</td>
<td>red</td>
<td>green</td>
<td>red</td>
</tr>
<tr>
<td>Laurel River Dam</td>
<td>red</td>
<td>green</td>
<td>green</td>
<td>red</td>
<td>green</td>
</tr>
<tr>
<td>Wolf Creek Dam</td>
<td>green</td>
<td>red</td>
<td>green</td>
<td>green</td>
<td>green</td>
</tr>
<tr>
<td>Dale Hollow Dam</td>
<td>green</td>
<td>red</td>
<td>green</td>
<td>green</td>
<td>red</td>
</tr>
<tr>
<td>Center Hill Dam</td>
<td>red</td>
<td>green</td>
<td>green</td>
<td>red</td>
<td>green</td>
</tr>
<tr>
<td>J. Percy Priest Dam</td>
<td>red</td>
<td>green</td>
<td>green</td>
<td>red</td>
<td>green</td>
</tr>
<tr>
<td>Cordell Hull Lock &amp; Dam</td>
<td>green</td>
<td>red</td>
<td>green</td>
<td>green</td>
<td>red</td>
</tr>
<tr>
<td>Old Hickory Lock &amp; Dam</td>
<td>red</td>
<td>green</td>
<td>green</td>
<td>green</td>
<td>red</td>
</tr>
<tr>
<td>Cheatham Lock &amp; Dam</td>
<td>red</td>
<td>green</td>
<td>green</td>
<td>red</td>
<td>green</td>
</tr>
<tr>
<td>Barkley Lock &amp; Dam</td>
<td>red</td>
<td>green</td>
<td>green</td>
<td>red</td>
<td>green</td>
</tr>
</tbody>
</table>

This table highlights the changing behaviours of the reservoir purposes over their lifetime.

### 7.4.3 | A strong water management system with stakeholder engagement

Cumberland River projects play a critical role in a regional system, including the Ohio and Mississippi Rivers. The Nashville District Water Management is a multidisciplinary staff comprising engineers and scientists. It performs complete system analysis every day. The mission of the Water Management Section is to sustainably manage the rich natural resources of the Cumberland River and to provide flood risk management, commercial navigation, hydropower production, water supply, environmental stewardship, and recreational opportunities to the people and businesses of the Cumberland Basin.
The USACE Water Management Section performs the following:

- Operates the reservoir system for flood risk management, navigation, hydropower, water supply, environmental stewardship, and recreation;
- Develops river and reservoir forecasts based on observed and expected rainfall amounts and anticipated reservoir operations;
- Develops and applies computerized water quality models;
- Designs physical modifications to projects to improve water quality;
- Develops, operates and maintains computerized databases for hydrological, meteorological, water quality, and biological data;
- Evaluates environmental impacts of proposed changes to reservoir operations.

Federal Partners including Tennessee Valley Authority (TVA), National Weather Service, and U.S. Geological Survey are important members of the water management team.

The water control program is an important task. For instance regarding the water quality, there is data collection (7 real-time water quality monitors, 4 real-time temperature, 62 stream sampling sites and 95 reservoir sampling sites) which allows a system water quality modelling (project specific CE-QUAL-W2 models). The water quality restoration is addressed to dissolved oxygen and minimum flow. The water control program relies on a strong data collection program using project data from 10 multi-purpose projects, 75 rainfall sites and 45 river stage sites. After that a hydrology, hydraulic, and reservoir simulation modelling is used to propose adequate reservoir system operations on a daily analysis of reservoir conditions, with balance operating objectives and prepared 8-day forecast.

The figure below (source USACE) presents all the stakeholders involved in the Cumberland water management system to address the 5 purposes: flood damage reduction, navigation, hydropower, environmental stewardship and recreation.

The TVA (Tennessee Valley Authority, see next Case Study) is naturally an important stakeholders with direct links on 3 issues (flood damage reduction, navigation and hydropower), as Cumberland river system contributes to the TVA system.
In regards to **flood operations**, there is collaboration between USACE Nashville District and the National Weather Service (NWS is a component of the National Oceanic and Atmospheric Administration (NOAA, is an Operating Unit of the U.S. Department of Commerce), with the mission of providing weather, water, and climate data, forecasts and warnings for the protection of life and property and enhancement of the national economy). NWS generates observed radar rainfall to USACE Nashville District, which then runs hydrology models to forecast reservoir releases and send them back to NWS, which uses forecast reservoir releases and rainfall to predict flood stages to the public.

In July 2014, the USACE Nashville District recently went live with the mobile website “**River Status**” that gives anyone with a smart device and Internet access an ability to view real-time water information within the Cumberland River watershed. Users get instant access to stream gages, rain gages, water quality data, and lake information (http://riverstatus.usace.army.mil/main.htm). The site also provides info from nearby gages, and the public can view flood hazard maps from the Federal Emergency Management Agency. There are a number of useful purposes of this mobile web. Fishing enthusiasts could use it to see if a dam is releasing water, the water temperature, and if the hydropower plant is generating. A potential home buyer could also check to see if a home is near or in FEMA’s identified Flood Zone. During significant rainfall events, people can get the rainfall amounts and can see the increase in the height of a local stream from a nearby water gage by looking at a hydrograph. Users have the ability to look at the data on daily, weekly, monthly or year-to-date charts.
7.4.4 | Main lessons learnt

The Cumberland River water management system requires coordinated operation of a complex system to fulfil a wide range of often competing purposes and benefits.

The figure below presents the preliminary findings of economic benefits of Cumberland system (Hadjerioua et al, 2014). The power generation represents less than 5% of the total economic value created along this water system.

Cumberland water system relies on strong and robust infrastructures that can adapt to evolving conditions in an integrated and participative approach.

The US Army Corps of Engineer sets clear priorities among water users during stress period (low water flows) which is the basis for an effective water management, avoiding or at least minimising potential conflicts among water users.

Stakeholder engagement and participation are at the heart of this system operation with USACE playing a key role in the process. The mobile website developed by USACE “River Status”, that gives anyone with a smart device and internet access an ability to view real-time water information within the Cumberland River watershed, appears at an effective tool to share information.

7.4.5 | References


USACE, 2014 “Management of the Cumberland River System” presentation by Benjamin L. Rohrbach, P.E. Hydrology & Hydraulics Branch Chief, Nashville District, for Tennessee Silver Jackets Meeting Old Hickory Lock and Dam, 09 April 2014

7.5 | Tennessee Valley Authority (United States of America, North America)

The Tennessee Valley Authority (TVA) river basin case study was provided by EDF. All data is issued from public information, mainly from TVA website and ORNL initiative; this was compiled by Emmanuel BRANCHE (EDF).

[Image: Map of the Tennessee Valley Authority (TVA) river basin with key information]

**Identity Card**
- **Type:** Basin / project
- **Status:** preparation/operation
- **Purposes:**
  - Hydropower
  - Flood control
  - Water supply
  - Irrigation
  - Fisheries
  - Recreation
  - Navigation
  - Water flow management

**SHARE topics**
- Sustainability approach
- Higher efficiency
- Adaptability for solutions
- River basin perspectives
- Engaging stakeholders
7.5.1 | Project description

All the information is issued from TVA website otherwise explicitly mentioned.

The Tennessee Valley Authority is the nation’s largest public power provider and a corporation of the U.S. government. TVA was established by Congress in 1933 to address a wide range of environmental, economic, and technological issues, including the delivery of low-cost electricity and the management of natural resources. TVA’s power service territory includes most of Tennessee and parts of Alabama, Georgia, Kentucky, Mississippi, North Carolina and Virginia, covering 80,000 square miles and serving more than 9 million people. TVA sells electricity to 155 power distributor customers and 56 directly served industries and federal facilities. Initially, federal appropriations funded all TVA operations. Appropriations for the TVA power program ended in 1959, and appropriations for TVA’s environmental stewardship and economic development activities were phased out by 1999. TVA is now fully self-financing, funding operations primarily through electricity sales and power system financings. TVA, which receives no taxpayer money and makes no profits, also provides flood control, navigation and land management for the Tennessee River system and assists utilities and state and local governments with economic development.

Since the 2010s, TVA adopted a bold corporate vision to become one of the nation’s leading providers of low-cost, cleaner energy by 2020. With this vision, TVA is working to improve its core business in the areas of low rates, high reliability and responsibility, and meet the region’s needs for the future through three (3) specific goals:

- Lead the nation in improving air quality
- Lead the nation in increased nuclear production
- Lead the Southeast in increased energy efficiency

TVA is pursuing its vision for 2020 while staying focused on its service-based mission: delivering reliable, low-cost electricity, environmental stewardship, river management, technological innovation and economic development across the region.

In 2011, an integrated resource plan, TVA’s Environmental and Energy Future, was completed to help guide decision-making for fulfilling the goals to achieve the vision. In November 2011, plans were approved for completing one of the two partially built reactors at the Bellefonte nuclear plant site by 2020. The transmission system achieved 99.999 percent reliability in 2011 for the 12th consecutive year. Since 2010, energy efficiency initiatives by TVA and local power companies have reduced electricity consumption by 765 gigawatt-hours (GWh), which is the equivalent energy to power 50,000 area households for an entire year.

TVA affirmed its commitment to improve the region’s environment. Under agreements with the Environmental Protection Agency and others in 2011, plans were adopted to retire 18 of TVA’s 59 coal-fired units by the end of 2017. Since 1977, TVA has invested more than $5.3 billion in clean air technology, achieving a 90 percent reduction in sulphur dioxide (SO2) emissions and more than 86 percent for nitrogen oxide emissions. Under the agreements, SO2 emissions will be reduced further to 97 percent and nitrogen oxide emissions to 95 percent below peak levels. In early 2012, an assessment of the work remaining to complete Watts Bar Unit 2 established a schedule for completion by December 2015.

TVA’s economic development efforts continue to support sustainable growth. TVA works with its customers and strategic partners to grow the region’s industrial base and support the retention and expansion of existing businesses and industries. Since 2005, TVA economic development support has helped to create or retain more than 300,000 jobs and $32 billion in business investment in the region. TVA’s strategic work to attract and retain jobs has earned a top 10 ranking for economic development among North America’s utilities by Site Selection magazine, a national publication, each year from 2006 through 2012.
The following paragraphs provide an overview of those purposes (power system, navigation on the Tennessee River, flood damage reduction, water quality, water supply, reducing the impact of droughts, and recreation).

**Power system: a large amount of electricity for the USA**

TVA is operating **fossil-fuel power plants (TPP)**. TVA’s 11 coal-fired generating facilities became the backbone of the power system in the 1950s, when TVA first began building coal plants to make electricity for the Tennessee Valley region. TVA’s fossil system also includes 106 natural gas-fired generators powered by combustion turbines. These generators can be quickly started and are vital for meeting peak electricity demands.

TVA is **operating nuclear power plants (NPP)**. TVA’s nuclear plants contribute about 6,600 megawatts (MW) of electricity to the power grid, making the Nuclear Power Group an integral part of the seven-state power system. About 30% of TVA’s power supply comes from its three (3) nuclear plants: Browns Ferry (near Athens, Alabama); Sequoyah (in Soddy-Daisy, Tennessee), and Watts Bar (near Spring City, Tennessee). Those plants alone make enough electricity to power more than three (3) million homes in the Tennessee Valley. As nuclear performance improves across the industry, TVA Nuclear’s challenge is to continue its mission to ensure safe plant operations and achieve its vision of being the best multi-site nuclear power operator in the world.

TVA is also operating **hydropower plants (HPP)**. TVA maintains twenty-nine (29) conventional hydroelectric dams throughout the Tennessee River system and one (1) pumped-storage facility for the production of electricity.
In addition, four (4) Alcoa dams on the Little Tennessee River and eight (8) U.S. Army Corps of Engineers dams on the Cumberland River contribute to the TVA power system (see previous case study on Cumberland river system).

TVA owns and operates one of the largest and most reliable transmission systems in North America. The TVA provides power to three main customer groups: (i) Distributors (155 distributors—municipal utility companies and cooperatives—that resell TVA power to consumers), (ii) Directly served customers (52 large energy-intensive industrial customers and 7 federal installations), and (iii) Off-system customers (12 surrounding utilities buy power from TVA on the interchange market).

The figure below presents Schematic Layout of the Tennessee Valley Authority Power Projects (Hadjierioua et al, 2014).

There is an interactive map to link to detailed information on all of TVA’s facilities (http://www.tva.com/sites/sites_ie.htm).
Navigation on the Tennessee River: Putting the waterway to work for the people of the TVA region

Navigation on the Tennessee River — made possible by TVA's system of dams and locks — has a significant impact on the economy of the TVA region. Actual savings vary from year to year depending on the volume and type of products shipped on the river. However, shipping goods by barge rather than by truck or rail reduces transportation costs by about $550 million each year. In addition, to compete with water transportation, railroads need to keep rates low, creating roughly another $500 million in savings for those who ship by rail or other alternatives to the river. This reduced cost means lower prices for consumers. Because one barge can transport as much tonnage as 60 semi-trucks or 15 rail cars, water transportation also reduces highway traffic, fuel consumption, air pollution, wear and tear on highways, and the number of tires sent to landfills.

The TVA system of nine (9) main-river dams allows boats to ascend or descend a “staircase” of quiet, pooled water and controlled current — a continuous series of reservoirs that stretches the entire length of the Tennessee River. Many industries in the TVA region owe their existence in large part to the availability of the waterway to move raw materials affordably, which means regular pay-checks for thousands of the region’s residents. The end result is a reliable transportation complex that is inexpensive and efficient to use. Efficient river transportation of food products for processing in the TVA region lowers the price of groceries for consumers nationwide, not just in the Southeast. The effects of money saved transporting goods here ripples across the entire economy. That’s why the TVA river system is a national as well as regional asset.

Flood Damage Reduction: a priority for TVA

Flooding was a serious problem in the Tennessee Valley region before TVA dams and reservoirs were built. Because of poor farming practices, floods washed away the topsoil, causing severe erosion and limiting farmers’ ability to grow crops. The potential for flood damage increased as cities and towns were built along rivers and in some cases, lives were lost. In an average year, the TVA system prevents about $240 million in flood damage in the TVA region and along the Ohio and Mississippi rivers. To date, the operation of this system has prevented over $5.4 billion in flood losses across the TVA region, including about $4.9 billion in damage averted at Chattanooga. The system has also prevented about $470 million in flood losses in the lower Ohio and Mississippi River drainage basins.

TVA uses reservoir operating guides to make decisions about moving water through the Tennessee River system. These guides show typical reservoir elevations throughout the year (expressed as the number of feet above sea level), as well as when the spring fill and winter drawdown are scheduled to occur. They help ensure there’s enough room in the reservoirs

---

Sharing the water uses of multipurpose hydropower reservoirs: the SHARE concept" - Case studies - FINAL
for flood storage while also providing for hydropower generation, navigation, water quality, recreation, and other benefits. Operating guides are based on many decades of operating experience. They take into consideration all the features that influence a reservoir’s ability to store and release water—the size and shape of the surrounding watershed, the reservoir’s surface area, and the average rainfall and runoff—as well as historical demands for water use and flood storage space at different times of the year.

The figure below (adapted by EB from TVA data) presents how TVA reduces the flood damage.

How TVA Reduces Flood Damage

TVA prepares for the winter flood season by lowering the level of flood-storage reservoirs to make room to hold the runoff produced by winter storms. When a storm hits, TVA holds the water back by reducing releases from the dams in areas where it is raining. When the rain stops and the danger of flooding is over, TVA gradually lets the water out to get ready for the next storm. In the summer, when flood risk is lower, TVA keeps lake levels higher to support recreation. To get ready for winter, TVA begins releasing water from tributary storage reservoirs at a faster rate following Labor Day weekend. This allows TVA to put the stored water to good use during September and October—which are typically hot, dry months—by generating electricity to power air conditioners and supplementing flows for water quality and navigation.

Main-river reservoirs don’t fluctuate nearly as much as the tributaries because of their original design and navigation requirements. Their draw-downs are staggered from July through the end of the year to ensure the released water can be used efficiently, generating electricity as it runs through the turbines at as many as nine dams downstream.

A small amount of flood storage capacity is reserved in all reservoirs through the summer months as a protection against flood-producing storms over limited areas.

- Tributary reservoir operating guides: Those operating guides for tributary reservoirs typically consist of two lines: a flood guide and a balancing guide. The flood guide is a seasonal elevation guide that shows the amount of storage allocated in a reservoir for flood damage reduction. The operating objective is to keep the reservoir below this line. The reservoir level at the dam may rise above the flood guide line as a result of large inflows, but the level is lowered to the flood guide line as soon as it can be done without increasing downstream flood damage. The balancing guide is used to ensure that water is drawn from tributary reservoirs equitably when water must be released from the reservoirs during the summer to meet downstream flow requirements. The operating objective is to keep the elevation of each reservoir similar relative to its position between the flood guide and the balancing guide.

http://www.tva.com/river/flood/how.htm

EDF-WWC FRAMEWORK « MULTIPURPOSE WATER USES OF HYDROPOWER RESERVOIRS » - EMMANUEL BRANCHE
• Main-river reservoir operating guides: Those operating
guides for reservoirs on the main Tennessee River typically
depict the top and bottom of the normal operating zone
for multiple system benefits, including flood damage
reduction. The top of the normal operating zone is
often exceeded, however, for the temporary storage of
high flows.

Water quality: a key issue for all stakeholders
The quality of the water in the Tennessee River system affects
not only the people who live in the TVA region but also
business and industry and the plant and animal life that are
part of the river ecosystem. In managing the river system,
TVA uses a integrated method that balances water quality
with the other demands on the system. TVA does not have
the authority to regulate water pollution. The Environmental
Protection Agency and each of the states that share the
river set their own pollution regulations and grant discharge
permits. Those controls are mostly focused on business and
industrial operations located along the river. However, it is
your responsibility to keep trash and other pollutants from
getting into the waterway by disposing of wastes properly.

The first step in managing water quality is to determine
the actual health of the river. TVA rates the condition of
each reservoir and 587 streams based on five ecological
factors. Sampling by TVA Watershed Teams made up of
water-resource professionals and education specialists
conducted sampling of fish at stream sites each year to help
determine key issues and steps that might be taken to improve
water quality at each site. TVA monitors for instance water
temperatures in the Elk River closely so that it can adjust
the temperature in the river. TVA targets stream sites
controlled to contain dissolved oxygen in the water released
to the river. TVA's integrated management of the Tennessee River
provides water for a wide range of public benefits. These
include water for drinking, industrial use and agriculture;
for generating hydropower and cooling nuclear and fossil
power plant components; and for navigation, recreation
and sustaining plant and animal life. In some cases, these
uses of water compete, especially under drought conditions.
TVA is committed to developing regional partnerships to deal
with these conflicts and help respond to the population and
environmental pressures of the coming decades.

Water supply: water as a limited resource that must
be protected and managed
Although the TVA region usually receives abundant rainfall,
averaging 51 inches per year, several extended dry periods
during the past 25 years have heightened public awareness
of water as a limited resource that must be protected and
managed. The Tennessee River watershed will add about
1.2 million more residents to the existing 4.7 million by
2030, according to recent projections by TVA and the
U.S. Geological Survey. Additionally, growth in urban
areas around the region, some of which are already facing
water-supply challenges, will increase pressure on the TVA
region's water resources. TVA is working with other federal
agencies, state and local governments, and communities
across the TVA region to meet these challenges. The goal
is to ensure adequate, sustainable supplies of water for
the region's continued growth.

TVA's integrated management of the Tennessee River
provides water for a wide range of public benefits. These
include water for drinking, industrial use and agriculture;
for generating hydropower and cooling nuclear and fossil
power plant components; and for navigation, recreation
and sustaining plant and animal life. In some cases, these
uses of water compete, especially under drought conditions.
TVA is committed to developing regional partnerships to deal
with these conflicts and help respond to the population and
environmental pressures of the coming decades.

Reducing the Impact of Droughts: another for reliable
water supply
The TVA Act lists flood control as one of TVA's primary
objectives. But in dry years, making the best use of the
available water is an equally important responsibility.
TVA helps minimize local water shortages during drought
conditions by managing river flows to keep reservoir levels
above water intake structures. Without the TVA system of
dams and reservoirs, the surface water supply would be
much less reliable than it is today.
Recreation

Millions of people enjoy recreational activities on TVA lakes each year. The lakes and the 293,000 acres of land surrounding them offer nearly limitless opportunities for fun-filled activities, including water skiing, canoeing, sailing, windsurfing, fishing, swimming, hiking, nature photography, picnicking, bird-watching and camping. It should be noted that a Mobile application was developed for smart-phones dedicated to the TVA Lake for an easy-to-use resource for operating on and around reservoirs and dams in the TVA region.

7.5.2 | Managing the river system flows as a key strategy

In May 2004, the TVA Board of Directors approved a new policy for operating the Tennessee River and reservoir system. This policy shifts the focus of TVA reservoir operations from achieving specific summer pool elevations on TVA-managed reservoirs to managing the flow of water through the river system. The new policy specifies flow requirements for individual reservoirs and for the system as a whole. Reservoir-specific flow requirements keep the riverbed below that reservoir’s dam from drying out. System-wide flow requirements ensure that enough water flows through the river system to meet downstream needs. These flow requirements help to enhance recreation opportunities on tributary storage reservoirs while meeting other needs: protecting water quality and aquatic resources, ensuring year-round navigation and providing water for power production and municipal and industrial use.

TVA enhances recreational opportunities by restricting the drawdown of tributary storage reservoirs during the summer — from June 1 through Labor Day. During this period, under normal operations, just enough water is released from these reservoirs to meet downstream flow requirements. TVA works to keep the water levels in these reservoirs as close as possible to each reservoir’s “flood guide level” — a guideline that reflects how much storage space each reservoir needs to hold back potential flood waters.

When water must be released to meet downstream flow requirements, a fair share of water is drawn from each reservoir. System-wide flows are measured at Chickamauga Dam, located near Chattanooga, Tenn., because this location provides the best indication of the flow for the upper half of the Tennessee River system. If the total volume of water flowing into Chickamauga Reservoir is less than needed to meet system-wide flow requirements, additional water must be released from upstream reservoirs to augment the natural inflows (a function of rainfall and runoff), resulting in some drawdown of these projects. How much water is released depends on the time period and the total volume of water in storage in 10 tributary reservoirs: Blue Ridge, Chatuge, Cherokee, Douglas, Fontana, Nottely, Hiwassee, Norris, South Holston and Watauga.

Based on the amount of water stored in these reservoirs in relation to the Minimum Operations Guide shown on the graph below, TVA will release enough water to provide the weekly average minimum flows at Chickamauga Dam shown in the chart below. When dry conditions prevail on the Tennessee River below Chickamauga, it may be necessary to release additional water to meet minimum flow requirements at Kentucky Dam.

TVA uses RiverWare in simulation and optimisation modes for daily scheduling of more than 40 reservoirs and hydropowerplants at 6 hour time-step. Their operating considerations include controlling floods, maintaining navigable depths, protecting aquatic communities, providing suitable levels and releases for recreation, and achieving economical hydropower generation schedules.

This model can manage daily scheduling, mid-term forecasting and long-term planning (see figure below). It is possible to switch between pure simulation, rule-based simulation and optimisation mode. The optimization modelling approach takes into account not only the power economics of the hydro system, but also other demands placed on the reservoir system. These demands, which include flood control, navigation, recreation, and water quality, as well as special operations for maintenance and community events, are defined in RiverWare as prioritized constraints. The optimization routine uses goal programming to satisfy all of the constraints in order of priority to the extent possible, and then with any remaining flexibility, optimizes hydropower operations to reduce the total integrated system power supply cost. Hydropower operations are optimized by maximizing the combined value of energy generated during the forecast period and water reserved in storage for future generation.
7.5.3 | TVA’s Involvement in Water Supply for the Tennessee Valley Region

TVA promotes the wise use, conservation and development of the water resources of the TVA region in carrying out a variety of water supply activities.

Issuing water withdrawal permits

TVA issues permits for all water intake structures. As a condition of these permits, applicants are required to report annual usage. This data is used in tracking existing usage and evaluating proposed increases in withdrawals from the Tennessee River system.

Meeting water-temperature discharge limits

TVA manages the river flow through dams to provide cooling water for its coal-fired and nuclear power plants. One method it employs is to use the cooler water from the bottom of reservoirs, which reduces the cost of power production, provides savings for consumers and helps ensure that power plants can stay online to meet power-system peaks.

Promoting water-supply planning

Federal and state policymakers recognize that cooperation and coordination are essential for water-supply planning in the years ahead. TVA works with local and state governments to promote regional water-supply planning and project implementation. In 2004, a watershed-wide partnership with states in the region was formed to:

• Improve regional cooperation in water resource management
• Provide a framework for coordination and information exchange among the states.

In addition to government agencies, this partnership could eventually include private utilities, coalitions, advocacy groups, regulators and industry, all key players in planning for the future of the region’s water. TVA also provides information and data for use in community-based planning efforts, and our scientists provide technical support to state agencies on regional supply issues.

Growth Readiness

Through the Growth Readiness program, TVA helps communities learn how land-use decisions affect water quality. The program helps planners, public works officials, and other community leaders:

• Comply with regulatory requirements,
• Make informed decisions about how to grow and prosper without jeopardizing the water resources necessary for future development,
• Evaluate their development rules using model principles developed by the Center for Watershed Protection,
• Lead a consensus-building process for adopting new rules and planning practices.
Officials from four communities helped develop and pilot the program. The Southeast Watershed Forum, the Tennessee Department of Agriculture, the University of Tennessee's Water Resources Research Center and TVA provided assistance. Since its start in the fall of 2003, Growth Readiness has reached more than 460 planners, public works officials and other community leaders serving more than 300 communities in Georgia, Kentucky, North Carolina, Tennessee and Virginia. As a result, over 120 communities have changed or will change their development rules to reduce water resource impacts.

**Improving water quality**

TVA's Watershed Teams work with municipal water suppliers, elected officials, community activists and economic development executives to protect and improve local surface and groundwater supplies by sharing water quality monitoring results, providing technical assistance and facilitating community-based actions. TVA also protects the region's drinking water by ensuring that reservoir levels stay above municipal and industrial intake structures along the river system and monitoring river temperatures to prevent algal growth from causing problems with taste and odor. Special reservoir operations are conducted as necessary to assist local water suppliers in dealing with accidental releases of contaminants that sometimes take place.

7.5.4 | Governance and stakeholder engagement: the Integrated Resource Plan

TVA periodically updates its power generation strategy. The purpose of the Integrated Resource Plan (IRP) is to identify the portfolio most likely to help TVA lead the region and the nation toward a cleaner and more secure energy future, relying more on nuclear power and energy efficiency and relying less on coal.

TVA asks the general public, its customers, and partners and regulators about their concerns regarding the sources it uses to generate power (fossil fuels, renewables, nuclear, etc.), how it reduces demand (energy efficiency programs, time-of-use pricing, environmental impact, etc.) and how it delivers power (transmission, environmental impact, pricing, etc.). Then TVA considers social factors that would also impact our generation (poor economy, unforecastable weather scenarios, less expensive technologies, etc.). TVA holds public meetings to gather input on the scope of the planning process and associated environmental impact statement (EIS: detailed assessment of major actions with the potential to cause significant environmental impacts). The presentations given at those meetings are available.

With this information TVA develops scenarios that are evaluated for viability and environmental impact. With the information received from the public and partners during scoping, TVA will develop a Draft integrated resource plan and a draft Supplemental Environmental Impact Statement (SEIS) that assess the environmental impacts of the scenarios proposed in the draft integrated resource plan.

In the meantime, TVA is working with the IRP Working Group (IRPWG), stakeholders who represent broad perspectives such as customers, businesses, activists, elected officials and economic development experts. This group will accompany TVA on nearly two year journeys to create and test this 20-30 year vision to meet TVA's power needs for the Valley. TVA and other stakeholders will meet frequently with them to get their feedback, insights and challenges as scenarios, strategies and plan measurements are developed along the way. Specific meetings are also organised.

7.5.5 | Main lessons learnt

The long term Tennessee Valley Authority's (TVA) experience on multipurpose water management at a basin level is recognized by all people. TVA, using an integrated approach, is engaging all stakeholders for co-construction, putting dialogue and communication as a priority.

The TVA river water management system requires coordinated operation of a complex system to fulfill a wide range of often competing purposes and benefits.

The figure below presents the preliminary findings of economic benefits of TVA system (Hadjerioua et al, 2014). The power generation represents less than 5% of the total economic value created along this water system.

It should be noted that many data are available to the public for other purposes (up-dated Reservoir operating policy, Water elevations at major cities, Rainfall and stream flows, TVA dams and power plants, River System Monitoring, Water temperature of the river, Aquatic plan management, etc.). IT technologies are made available to public, all stakeholders, to better understand the system as a whole.
Most of the dams/reservoirs were not initially design for all purposes, and social requirements have evolved along time. By using appropriate governance and software, TVA manages the river system flows as a key strategy.

### 7.5.6 | References

**Branche E., 2014** “The multipurpose water uses of hydropower reservoirs: success stories as good examples”, Hydro2014 paper, Italy, October 2014


7.6 | Durance-Verdon (France, Europe)

The Durance-Verdon valleys case study was provided by EDF. All information is issued by EDF.

7.6.1 | Project description

The Hydraulic Operating Group of the Durance and Verdon Valleys runs 30 plants and 17 dams based in the Hautes-Alpes, Alpes de Haute-Provence, Var, Vaucluse and Bouches-du-Rhône Departments (South-East of France). It produces an average 6.5 billion kWh per year, using clean and renewable energy, equal to the annual residential consumption of a city with over 2.5 million inhabitants. It accounts for 40% of the electricity produced in the (Provence-Alpes-Côte d’Azur) PACA Region. The Serre-Ponçon and Sainte-Croix water reservoirs in particular and the hydro-electrical infrastructures in the Durance and Verdon Valleys help serve the sources of demand for water and renewable energy across the region and foster territorial development. The main facilities are commanded remotely, from the Hydraulic Command Centre (CCH). It guarantees fully-synchronized operations capable of generating up to 2,000 MW power in less than 10 minutes, and thus supply customers in a competitive and responsive manner.
EDF (Electricité de France) Group is an integrated energy utility active in all areas of the electricity market: nuclear, renewable and fossil fuel energy generation, transmission, distribution and marketing, energy efficiency and management services, as well as energy trading. With a net installed capacity of 140.4 GWe worldwide, and global production of 653.96 TWh as at 31st December 2013, the EDF Group ranks among the world’s leading energy utilities, with the biggest fleet emitting the least amount of CO₂ per kilowatt-hour generated. The 239 dams-reservoirs operated by EDF in France enable the storage of 7.5 billion cubic meters of water, i.e. EDF manages 75% of national surface storage reserve.

The figure below presents a schematic vision of the Durance-Verdon valleys and its hydropower plants.
7.6.2 | Management of the multipurpose scheme

Water shared as a basic assumption

Built in 1955 by EDF and managed by them since that date, the Serre-Ponçon dam and all of the hydraulic production structures in the Durance and Verdon regions form the source of solidarity-based water management in the Provence-Alpes-Côte d’Azur Region. From its very inception, EDF’s Serre-Ponçon Site – an immense water reservoir holding 1.2 billion m³ of water – was designed to capture and store water resources and channel them to all sources of demand: producing renewable energy, supplying drinking, agricultural and industrial water and providing for the tourist activities developed around the dams that contribute to the region’s business activity and attractiveness. A structure unparalleled anywhere in France, it secures regional water management by averting drought for Provence and regulating the formidable flooding to which Durance has been subject in the past.

The French law of 1955

It’s by the law “development of Serre-Ponçon and Lower Durance” of January 5, 1955, adopted almost unanimously by the two Assemblies that the French State declared of “public utility” the development of Durance and conceded the construction and operation to Electricité de France (EDF). In addition to regulating the stream, the Assemblies assigned to the organization two key missions: the water supply of the Lower Durance for irrigation and drinking water, and the development of water power for production electric Power. The French State also decided to establish an agricultural reserve of 200 million m³ in the reservoir of Serre-Ponçon to address weaknesses in the natural flow of the Durance in a period of intensive irrigation. The Agricultural Ministry indeed financed a part of the Serre-Ponçon dam.

It is worth noting that in order to get original acceptance by the local population for the dam; an innovative consultation process was undertaken, outlining all these potential benefits.

The law of January 5th, 1955 “The development of Serre-Ponçon and basse-Durance” enhance these structures of public utility in order to achieve hydroelectric facilities on the Durance River to:

- Generate energy,
- Ensure the supply of drinking water, industrial water and irrigation water,
- Regulate the course of the Durance River (limit the effects of floods and water shortages).

In this context, the requirement of a balanced water sharing makes sense. It is important to highlight the 1955 Law and related texts, EDF / Ministry of Agriculture and concession agreements, which have written in stone the water sharing principles between irrigation, drinking water and hydropower. It is also important that some stress that they feel that all other benefits around Serre-Ponçon, as the Cornerstone of the valley, are mitigation measures to occupy their territory. They never, however, believe that tourism benefits are compensation for the price paid by the municipalities adjacent to the implementation of the reservoir.

In addition to the generation of renewable energy, the main purposes of the reservoirs are securing water supply (flood control, drought mitigation and drinking water), tourism, environment, ensuring safety. The following items proposes a description of those purposes:

- **Securing water supply:** The water retention zones formed by the Durance, and Verdon Dams, along with the EDF Canal, are as many reserves that secure water supply across the territory and help ensure that this precious resource will be managed in a mutually-supportive manner for irrigation, drinking water (Marseille, Aix and the cities of in coastal Var) and industrial water (Fos, Berre, Cadarache, Sisteron...). The EDF Canal that stretches over 250 km, from the Serre-Ponçon Retention Zone to Etang de Berre, and the Verdon Dams are industrial structures dedicated to producing renewable energy. They also help make it possible to supply the Hautes-Alpes and Alpes de Haute-Provence with water and convey the water found in the drainage basins to the Vaucluse, Bouches-du-Rhône and Var, impacted by greater inadequacies. The Marseille Canal, operated by the Société des Eaux de Marseille (on behalf of Marseille Provence Métropole), the Provence Canal, operated by Société du Canal de Provence (on behalf of the PACA Regional Council), and the Basse-Durance (lower Durance) irrigation canals draw water from the reserves formed by the hydraulic production structures managed by EDF and convey it to users with the aim of serving their needs as best possible.

A potential 250 million m³ water reserve can be mobilized from the Verdon Retention Zones in the Verdon and the Bimont SCP Dam, near Aix-en-Provence. In addition, from 1 July to 30 September, a potential 200 million m³ water reserve in the Serre-Ponçon Retention Zone will be made available to the Durance Executive Commission (CED), composed of the Irrigators’ Trade Unions, in order to cope with water irrigation and supply needs during the summer. Thus, each year, nearly 2 billion m³ are dedicated to supply drinking water to 150 municipalities – or over 2 million clients – to the main industrial hubs in the region and the irrigation of 150,000 hectares of farmland.
• **Tourism: an emerging use more and more significant for the economy.** The Serre Ponçon has gradually become a major center of tourist attractiveness (positioning as real bioclimatic crossroads between the Alps North and South, the status of biggest dam in Europe and the presence of the largest artificial lake in Europe by volume); “Sailing Resort” label; good water quality for swimming; aquatic and remarkable landscapes, fishing interests; the implementation of the Coastal Law for bordering communities of Serre-Ponçon. Therefore after decades the Serre-Ponçon reservoir is becoming a lake for the people. Therefore EDF has fostered a unique structure to enhance economical development the banks of the reservoir, with the creation of SMADESEP (*Syndicat Mixte d’Aménagement et de développement de Serre-Ponçon*) on May, 30th 1997. This is a public administrative institution that includes the General Council of the Hautes-Alpes, the community of communes of the region of Embrun, the community of communes of the region of Savines Serre-Ponçon, the community of communes of the Region of Serre-Ponçon and the commune Chorges. SMADESEP purposes is to manage a consistent development of quality tourism, this is the main goal which unites nine riverside municipalities in the Hautes-Alpes of the Basin Serre-Ponçon, namely Baratier, Crots, Embrun, Savines le Lac, Le Sauze du Lac, Prunieres, Puy Sanières, Chorges and Rousset. The Framework convention: The SMADESEP was appointed by EDF as manager of the hydroelectric public domain of Serre-Ponçon, granted to the company by the 1955 law establishing the facilities of the Durance, and therefore the dam. Succeeding several formalized partnerships since 1999, the “framework” convention of 16 June 2008 considerably strengthens the links between the SMADESEP and E.D.F. until the end of the EDF concession in 2052. For all socio-professional workers around this reservoir, the long term registration of their project is necessary to ensure a sustainable and harmonious development of their activities, to develop projects on the long term and to make investments, to gain serenity in everyday life and to imagine the future with a quality requirement. This is why, very concretely, the Temporary Occupation Authorizations, it is possible to issue them since 2008, now for 10 years and for free. For SMADESEP, to imply accurate and fair rules, to share, to ensure compliance by each to preserve the beauty of the site and to keep control of its management and its development, it requires commitment, conviction, and time. It is to this purpose that a charter of good conduct specifying the conditions of riverside occupation of the Lake of Serre-Ponçon, applies to all. It ensures compliance of the beauty of the site and the control of its development. For elected officials and policymakers of the territories, the local economic development is not built or imagined in a day. Through this partnership, promoting access to banks and creating favorable conditions to a sustainability of activities, ensuring quality equipment, EDF and SMADESEP offer them a close commitment, guaranteed over time. Finally, to EDF, being offered the opportunity for a lasting confidence, it is the guarantee to make further progress in sharing about the respective issues, it is to give time for understanding but also for anticipation faced to new challenges and new expectations about the use of water. It should be noted that there is also a similar enhancement around the reservoirs and neighbouring districts on the Verdon River with the PNRV (Parc Naturel Régional du Verdon).

• **The environment: biodiversity and balance of aquatic environments.** Today, the balance of aquatic environments and the safeguarding of the natural environment have become important to society and are a requirement of sustainable development, as recommended in the European Union Water Framework Directive (EU WFD). The principal problems encountered after fifty years of management of resources in this valley are morphological imbalances of riverbeds and limited development of aquatic environments. EDF thus studies methods to adapt the management of the power plants to seek best possible balance between minimum loss of renewable energy and benefit to the aquatic environment. This supposes prioritizing and co financing corresponding actions, involving all partners associated in the “Durance Plan” implemented and supervised by the French State. Two key measures were proposed:

  ➔ Integrated sediment management (there is a basin sediment transport strategy along the durance River combining management measures and dredging main reservoir or rivers including for instance: restoration of sediment transport by totally opening valves during floods, or by planned hydraulic flushes outside flood periods, etc.)

  ➔ Experimental variation of the compensation water greater than the contractual value of 1/20th of the mean annual discharge throughout the year: this action consists in applying values of seasonally adjusted minimum compensation water over a period representative of biological cycles and an evaluation of the response of the aquatic environment to these new modes of flow. This resulted in new levels of compensation water to be applied to the Durance River downstream from Serre-Ponçon as of January, 1st 2014 within the framework of the 2006 Water Law.

The presence of hydroelectric infrastructures can, as they modify the characteristics of a river, create ecological conditions conducive to the development of new milieus and species. In order to work for the preservation of such milieus, EDF has become partner to the Natural Areas Conservation Authority of Provence-Alpes-Côte d’Azur
EDF actively invests in coordinated efforts involving all of the water sector players in the territory, who determine shared action programs for the benefit of the river and its ecosystems. With commitments under the Durance, Verdon and Buëch River Contracts, and contributing EUR 21 million in funding to their execution, EDF heads a large number of public interest initiatives to protect the river and lower potential impact on the environment. The aim is to foster the circulation of gravel and sediment to encourage life in the milieus and limit flood risk in the surrounding urbanized areas. EDF is also involved in projects to restore and manage natural milieus, such as the fight against invasive species or the installation of fish passes to facilitate the movement of fish species.

Example: the partnership on the Verdon. Since 2008, EDF has been involved in a partnership with the Verdon Regional Natural Park, to secure harmonious development for the territory and protect the environment. Through this effort, conducted in close coordination with all of the players across the territory and the French Water Agency, the flows returned to the river downstream from the production infrastructures have been increased since April 2011, in order to improve biodiversity and the functioning of water environments. The flows have been raised by a factor of 6 downstream from the Chaudanne Dam and by a factor of 2 downstream from the Grénoux Dam, and bring public safety action to the zone downstream from the structures and nautical activities to the Gorges du Verdon area. To limit renewable energy losses, some small hydro power plants, with capacity to turbine the additional flow and transform it into electricity were installed.

In addition EDF alongside its partners participates in gaining scientific and environmental knowledge on the species found in rivers (better understanding and protecting the milieus). The aim is to bring about greater consideration and respect for their living modes, habitat and reproduction zones. This understanding makes it possible to adapt environmental decision-making on the work streams, as well as the operating modes and management of the power generation structures.

Example: the rehabilitation of the Etang de Berre. The waters of the Durance River, along the EDF canal, converge with Etang de Berre. To limit the environmental impact of the disposal of freshwater in a lagoon area, EDF has adjusted its management policy, keeping to specific quotas on freshwater and silt influx and salinity thresholds. Water quality control and innovative experimental monitoring were instituted specifically for the project. Through its commitments under the Etang de Berre Contract, EDF and its partners – including Syndicat Mixte de l’Etang de Berre – works to improve the water body’s ecological status and develop usages around the natural area.

- **Ensuring safety: a priority for EDF.** Ensuring safety in production facilities: EDF operates the hydroelectric power generation plant, putting its expertise and skilled staff of 490 to run the facilities at optimal performance levels. The structures are subject to stringent inspection, monitoring and maintenance throughout the year. EDF operates and maintains infrastructures under the supervision of the Regional Authority for the Environment, Development and Housing (DREAL), which regularly performs inspections and checks, in accordance to factors such as the size of the facilities. Probes are conducted on an on-going basis, using specialized instruments placed inside the structures, including timers, piezometers and flow regulation systems. Several times a year, technicians make visual inspection tours of the facilities, the results of which are written up in a Monitoring Report provided to DREAL. 12 dams exceeding 20 meters are found across the PACA Region. They are subject to specific monitoring measures and a complete review every 10 years, in particular the portions of the infrastructure that usually remain immersed. In order to guarantee the stability of the infrastructures in the event of seismic activity, the dams were built to withstand the highest levels of earthquake activity known to the Region. Since their original construction date, further statistical and geological knowledge of seismic activity has come to light and new standards have been adopted accordingly.

Third-party safety: Safety downstream from the structures is a priority for EDF, due to the functioning of the hydroelectric structures, which can entail significant variations in the river’s flow or in EDF’s canal on the Durance River. Operating procedures have been adjusted to mitigate risks during powerplant start-up: advance scheduling, successive power thresholds, etc. EDF does everything in its power to inform and raise awareness in its audiences: signalling panels, brochures and posters disseminated widely (30,000 copies), conferences in schools, 50 seasonal workers mobilised each summer to remind users of preventive rules on the ground, etc. The EDF canal is an industrial structure that also entails risks. Access to the canal banks, which are slanted and
slippery, is prohibited for safety reasons. The risk of falling into the canal is high, while the current can be extremely powerful and the temperature very cold, even in summer (approximately 15°C).

### 7.6.3 | Operation of the Multipurpose Scheme

**Operation of the Serre-Ponçon reservoir from a multipurpose perspective**

There are two main issues regarding multipurpose uses.

- How to reconcile, regardless of the status of the resource, water supply, electricity generation and tourism?
- How to deal with conflict situations which may be exacerbated along existing or new issues?

EDF **draws upon a high-performance meteorological forecasting system** (over 30 measurement points, identifying snow cover, precipitation and temperatures across the Haute Durance basin), in order to anticipate future water influx. Infrastructure management is adjusted around the clock, in order to reconcile the needs resulting from all forms of use and the safety of individuals and property.

It is very important to have a step-by-step approach to address the management of multipurpose water uses of hydropower reservoirs: **1st/ knowledge, 2nd/understanding** and **3rd/ Management**.

#### The multi-purpose water management is often to reconcile the interests of the upstream and downstream: an adapted strategy for water management

---

The Durance water resources, though relatively abundant, are highly variable and, certain years, unevenly spread. Thus the Durance-Verdon junction annual resources can vary from 3 to 8 billion m³, year to year. These numbers highlight the difficulty in meeting the needs, at any one time, of all users. A dense network of sensors (flow, snow, rain, temperature, etc.) allows, by means of hydrological models developed by EDF, the evaluation of the hydrous stock of the Durance and Verdon valleys and its fluctuation over time, as well as the volume of flow and the probability of occurrence.

The management of seasonal reserves as that of Serre-Ponçon follows an annual cycle which must take into account the hydraulic characteristics of the river, the various uses with their contractual obligations, and environmental requirements. It must also, while satisfying the other uses, find the economic optimum in order to generate electricity at the lowest possible costs, and at the right moment, i.e. when the electric grid needs it most. It is naturally conditioned by the installations physical limits.
An increasingly complex management
Quantitative and time variability of the water resource …
… and also:
• Increased needs of uses to be met,
• Operating constraints to be taken into account,
• New regulatory developments,
• High level of safety facilities to ensure,
• Power grid security to ensure.

The lake is draw down during the winter season during peak electrical production. In spring, generation is adjusted, according to water cumulative flows, to restore the winter energy stock and agricultural reserves, in order to reach, at the beginning of the summer, a level required for recreational activities. During the summer, through electricity production, water flows into the lower reaches of the Durance providing enough volume for peak irrigation needs, which generally results in a drop in level, also compatible with tourism in the majority of cases. The cumulative autumn flows supplement storage and prepare the stock for a new winter. Drinking water is consistently provided throughout the year.

The resources required for the four uses – electricity generation, irrigation, drinking water and tourism - are sufficient most of the time, approximately 8 years out of every 10. During droughts, when hydro resources become rare and conflicts on best use arise, it is time for dialogue, or even arbitration.

The figure below presents a typical filling curve of the Serre-Ponçon reservoir according to multipurpose uses (drinking water, hydropower, agriculture and tourism). Tourism is not a contract condition but is also included in reservoir management objectives.

The operation/management principle of Serre-Ponçon reservoir is based on:
• A concerted management planning,
• Forecasting hydro-meteorological models, and
• Sharing of information.
EDF actively invests in **coordinated efforts involving all of the water sector players in the territory**, who determine shared action programs for the benefit of all water users, the river and its ecosystems.

### 7.6.4 Consultation and participative approach as an effective tool

Beyond a deep culture shared by the people of Provence and high-alpine, where everyone understands the value of water, and the know-how on water resources management acquired by EDF, there is sometimes a painful experience during dry years. This has led stakeholders, with the support of French Government, to build effective approaches to dialogue and to develop the tools to avoid or mitigate the crisis.

The hydropower installations have positive effects on both economic development and the environment, and EDF has a proactive management policy in relation to its hydropower resource, which it enforces in cooperation with various water stakeholders. EDF has entered into agreements with local elected officials, farmers, fishermen, managers of tourist sites and manufacturers.

EDF gives preference to consultation with local users. This process aims first at measuring the real effects of hydropower operations on the environment and on other uses, before attempting to minimize these effects when technically possible and financially reasonable.

The consultation is part institutional, but it is also constructed in crisis situations. It is also driven by the efforts driven by the water law of 3 January 1992, inviting players to work together to seek a balanced sharing of water resources for preserving the environment.

The figure below presents a schematic vision of the Basin Committee, and the basin authorities in France.
Discussion forums and tools to promote policies integration

- Discussion forums:
  - The Basin Committee brings together stakeholders (elected representatives, users and administrations) to deliberate and to take decisions in the interest of all in water resource matters,
  - The EPTB (Établissement Public Territorial de Bassin, basin territorial public institution): regions, departments and areas bordering a common waterway; logic upstream-downstream reasoning; arbitration and processing of the various requests on a hierarchical basis.

- Tools:
  - The SDAGE (Schéma Directeur d’Aménagement et de Gestion des Eaux, River Basin Management Plans, RBMPs) and the associated Programmes of Measures (PoM): prioritised objectives and measures at catchment level;
  - The SAGE (Schéma d’Aménagement et de Gestion des Eaux) is adapted to the sub-basin level to Development and Water Management Plans;
  - Other types of forward planning documents: river contracts (drinking water, water treatment, environment), management plan of low water levels (resources/needs balance), territorial project for the creation of new dams, etc.

The Law of July 11th, 1907 decreed the establishment of a government regulation to prescribe measures to ensure distribution of the waters of the Durance downstream Mirabeau’s bridge (i.e. Cadarache place) and creates the Executive Committee Durance (CED) to enforce it. CED, under the control of the Ministry of Agriculture, has for this purpose a power of police. It exercises this role perfectly still, in close partnership with EDF. It is a standing forum for exchange of information, evaluation of the situation and development decisions related to agriculture, in a normal situation by continuously dialogue, as well as in crisis.

Institutional cooperation has turned in recent years into a true partnership between the CED and EDF, complemented by the development of wide information of the Serre-Ponçon reservoir neighbors, meetings within the SMADESEP and tourism professionals, working closely with the prefect of the Hautes-Alpes.

In addition, regular appropriate communication to the circumstances shall be made to all water users, the general public and the media. Report regularly on the situation, the outlook and the measures taken to reconcile the different water uses to give visibility to the public authorities and economic operators is the purpose of this information. Agreements with key players are defining those terms.

Gradually, the planning tools have been deepened, particularly with respect to predictions of inflows, the use of agricultural reserves and variations in Serre-Ponçon reservoir water levels, during filled in as well as in the summer period. Those tools are adapted to serve as communication purpose with the governments and EDF partners.

7.6.5 | A shared vision of the future among stakeholders with “R2D2,2050” project

The evolution of the water resource and the water demand under climate stress and depending on demographic and socio-economic territories evolution may require development of adaptation strategies (water savings are the most obvious lever, plus crops choice and development choices). This will ensure long-term effectiveness of a model that has proven to serve the general interest and to find answers to reduce water use conflicts that could arise if nothing is done. Access to water is in this context a major strategic challenge for all stakeholders. The good structural design of water infrastructures give all water users time to adjust governance to find and to implement solutions to preserve the future. This is the collective challenge of tomorrow!

In a time of changing needs, EDF is committed alongside its partners to preserving water resources and takes an active part in the forward-looking studies relating to the impact of climate change.

The climatic parameters are changing on the Durance & Verdon valleys. They will result in degraded techniques and energy efficiency which will represent a significant cost to EDF (energy loss, operation, technical and specific constraints).
A hydrology that queries

Although rarely mentioned, the impact of climate change on energy production is a real issue and it also impacts other water uses and the environment. It is essential to communicate EDF’s vision of this situation with the other stakeholders in order to have and support a shared vision.

A shared vision for the water users

- What priorities for what kind of development?
- What balance between uses (basic/emerging)?
- What balance between regulation, contracting and adaptation of individual and collective behavior?
- How to adapt to a constantly changing pattern?
- Who is willing to pay for these changes and their consequences?

Therefore there are fears about resource availability and sustainability of certain uses (water supply, environmental degradation, tourist water levels, economic development, fisheries, recreation...), which may lead to perceptible tension in the relationships. A collective awareness is therefore required on this matter as well as an increased need for solidarity and cooperation. A contribution by all stakeholders is required for the effort to develop fair practices and behaviors, and a converging approach covering different expectations while preserving the issues specific to each actor.
Uncertainty exists. It is up to all stakeholders to collectively manage and prepare for tomorrow’s developments with less water and more risks. The answer to those challenges is not unique and should be addressed on a case by case approach. Among the potential solutions, one can promote:

i) Management planning (modeling tools) to anticipate and provide visibility to the different stakeholders;

ii) Consultation to understand the issues and share;

iii) Communication to explain and support guidelines;

iv) Convention development and partnership;

v) Incentive to save water (for the agriculture sector for instance); and

vi) Development of the culture of risk (for extreme events such as drought, floods).

Working in connection with IRSTEA (Institut national de Recherche en Sciences et Technologies pour l’Environnement et l’Agriculture), it is the National Research Institute of Science and Technology for Environment and Agriculture is a public scientific and technical institute in joint supervision with the Ministry of Research and the Ministry of Agriculture and is holder of an agreement with the Ministry of Ecology, the co-signatory of its constitutive decree, EDF Research and Development teams contribute to the large-scale program dubbed R2D2,2050 (Risk, Water Resources and Sustainable Management in Durance in 2050). This is a partnership project aimed at assessing the possible impacts of climate change on the quantity and quality of water resources, biodiversity and the changing demand and uses. The goal is to inform the communities and public authorities about the measures required in order to adapt to one of the 21st centuries’ greatest challenges.

The research project “R2D2,2050” will in particular provide insights on:

- changes in the hydrological regime of the major rivers of the watershed and the water supply;
- applications in current and future water uses water (hydropower, agriculture, tourism, etc.), including the main aquatic ecosystems, local or external, which put pressure on the hydro Durance-Verdon;
- potential future imbalances resulting from the confrontation supply / demand under scenarios of climate change and socio-economic development;
- leeway and management alternatives to ensure a “balanced and sustainable” management of water resources in line with the objectives and challenges of planning;
- uncertainties attached to the main results obtained, as well as the relative importance of potential sources of uncertainty.

i) Structured in different groups of tasks, this research project R2D2,2050 is based on three principles of innovative search:

ii) the development of an integrated, multidisciplinary approach to build an operational accurate representation of how the river system taking into account the main biophysical and decision-making processes, their interactions and their spatial distribution;

iii) the simultaneous application of the same watersheds of different hydrological models and methods for assessing future water demand to reduce uncertainties resulting from methodological choices;

iv) the mobilization of local players.

to 1) co-construct territorial socio-economic scenarios, 2) share the assumptions and results, and 3) assess their operational relevance in the context of policy initiatives.

Funded under the GICC (Gestion et Impact du Changement Climatique) program of the Ministry of Ecology and the Water Agency Rhone-Mediterranean and Corsica, the R2D2,2050 project is implemented by seven partners coordinated by IRSTEA: IRSTEA Lyon, EDF R&D LNHE Chatou (national hydraulic and environment laboratory of the Research and Development Unit of EDF), EDF DTG Grenoble (EDF engineering unit in charge of measuring and predicting the available water resource (rain, snow, snowmelt) to monitor the change in reserves, the water level of dams and flows of rivers; measuring and monitoring the quality of water, air, and make environmental impact diagnoses: acoustic, water temperature), Pierre et Marie Curie University Paris (the leading French scientific and medical university), IRSTEA Antony, LTHE Grenoble (a leading French research laboratory focused on the hydrologic cycle and its links with the Earth’s climatic and environmental changes), Société du Canal de Provence (Canal Company in Provence aiming at developing and managing regional water resources, in order to provide a safe and reliable water supply for agriculture, industry and domestic use), ACV (a consulting and research company specialized in policy development and in environmental policies and strategies implementation). Its duration is three years (December 2010 - December 2013).

Research activities are conducted in close collaboration with key players in the area, from targeted interviews and local workshops or themes that complement the prospective workshops planned.
Local stakeholders: key players of the area

A Steering Committee for local interaction comprising key players in the area (including in particular the Provence-Alpes-Côte d’Azur (PACA) region, the Water Agency Rhone-Mediterranean and Corsica, the Regional Directorate for Environment, Physical Planning and Housing (DREAL)…) will keep it regularly informed of all players in the area regarding project implementation and results.

The final results of this project will be published in the coming months.

7.6.6 | Water saving conventions to foster solidarity across the water basin

The management of the Serre-Ponçon reservoir has thus multiple objectives – electricity production, flood management and water supply for irrigation, drinking water and industry. Tourism is not a contract condition but is also included in reservoir management objectives.

EDF is required to deliver 200 Mm$^3$ to irrigators between 1st July and 30th September annually (as Ministry of Agriculture financed part of the dam construction), and an information bulletin is sent each week to farmers about irrigation flows.

An original conventional device initiated in 2002 between EDF and Canaux de Vaucluse

This innovative approach is based on the following principle:

- An obligation to deliver the requested value (obligation of result);
- The water saving target is reviewable and set by the Canaux de Vaucluse (channels of Vaucluse department);
- The compensation is paid by EDF if the goal is reached;
- A quick degression is used if the target is not reached;
- Incentive to reach the target and to go beyond, and the approach is replicable.

EDF encourages farmers for saving water by financing modern systems for water use reduction. Through this specific agreement (Water Saving Convention signed in 2002), which leads EDF to payback a part of the saving costs if the targeted objectives are reached, the agricultural consumption for one partner decreased from 310 Mm$^3$ in 1997 to 220 Mm$^3$ in 2012 (i.e. a saving of 90 million m$^3$ in reference to the consumption of 1990s (60 million m$^3$ since the signing of the agreement).

EDF, in association with the Water Agency, participated in several studies. EDF and the Water Agency are working on biology continuity (fish passes) and sediment continuity (releases or the realization of an input channel valve at Escale that allows dam-removal). The Plan Durance reports on the implementation and effectiveness of these additional economic benefits.

A win-win solution for stakeholders

Thanks to this convention significant water savings were reached (a 30% reduction of water by the irrigators), and this is a win-win device for:

- Irrigators: they have an attractive annual compensation, and a better control of the Serre-Ponçon reservoir;
- Energy: there is a better seasonal use with the saved water volume stored (which could be generated on peak hours) but a limited energy gain (as those savings are located downstream end of the chain; the valuation is recovered 20% on the energy side and 80% regarding appropriate time generation);
- Environment: it benefits from water savings that were used by EDF;
- Tourism: it contributes to keep the reservoir water level of Serre-Ponçon.
A second generation agreement

A new Convention is under progress, which is extended to other stakeholders such as the Water Agency and the local authorities. The concept has now been proven, so the next objective is to have a more holistic approach covering the whole Durance-Verdon river basin with stakeholders committing to implement water savings for the long term. However, what is also needed is to accelerate the potential for water savings to be made by encouraging investments that will facilitate water savings. This next step regarding new convention could rely on the following principles.

The Water Agency funds investments that will allow saving water (regulating, …) as part of a “contrat de canal” (channel contract), against 25-year commitment.

EDF pays annually to the channels based on a multi-year program of water savings (9 years) taking into account: (i) water savings already achieved, (ii) higher payment for new water savings, and (iii) indexing the payment on the electricity market.

The water savings are allocated to the Durance based on for example: (i) the benefit of water savings must be shared fairly between its way back to the milieus (or securing upstream boundaries) and to hydropower, (ii) a returned at different points of the water basin for a volume equivalent as a volume equivalent to economic recovery.

Examples: flushing to unclugged the river bed, increased of the minimum environmental flow to exceed the prescribed threshold value.

This convention is now operational since 1st January 2014. It provides new water savings of 30 million m³ in 9 years.

The energy loss evaluation method

The evaluation of energy loss is based on a method developed jointly by EDF and the Rhône-Méditerranée-Corse Water Agency, who provides part of the financing. It is a simplified method worked out to provide the reference, in negotiations between EDF and other users, on the cost to hydropower generation of new external constraints or uses.

Although this method was implemented by EDF in the Durance valley, it can be similarly applied to any electricity producer in France. The impact on energy production of any external demand before implementation can be evaluated, so that decisions can be made with full knowledge of the facts. It can be used as a basis for fair financial compensation for the hydropower producer for cases of both loss in production or simply a shift from optimal operation of the power plant to take into account other uses.

It consists in evaluating losses due to lost or shifted energy, with respect to a year divided into specific periods, and then to evaluate them on the basis of a representative price of electricity market futures.

Given the multipurpose water uses of Serre-Ponçon hydropower reservoir, requirements and constraints, EDF wanted to use water valuation to help manage the allocation of regional water resources and optimize water use not only for itself, but also for other stakeholders. The application of water valuation based on energy loss evaluation method was using taking into a combination of purposes. This included helping to: improve operations and management (through option appraisal and water use efficiency); enhance overall environmental and social considerations; and assess how much EDF should compensate the irrigators for reducing their water consumption.

The idea is to compare 2 scenarios were evaluated: one based on current water withdrawn by the irrigators and another one with XX Mm³/year of water savings. The valuation focused on the value of each m³ of water being saved under the Water Saving Convention.

The results of the valuation in the case of the convention are confidential, but in general terms it revealed how much additional value in terms of energy prices could be generated through the water saving initiatives. The results showed that in addition to simply the volume of water saved, a key benefit was the timing of the water savings because the saved water could be used to generate more electricity during peak periods of electricity demand when electricity prices are higher.

7.6.7 | The “EDF Value creation methodology”: effective benefits quantification and evaluation

EDF created the Value Creation Project for the development of a systematic assessment tool for benefit sharing around reservoirs (Branche and Schumann, 2015).

The project has four (4) objectives:

- Identification of socio-economic and environmental values created by hydropower installations as well as their spatial and temporal distribution
- Analysis of the contribution of the operator to the value creation in a given region
- Evaluation in qualitative, quantitative and, if possible, monetary terms of the created values, including non-power considerations around drinking water supply, employment creation, irrigation, tourism, navigation and flood protection
• Development of didactic ways to present values and to facilitate stakeholder engagement around the created values

In its first phase from mid-2013 to mid-2015, this project created a Methodology Guide to allow the evaluation of values linked to the uses of the water resource (drinking water, agriculture…) as well as non-water values created around hydropower (tourism, development of local transports networks or economy…). Five (5) categories for assessment were identified and applied on a number of test cases:

• Electricity services,
• Socio-economic values,
• Societal values,
• Environmental values,
• Risk management, including flood and drought.

An internal methodology working document was tested in 2014 at three sites in France (Chassezac in June 2014, Lévezou in July 2014 and Mont Cenis in August 2014). In February-March 2015 full methodology applications were undertaken at the Durance-Verdon in France and at Nam Theun 2 in Lao PDR.

The Durance-Verdon hydropower system contributes significantly to the socio-economic development of the South-East of France, providing a wide range of socio-economic benefits.
• Its storage infrastructure supports the delivery of 27% of the total drinking water supply of the PACA region. In addition, it supplies water to 91,400 hectares of irrigated land (mainly orchards, vegetables and forage crops) that support directly or indirectly around 20,000 jobs;

• Tourism also benefits directly or indirectly from water and from the way water-related infrastructure is managed (e.g. stabilizing water levels in storage lakes so recreational activities can take place, or controlling river discharges in line with requirements of kayaking or canoeing). Summer tourism alone generates around 500 M€/year of turnover and 13,630 jobs, with tourism activities being particularly important around the two lakes of Serre-Ponçon and of Sainte-Croix;

• The Durance-Verdon hydropower system helps addressing climate change challenges, avoiding the emissions of GHG that would have been emitted otherwise if other sources of energy would have been used. It is estimated that 2.1 Mt/year of CO₂ are not emitted thanks to the electricity produced by the hydropower system.

The temporal distribution of the values created around the Durance-Verdon Complex is described in the figure below.
7.6.8 | Main lessons learnt

Based on this example of Durance-Verdon valleys, it is possible to draw down some first conclusions on “the multipurpose water uses of hydropower reservoirs”. The today management of the Serre-Ponçon dam/reservoir acquired a certain maturity and demonstrates real will of the stakeholders to show solidarity in the most critical situations (droughts) in satisfaction of tourism professionals involved in the reservoir. However, nothing is set in a time when there has been a sharp rise in environmental, social and economical issues or new uses.

For the Durance-Verdon valleys in France for instance, the French law provided an excellent framework to initiate dialogue and set up appropriate governance and consultation process, and those valleys used an innovative consultation process still the 1950s. But it should be noted that this is not the case everywhere in France and for other hydropower reservoirs.

It is very important to develop a broad consultation of stakeholders on the water management in its economic, social and environmental dimensions. This will lead to share issues and build the future collectively. It is essential to have a capacity building strategy on that matter to provide visibility for the water uses satisfaction in view of the evolution of the water resource and thus prevent conflicts. In order to reach this target, it is mandatory to provide the means to build this shared future vision. The optimum is to exceed the sectorial interests of each user type (agriculture, tourism, hydropower, drinking water production, fishing, etc …) to determine a balance to be achieved based on the public interest.

It is essential to consider expectations that are sometimes paradoxical, in an evolving regulatory and legislative context in order to have a sustainable development (to ensure a large balances of economic, social and environmental issues).

However the sharing of water is complex: the overall management of this resource is equivalent to a management of contradictions as depicted in the figure below.

---

The sharing of water is complex: the overall management of this resource is equivalent to a management of contradictions

- To maintain a reservoir water level consistent with tourism activities
- To support the downstream flows for irrigation
- To turbine water in case of peak electricity demand or uncertainties in the power system
- To induce no important changes/variations to the downstream flows
- To store water in the reservoir during the summer to be used for the winter period
- A severe drought is affecting the region
- To store water for various uses (energy, drinking water, irrigation, tourism …)
- To be ready to manage a flood
- To promote water sports
- To dissatisfy fishermen

Dialogue and collective approach are essential to build-up a win-win situation and to understand the benefits of this kind of bilateral convention for both parties. It is also important to use robust and relevant data and tools to bring objective information to the negotiation table.

A key success factor of the convention between EDF and “Canaux du Vaucluse” to save water was to initially start with a moderate ambition: a limited number of stakeholders and a reasonable (i.e. achievable) target for water savings. The successes of the first conventions lead to other conventions and new stakeholders to be involved in this water saving process to have this win-win solution.

The evaluation of energy loss method allows quantifying an estimated cost, for the community, of any environmental measure or water uses affecting renewable hydropower generation. EDF has been using this approach “evaluation..."
of energy loss method” for several years and for various arrangements. It has the advantage of contributing in the rationalization of cost-benefit analysis (CBA) of any new use, by supplying the estimation of the cost. At the same time, the evaluation of benefits for other users or the community in general, must be estimated by other methods (for example willingness to pay, avoided costs, etc) in order to find the best solution for the community.

In case of changes in water uses, hydropower generators should be favorable to proposals which correspond to sustainable development, i.e. that provision of priorities between different uses are well defined and that the measures modifying economic equilibrium of the hydroelectric concession are co-financed by the interested parties. Finding the best balance between loss of renewable hydropower and optimal benefit for the environment and/or for the society must be the principal concern in negotiations between the various stakeholders.

The "water" resource is of major interest for hydropower generation but above all for economic development in the PACA region through the multiple water uses:

(i) Tourism, leisure and cultural heritage (around artificial lakes or water streams which were arranged),
(ii) Agriculture (through irrigation),
(iii) Drinking water (from reservoirs),
(iv) Industry (use of the water in the industrial process)
(v) Environment (biodiversity conservation, groundwater supply, CO2 emission avoided),
(vi) Security/safety (protection against floods, warning of flood, earthquake)
(vii) Social Cohesion (local employment, transportation & navigation, cultural association, rural habitat, etc.)

Some of these activities such as tourism, water recreation or environmental sources, which are all benefit for economic development and wealth for the territories, have emerged due to the existence of the Durance-Verdon hydropower valleys.

The Durance & Verdon valleys have reached, 50 years after their implementation, the economic development objectives that were assigned to its origins, by creating wealth in the entire region, value for all beneficiaries from an economic point of view and in terms of job creation.

7.6.9 | References

Branche E., 2014 “OECD/Brazil Policy Dialogue on Water Governance - The Durance-Verdon valleys: a model to address the multipurpose water uses of hydropower reservoirs”, France, October 2014

7.7 | Villerest (France, Europe)

The Villerest project case study was provided by Etablissement Public Loire. All information is issued by EP Loire and public information; this was compiled by Emmanuel BRANCHE (EDF).

7.7.1 | Project description

The Loire River is the longest river in France (1,020 km) stretch between its source in the Southern Massif Central and the Atlantic at Saint Nazaire. Its drainage basin (115,120 km² in area) covers one-fifth (1/5) of France.

The Villerest dam is located on the Loire upstream of Roanne, in the Loire department (42). Built following a decision of the French State and under the responsibility of the Interdepartmental Institution for the Protection of Vals de Loire against Floods, it was commissioned in 1985. This arched concrete gravity dam with a height of 59 meters is equipped with a free spillway surface, and five (5) middle distance valves and a bottom valve. It creates a reservoir of 128 Mm³ for total surface of 770 ha. The Villerest dam/reservoir has a dual function of flood control and support of hydraulic flows of the Loire River.

It is owned by Etablissement Public Loire (EPL) which is responsible for its operation. Serving 50 local communities that currently make up the EPL, it has operated for over 30 years at the coherence of actions across the Loire basin and its tributaries, for a sustainable development. EPL is the manager of structuring operations on this scale,
with inter-regional and inter-departmental characters. EPL's innovative achievements are concentrated in four (4) main areas:

- Water resource management for Naussac and Villerest dams (low flows and floods periods);
- Management and reduction of flood risk;
- Stimulating research, development and innovation;
- Water development and management.

EPL's operations are also based on the animation of a network of stakeholders and multilevel cooperation. They are part of a triple logic of solidarity, subsidiarity and economies of scale for the benefit of all partners. In law enforcement Risks of 2003, this Institution was recognized in 2006 as a Public Institution Territorial Basin on part of its intervention territory. The entity is a member of the French Association of EPTB since its inception.

The Villerest dam was commissioned in 1985. The dam was designed as a multi-purpose infrastructure from the start, however new purposes appeared after its implementation. It was aiming at:

- Flood mitigation (major floods of the Middle Loire (1846-1856-1866) are due to the combination of high floods on the Allier and Loire Rivers at Bec d’Allier. By its action on flood retention at the upstream Loire, the Villerest dam contributes significantly to reducing their impact across the Loire, while providing significant protection in Loire Burgundy);
- Water supply (domestic/ industrial);
- Irrigation/ soil leaching;
- Power pool cooling for thermal power plants;
- Hydropower (one year after the commissioning of the dam, a hydroelectric plant was commissioned and licensed by the French State to Electricité de France (EDF), adding another secondary use);
- Recreation (additional activities to those planned originally, were developed around the reservoir. These activities were not considered as part of the operation/ management of the reservoir. However, the water regulation associated with the operation of this dam was endorsed after a public inquiry took into account, to a limited extent, the constraints of these uses, particularly the maximum rating/water level in normal operation).

In addition to flood mitigation, the second main function of Villerest dam is to maintain a minimum flow in the Loire in periods of low water to allow the satisfaction of the various water uses. The Naussac dam, in the upper basin of the Allier, also owned by the EPL, performs the same function on the Allier and the Loire Rivers).

**Storage allocation**

Principles of the operation and management of the Water associated to Villerest dam are specified by the Water Regulations approved by Decree of 4 May 1983. This regulation is supplemented by the operating guidelines established under Water Regulations that have been approved by the Ministry of Environment on 24 April 1985. The water regulation defines the states of flood, flood risks, and support of low flows. It also defines the related policies for the operation of the reservoir. The regulations specify particular requirements for the water release and their variations.

**Dam safety issue**

Such dam requires annual major maintenance: for example, the resumption of sealing of valves in 2010-2011, but also maintenance of the control building, maintenance of computer guidance tools, etc. The Villerest dam is a large dam, classified “Class A” in the words of the Environmental Code (France), that is to say, subject to the strongest control regulations. Daily monitoring is ensured by the operator on the site. Each year, a detailed inspection takes place in the presence of the Departmental Directorate of Equipment and Agriculture of the Loire, responsible for the control. Finally, a further inspection and design review is conducted every ten years.

**Water quality issue**

Monitoring of water quality is performed each year. The results are available on the website of the EPL. To address the problem of eutrophication, affecting many bodies of water or rivers, measures to reduce phosphorus inputs, from fertilizers, domestic and industrial effluents and natural inflows, are undertaken. The EPL supports awareness campaigns in the department of the Loire, to reduce the use of phosphates.

**7.7.2 | Different operation modes according to natural conditions**

The dam management/operation principle is to control the out-flows by opening more or less the mobile dam gates, based on anticipated flow rates and observed inflows at the entrance of the reservoir. There are four main operation situations: 1) in normal operation, 2) during low water period, 3) during flood risk period, and 4) during flood period.
1) **In normal operation** (i.e. excluding periods of flood risk, flood and low flows as defined in the Water Regulation) the reservoir is operated as described below.

The dam is operated with a maximum level, which varies according to the period of the year, and a water fluctuation of 50 cm if inflows are enough, while respecting:

- Maintaining a minimum flow of 12 m$^3$/s downstream the dam,
- Variations of the downstream permitted flows,
- The outflow cannot exceed 1000 m$^3$/s.

The maximum level (ZN) is defined by the operating diagram below:

![Operating diagram](image_url)

**Responsibilities of the dam manager and powerhouse manager:**

The water regulation of Villerest dam (instructions Operation-Article I.2) provides that the detailed definition of the outflow in normal times, outside of transitions maximum level specified in the operating plan, are subject to the approval of the department responsible for the water police. The outflow of the dam can be restored either by the dam devices (valves of middle distance, bottom valve or valve for low flow rates) or by the turbines of the hydroelectric plant granted to EDF. The determination of the value of the outflow can be operated either by the control system of the dam: it is the so-called “dam mode” (water can be discharged by the valves or through the turbines of the plant), or directly by the manager of the powerhouse: it is now the so-called “powerhouse mode” (water being discharged from the powerhouse). The Decree awarding the power-plant provides the approval of a specific set of rules establishing the coordination between the plant and the dam, and thus the division of responsibilities between the dam manager and the powerhouse manager. The Etablissement public Loire (EPL) requested that this order has been established, which to date has not yet been done. These 2 operation modes are described below:
• Operation in « dam mode »

Operation is managed in automatic mode on-site or in manual mode in case of controller failure. The principle of operation, excluding flood, low water periods and out water rating changes, is the transparency (i.e. outflow = inflow). As the strict application of this principle is not desirable, since it would result in an impact on the downstream fluctuations flows related to the operation Grangent, it was admitted a limited daily of 50 cm level fluctuations. The algorithm at stable water level, is to maintain a level at the dam below the maximum allowed water levels at the dam, while respecting:

→ A minimum water level, corresponding to an authorized water fluctuation of 50 cm below the maximum level,

→ A minimum flow of 12 m$^3$/s downstream dam.

It is designed to reduce as far as possible, the artificial variations come from upstream. The inflow which serves as input data is evaluated from the change in rating and average outflow on different time intervals. The time step depends on the selected flow rate value. At low flow rates, long time is favoured to smooth actual inflow changes and uncertainties related to the water level. The time step is progressively reduced as the flow rate increases in order to account for flow variations associated with a peak of water.

• Operation in «Powerhouse mode»: in this mode, the plant operator determines the set of total outflows. The guiding principle is to optimize energy production by placing turbining hours during peak consumption, while respecting the water fluctuation and the maximum water level (i.e. operation under constraints). An exchange of information takes place between the dam manager and the powerhouse manager, to switch from one to the other mode. To enter the powerhouse mode, a dialogue is established between the dam PLC and the powerhouse using the following protocol:

→ The operator of the power-plant must apply for the passage to powerhouse mode
→ The operator of the dam allows the passage in powerhouse mode,
→ The operator of the powerhouse sets the turbine inflow.

The way-out of the powerhouse mode is made either by the powerhouse/dam manual application or automatically if:

If the water level is closed to water fluctuation (rating below the minimum water level or rating higher than the maximum water level - 5 cm),

If a group becomes unavailable.

2) During low water period: this period may extend from June to November, the dam provides support for low flows of the Loire river, guaranteeing an average daily minimum flow of 12 m$^3$/s immediately downstream and contributing to ensure with the Naussac dam the objective to Gien.

The objectives of flows on the Loire and Allier rivers are set by the regulations of water in line with the SDAGEs. In case of severe drought, the Reservoir Management Committee of Naussac and Villerest and severe low flows of the Loire-Bretagne basin, chaired by the Prefect Coordinator of the Loire-Bretagne Basin, may decide to reduce the targeted flows.

The outflow target is set by EPL from the Orleans headquarters on a daily basis and transmitted on-site for application. The discharge is calculated using dedicated software for decision support (LOLLA). The data are issued by observed daily mean discharges, the observed and predicted rain and water levels to Villerest and Naussac dams. It then predicts non-influenced different points until $T_p + J$ where $J$ represents the day of operation and where $T_p$ is the propagation time of the water discharge to reach the station in question.

3) During flood risk period: there is a risk of flooding in the following cases (according to the French water regulation):

→ Throughout the months of May and from September 15th to November 30th,

→ When the competent operator notices on the upper basin of the Loire of more than 50 mm rainfall in height in less than 24 hours on one rainfall positions in the system of flood forecasting at the entrance to the dam reservoir Villerest,

→ When the flow of the Loire river above the threshold of 350 m$^3$/s in Bas en Basset or at the entrance of the Grangent reservoir.
The on-site dam operator is alerted by the forecaster of the EPL from Orleans, who tells him the operating rules. The reservoir is managed:

- A constant water level if the dam rating is below ZX when the declaration of flood risk is set (ZX = 304 m asl from September 15th to November 30th, 314 the rest of the year)
- By lowering the reservoir level to a reference level ZX, if the dam rating is above 314 m asl at the time of the call.

4) During flood period: The principle of Villerest dam operation is to control flood in the outflow by opening more or less mobile floodgates, according to the flows predicted and observed at the entrance of the reservoir. Thus, at the height of the flood, the outflow is less than the inflow, which reduces the maximum levels that would have been achieved downstream.

There is a flood state as soon as 1000 m$^3$/s are expected or observed at the entrance of the reservoir. The flood state ends, after passing the maximum flood period, when the reservoir level dropped to normal operating level. The on-site operator is alerted by the forecaster of the EPL in Orleans. During the flood duration period, which can reach six (6) days, the operator shall apply outflow targets that are developed in Orleans and sent for application to the site every hour for the next four (4) hours ahead.

The development of the guidelines requires to firstly perform a forecast upstream of the reservoir. This forecast cannot be performed automatically. It requires the intervention of a “forecaster” and the use of dedicated software. The software currently called Garhy incorporate the forecast and operation processes. The sequence used is the following modules:

1. Data validation

Data (rainfall, flow, water levels reservoir & dam) is transmitted every hour by the CRISTAL system to the application. The forecaster checks the consistency of data transmitted, possibly corrects it and validates it for the next calculations.

2. Water inflow forecast upstream the dam

Water flow forecasts of the Loire river to the entrance of the Villerest river are calculated using a specific model that incorporates possible station failures. It operates from data collected in real time by the CRISTAL network, previously validated by the forecaster. It provides forecast flows into the reservoir with a maximum of 18 hours in advance. It consists of a series of rainfall-runoff models and propagation models in the river. The incoming hydrograph is then extrapolated following a flood “type” established from historical floods to have sufficient maturity (about 48 hours).

3. Module of the flow calculation to be released by the dam

Using a flow simulation model in the reservoir, the flow values to be released by the dam are evaluated so as to minimize the peak flow of the flood without exceeding the maximum permissible rating by the Water Regulation of the dam. The model uses the equations of Barre de Saint Venant and was designed and configured specifically for a real time operation.

4. Decision flowcharts

Many situations may occur during the flood management period: increased stored water volume of the reservoir by water release before the arrival of the flood, taking into account a possible flood downstream in the Morvan, a risk probability of a new flood after the first. In addition, care must be taken to limit the variation in outflows on the one hand for the safety of residents of the downstream area and also to reflect the operating constraints of the navigation dam downstream from Roanne owned by Voies Navigables de France (VNF). All these cases are identified and organized in predefined flowcharts decision. In case of failure of the upstream forecast model and flow model, operators use a back-up model for having a reduced capping by half compared to the whole system.
The principles of flood control at Villerest dam

During the flood period, the water level at the dam should not exceed the values laid down in the French water regulation, which depend on the maximum inflows. The higher the flood is, the greater the maximum permitted level is. These values were set in order not to exceed and deteriorate the water level upstream. Schematically, dam management during such flood period is operated in 3 periods:

1. **1st period: Preventive destocking**
   Preventive destocking occurs when a flood of a higher intensity than 1,000 m$^3$/s is provided at the inlet of the reservoir (Feurs). This is followed by a destocking up to 1000 m$^3$/s, not harmful to the downstream flow.

2. **2nd period: flood control**
   When planning the maximum rate of the flood, we calculate the rate capping, which will alleviate the tip of the flood. The objective is to make best use the volume of the dam.

3. **3rd period: return to normal level**
   This period corresponds to a destocking to return to normal operating condition.

Theoretical effects of Villerest dam on floods are described below:

- The dam does not intervene in flood lower to 1,000 m$^3$/s,
- It halved the autumn floods below 4000 m$^3$/s,
- It lowers by 2,000 m$^3$/s throughput autumn floods exceeding 4000 m$^3$/s.

**7.7.3 | Shared responsibilities of stakeholders based on economy**

The management and financing of the dam and the powerhouse are two (2) distinct entities. The financing of the dam construction was provided by the French State and the Water Agency, with a small participation of the minority stakeholder community. The financing of the powerhouse construction was provided by EDF.

**Financing of the infrastructures**

The decision to build the dam was made based on several studies. Regarding flood management, a study of economic interest was performed. This study included an estimate of the project cost and an assessment of the damage costs with and without the dam. Regarding low flows, the estimate of the required reservoir volume was made from consumption estimates of: i) domestic supply need, ii) operation of nuclear power plants need (on the basis of a program of 14 new units of the nuclear program), and irrigation need. Commissioning of nuclear power plants (12 generation units on the average Loire River) was related to the construction of the Naussac dam and Villerest dam. The drinking and agricultural water uses are also heavily impacted during dry years. However this economic cost is not quantified.

**Economic aspects during operation: a clear distinction among bodies**

- For the dam, the inter-prefectoral Order of November 10th 2006 authorized the EPL to ask water users of the Loire and Allier rivers to pay for the operation, maintenance and support of low flows management. This involvement takes the form of a fee-for-service, introduced on January 1st 2007, which is to be paid by users taking water from all reservoirs to Nantes city. All of these expenses are subject to a specific budget, separate from the main budget of the EPL. The revenue of the budget are paid: (i) by the low flow support users, via a fee for expenses related to low water, and (ii) the members of the local communities which are EPL members for expenses related to flood management. Income generated by the fee cover 100% of Naussac expenses (dam and powerhouse),
80% of Villerest dam expenditures and 20% of expenses related to oversight of the management of high and low flows.

- For the powerhouse, the revenues and expenses related to Villerest power plant are exclusively provided by EDF, for which the plant is licensed by the French State until 2060.

**The different stakeholders and governance issues: a transparent and participative process**

The EPL is the owner of the Villerest dam (flood control and low water support) and Naussac dam (periods of low flow). They are responsible for their management. Local operation of the dam is managed, on behalf of the EPL, by BRL an exploitation company under service contracts. Instructions for reservoir releases are determined by forecasters of the EPL.

The French State provides data measurement of the CRYSTAL network used by EPL to set input data to the software used to operate the system. Data provision is subject to an agreement. It also ensures the application police of water regulation, and it provides security control police of the dam. The Steering management is performed in Orleans flooded by forecasters Institution in low water, the DREAL Centre (Directions Régionales de l’Environnement, de l’Aménagement et du Logement, representant of the French State in region). In the context of financial agreements, the DREAL Centre provides logistical support to the establishment and provides network data CRYSTAL necessary for the management of the works. Control of operating the facilities is provided by the State: Prefect of the Lozère for Naussac and Prefect of the Loire for Villerest.

EDF is the owner of the license of the hydropower plant. Decree November 5th 1984 on the organization and operation of the Villerest water, set the license to EDF until 2060.

The dam priorities and operation principles in flood period are fully defined in the French Water Regulation, a State-approved procedure after a public inquiry.

For low flow period, the objectives of the Loire and Allier rivers are set by the water regulations in line with the SDAGEs (Schéma directeur d’aménagement et de gestion des eaux, RBMPs). In case of severe drought, the reservoir Management Committee of Naussac and Villerest reservoirs and severe low flows of the Loire-Bretagne basin, chaired by the Prefect Coordinator Loire-Bretagne, may decide to reduce these targeted flows.

**7.7.4 | Main lessons learnt**

The French law provided an excellent framework to initiate dialogue and set up appropriate governance and consultation process, and those valleys used an innovative consultation process.

Hydropower was added one year after the commissioning of the dam.

The reservoir priorities and operation principles in flood period and low flow period are fully defined in the Water Regulation or through River Basin Management Plans (RBMPs).

**7.7.5 | References**


EPTB Loire, 2014 “Cadre pour solliciter des études de cas des pays partie prenante – Villerest”, Hélène Xhaard, 7 mai 2014

7.8 | Kandadji (Niger, Africa)

Kandadji project case study was provided by the World Bank Group. All information is issued from the World Bank Group; this was compiled by Emmanuel BRANCHE (EDF).

### 7.8.1 | Project description

The Kandadji project combines large-scale hydropower with livelihoods development and irrigation in a vulnerable and insecure part of the Sahel region. One of the major challenges is to leverage sufficient concessional financing (hydropower aside, many of the benefits such as irrigation mostly do not generate sufficiently attractive returns for the private sector). The World Bank finances 25% of the total Kandadji Program cost with the remaining costs financed through a combination of co-financing from 10 different development partners and counterpart financing from the Government of Niger. The need to effectively coordinate a large number of financiers adds an extra layer of complexity to an already challenging project.

The Kandadji Project is located on the main Niger River in Niger, about 60 km downstream from the Mali border, 187 km upstream from Niamey, the capital of Niger. The project includes the multipurpose Kandadji Dam, a 26 m high embankment dam with a crest length of nearly 8 km which creates a reservoir of about 1.6 M m$^3$, designed to (i) produce 629 GWh annually (ii) irrigate an area of 45,000 hectares and (iii) guarantee a minimum release of 120 m$^3$/s at Niamey for water supply and

#### Identity Card
- **Type:** Basin / project
- **Status:** preparation/operation
- **Purposes:**
  - Hydropower
  - Flood control
  - Water supply
  - Irrigation
  - Fisheries
  - Recreation
  - Navigation
  - Water flow management

#### SHARE topics
- **Sustainability approach**
- **Higher efficiency**
- **Adaptability for solutions**
- **River basin perspectives**
- **Engaging stakeholders**
ecological restoration. The 130 MW powerhouse is located at the toe of a concrete block on the right bank of the river, which also hosts the spillway and appurtenant structures. The Government of Niger established the High Commission for the Development of the Niger Valley (HCDNV) in 2002 with the mandate to implement the Kandadji Program. The total investment cost of the Kandadji Program is US$ 1.05 billion (2014 prices). Construction of the dam, which commenced in 2012, is stalled following the cancellation of the civil works contract due to poor performance. Construction is due to resume in early 2016, once strengthened project implementation arrangements are in place (including a remove reinforced new supervising engineer and extensive technical assistance (TA) support for the implementing agency). As such, dam civil works are now expected to be completed in 2020.

The Kandadji Project has been studied since 1976, initially with a design focus on national hydropower benefits with no regard to regional impacts and benefits. In the mid-1990s, after repeated and extensive droughts and extreme low flows in the Niger River that had severely constrained agriculture, worsened food security, and disrupted domestic and livestock water supply, the studies focused on optimizing the multiple project benefits from a regional perspective. These were coordinated by the Niger Basin Authority (NBA). The NBA is an intergovernmental organisation in West Africa aiming to foster co-operation in managing and developing the resources of the basin of the River Niger. Nine (9) nations which include part of the Niger Basin are members: Benin, Burkina Faso, Cameroon, Chad, Côte d'Ivoire, Guinea, Mali, Niger and Nigeria. The Kandadji dam’s multipurpose potential fully took shape in the context of discussions, starting in 2002, around the Niger Basin Long-Term Shared Vision Process supported by the World Bank jointly with other development partners. This process led to a Niger Basin Sustainable Development Action Plan (2007) which optimized national programs such as Kandadji at the regional level. This optimization involved, among other things, designing an economically attractive Program for Niger and the other riparian countries while limiting the regional impacts. It ensured that activities are sized appropriately to the limited water resources available at the Basin level. Ultimately, in 2008, this process culminated in the Niger Basin Investment Program where Kandadji dam was selected as one of the 3 priority regional investment infrastructures for the basin (the other two being the upstream reservoirs of Fomi and Taoussa).

The project will be funded through concessional financing. Indeed, one of the major challenges is that, hydropower aside, many of the benefits (including irrigation) are not attractive to the private sector. The total investment cost of the Kandadji Program includes: (i) US$ 330 million for the construction of the Kandadji dam and associated civil works; (ii) US$ 260 million for the equipment and installation of the power plant; (iii) US$ 117 million for the transmission lines and road deviation (iv) US$ 170 million for local development initiatives (including 6,000 hectares of irrigation development); (v) US$ 160 million for environmental and social mitigation measures (including resettlement of about 38,000 people); and US$ 3 million for regional supervision by the NBA. The World Bank finances 25% of the total Kandadji
Program cost with the remaining costs financed through a combination of co-financing from 10 different development partners and counterpart financing from the Government of Niger. The importance of adequate coordination between all stakeholders has been repeatedly identified as a critical component for success in complex, multi-sector projects that involve multiple stakeholders. For this reason, continuing support for capacity development of the HCDNV and NBA remains a key focus of the proposed project.

7.8.2 | Main challenges

During its history, the Kandadji Project has undergone several design modifications and updates. One of the major changes was the shift from a national-based design to a regional-based design. A larger reservoir would enhance hydropower production and national benefits (i.e. irrigation, water supply, etc.), but increase trans-boundary impacts, such as an increased level of resettlement, notably in Mali, and reduced hydropower production in Nigeria. Following the regional approach, the water storage was significantly scaled down from more than 10 billion cubic meters to about 1.56 billion cubic meters. The reservoir capacity for the Kandadji Project has been optimized on the basis of storage capacity, power production, irrigation development, and environmental and social impacts. Different full supply levels were tested from 226 meter above mean sea level (m a.s.l.) to 230 m a.s.l.. The optimal level was eventually selected at 228 m a.s.l. based on energy production of more than 600 GWh, resettlement of about 38,000 people, securing water for 45,000 hectares of irrigation, and ensuring a minimum low flow during the dry season of 120 m$^3$/s at Niamey (for livestock, water supply, fishery and navigation) and 80 m$^3$/s at the Niger/Benin/Nigeria border (for downstream water use).

The importance of adequate coordination among all riparians – nine (9) countries in the case of Kandadji – has been repeatedly identified as a critical component for success in complex, multi-sector projects in trans-boundary river basins. For over a decade, the Niger Basin Authority (NBA) has been engaged in an extensive shared visioning process with riparian countries to optimize the construction of major water infrastructure in the basin. This culminated with the Niger Basin Sustainable Development Action Plan and Investment Program, where the Kandadji project was endorsed by the 9 Heads of State as one
of 3 priority multipurpose projects in the Basin. Through this basin-wide lens, the design of Kandadji dam was revised, reducing reservoir size to minimize upstream and downstream impacts, while maximizing national level non-hydropower benefits.

Concerns from downstream countries (notably Nigeria) were partially overcome through continued basin level dialogue under the auspices of the NBA. New institutional frameworks are being established under the auspices of the Niger Basin Authority, including the Niger Basin Water Charter endorsed in 2010 (with its Annex 2 regarding the coordinated management of dams currently under preparation) as an essential part of this necessarily adaptive basin-wide, multi-sectoral approach.

For Niger, reduced sizing/hydropower revenues were well compensated by the fact that focus on non-hydropower benefits, with large emphasis on irrigation and the creation of an agro-business growth pole can ultimately scale up the local development of affected communities around the Kandadji infrastructures. If parallel infrastructure development is supported by all riparian populations, another major advantage is enhanced ability to attract major concessionary financing from IFIs. Where alternative financing options are limited, this is a major plus point.

Other technical challenges remain, and will continue to require a highly adaptive and flexible management approach, at the national and basin level. For instance, recent topographic lidar data indicate that the reservoir tail reaches further into Mali than initially envisaged, while the overall reservoir storage capacity is 40% lower than originally estimated (from 1.6 to 1 billion cubic meters). Both results may have implications for dam design, operating rules and overall cost and benefits — and will require careful consideration by the new supervising engineer in the context of the forthcoming review and finalization of the overall dam design, within continued oversight by the Niger Basin Authority.

New institutional frameworks being established under the auspices of the Niger Basin Authority (such as the Annex 2 of the Niger Water Charter under preparation regarding the coordinated management of dams) become an essential part of this necessarily adaptive basin-wide, multi-sectoral approach – particularly during the post-construction phase (i.e. operational phase).

7.8.3 | Economic and financial issues

The Kandadji Multipurpose Project will ultimately generate the following benefits: (i) more reliable flows of water for downstream irrigation development, livestock, water supply for Niamey, and for environmental flow regeneration; and (ii) additional power supply in Niger and to the West African Power Pool (WAPP).

Niger had traditionally relied upon (attractively priced) power imports from Nigeria (currently for about 80% of its consumption). However, in recent years, due to growing domestic demand and constraints on availability of Nigerian power, Niger has increasingly had to turn to significantly more costly thermal plants and private/industrial generators to meet short-term needs. In this context hydro represents a very cost effective option if compared to existing power production tariffs of the thermal option (0.11 US$/kWh) or diesel option (0.19 US$/kWh). For the purpose of the economic analysis the value of Kandadji supply has been set equal to the current weighted average tariff of 0.15 US$/kWh. This in no way reflects a presumption that the current tariff design is itself economically efficient; however, power purchases currently are made at this rate, and it is presumed that unmet demand would pay at least as much.

The original economic analysis conducted in 2012 sought to highlight the benefits of a multi-sectoral approach (comparing returns for stand-alone hydro versus multipurpose), while acknowledging the potential upstream and downstream impacts, and the need for climate resilient infrastructure. It assumed that (i) construction of the dam and powerhouse takes 6 years with the power station on line by mid of last year of construction, (ii) the discount rate is 12% and (iii) the period for the analysis is 35 years. The Economic Internal Rate of Return (EIRR) of Kandadji Program considered as a stand-alone multi-sectoral project was 16% and dropped to 14.6% when the impact of the water abstraction (due to irrigation, water supply and reservoir evaporation at Kandadji) on the hydro generation in Nigeria of the downstream Kainji and Jebba dams is considered. The EIRR further reduced to 13.5% when the impacts of the two large reservoirs of Fomi (Guinea) and Taoussa (Mali) with associated irrigation schemes are taken into account. The Kandadji Program was therefore found to be economically attractive as a standalone project as well as under the scenarios that include other upstream and downstream multipurpose investments. Given the numerous potential uncertainties affecting both costs and benefits, sensitivity analyses were also conducted around a wide range of scenarios, including cost overruns and runoff variations due to climate changes. Importantly, results showed that the project economic viability was sufficiently robust as to withstand potential future shocks during construction or operation phase.

Indeed, following the subsequent cancellation of the dam civil works contractor in 2013 (and the ensuing significant project cost and time delay increases), the economic analysis was re-run, and still found to be viable, under all but the most unfavourable assumptions.
7.8.4 | The main management issues

The overall post-construction management arrangements for Kandadji HPP are not yet finalized (a review of management options is currently being commissioned, to be financed under the project). The institutional arrangements will need to cover three (3) distinct aspects: (i) the management of the assets “Gestion de patrimoine” (including the power plant and dam infrastructure assets and associated financial obligations); (ii) the multi-sectoral management of reservoir releases (at the national and regional level) and (iii) the operation of the Kandadji HPP and dam (including the possible involvement of private sector).

An independent operator will most likely be in charge of operating and maintaining the project. NIGELEC is the Nigerien main commercial operator present in all segments of the electricity sector. The power generated directly by the Kandadji HPP will be sold to the existing customers of NIGELEC. It is assumed that NIGELEC will bear the costs of the transmission line and the substation in Niamey. Revenue from the charges will allow NIGELEC to service the debt for financing these components. The independent operator will be able to operate the hydropower plant, the dam and other project components under its responsibility without the need for external or international financial support. The difference between direct revenues and direct expenditures shall be allocated to various purposes, such as debt repayment, creation of a fund for future major overhaul of electromechanical equipment, routine financing of a “local development fund” aimed to offer continued support to local communities. Striking the right balance in the use of available financing among multiple alternatives is one of the key missions of the study financed by this project.

Kandadji case study testifies how the ability to reframe national infrastructures within regional context is critical for strengthening / optimizing non-hydropower benefits and ultimately the project viability (reduced opposition from affected communities, increased availability of concessional financing, etc.). However, transboundary, multistectoral infrastructure is also inherently complex – and necessitates a highly adaptive management approach (and the institutional framework to do so) to address evolving knowledge and on the ground-realities, throughout the construction and operation phases.

7.8.5 | Main lessons learnt

The importance of adequate coordination among all riparian countries – nine (9) countries in the case of Kandadji – has been repeatedly identified as a critical component for success in complex, multi-sector projects in trans-boundary river basins.

The main difficulties for the Kandadji Program occurred since the decision on the design and financing of different parts (dam for flow control and irrigation, and the power plant) was taken at different occasions. The poor performances of the first dam civil contractor further complicated the situation. Based on those two issues, the main lesson learnt for a multipurpose water reservoirs were: i) Do all study and stakeholder negotiations and don’t prepare designs and contracts until all have agreed on scope; and ii) Prepare good contract documents and specifications, select a contractor who is experienced and capable and provides a realistic bid and supervise the work with skilled and experienced engineers.

The design of the project was optimised at basin level to maximise multi-sector benefits while minimising downstream impacts.

The development of multi-purpose dams are challenging since often some of the intended benefit streams do not necessarily provide sufficiently attractive economic and financial rates of return to ensure repayment of commercial loans or to generate private sector interest. In Kandadji this was overcome by developing the project as a public project with broad political will to include irrigation and flow control for livelihood improvements although this did not change the EIRR much. There are large numbers of donors to secure the sufficient concessional financing.

This project is associated with ambitious large scale resettlement.

7.8.6 | References

NBA, 2015 http://www.abn.ne/

World Bank, 2015 “Kandadji case study”, Rikard Liden, 15th January 2015
7.9 | Lom Pangar (Cameroun, Africa)

The Lom Pangar project case study was provided by Agence Française de Développement (AFD), World Bank document and EDF. All information is issued by public information; it was compiled by Emmanuel BRANCHE (EDF).

7.9.1 | Project description

Cameroon has installed electric generation capacity of around 932 megawatts (MW), of which 721 MW (77%) is hydroelectric, the remainder installed capacity is expensive thermal grid (HFO, diesel) as well as isolated power generation. The average electricity access rate is around 48%, but much lower in rural areas (14%).

Although Cameroon possesses immense hydropower potential (12,000 MW), power outages and the high cost of electricity have reduced GDP growth by 1 to 2% per year, according to World Bank estimates. The number of households connected to the power grid remains very low—less than 14% in rural areas, and 57% in urban areas. Cameroon possesses tremendous hydropower potential with the Sanaga River Basin alone representing half of this untapped potential. The construction of the Lom Pangar hydropower dam is aimed at boosting Cameroon’s electricity generation capacity and reducing seasonal fluctuations of water flow in the Sanaga River. By considerably increasing the supply of electricity to the Cameroonian households and businesses, the project will stimulate the country’s economic development.
An important step in developing Cameroon's largely unexploited hydropower potential is the construction of a regulating dam at the Lom Pangar site in the Sanaga river basin. The regulating dam will increase the guaranteed all-season hydropower capacity on the Sanaga River by approximately 40 percent. The Lom Pangar project is under construction, its main purposes are power generation and flow regulation. The partial filling of the dam is scheduled for August 2015 and completion in June 2016.

The Ministry of Energy and Water of Cameroun (MINEE) is responsible for the development and implementation of energy policy and sectoral planning. The privatization of the National Electricity Company (Sonel) in 2001 led to the creation of AES Sonel which is now called ENEO, the public service concessionaire electricity (generation, transmission and distribution) until 2021. The company Electricity Development Corporation (EDC), founded in 2006 by decree Presidential, was specially created to develop Lom Pangar. Its scope of activities includes the construction and operation of the reservoir dam at Lom Pangar and operating the three control structures existing on the Sanaga now operated by AES Sonel.

The construction of the Lom Pangar dam is intended to tackle chronic energy shortages by boosting hydropower production in Cameroon and reducing seasonal fluctuations of water flow in the Sanaga River. It will also store water during the rainy season and release it during the dry season, thus increasing the hydropower generation capacity of the Sanaga River by roughly 40% per year. Built on the Lom river in eastern Cameroon—roughly 4 kilometers downstream from the confluence with the Pangar River, and 13 kilometers upstream from the confluence with the Sanaga River—this regulating dam will also lead to a 120 MW increase in the permanent production capacity of two existing power plants, Edea (264 MW) and Song Loulou (384 MW).
The creation of the Deng Deng national park located near the project site is designed to avoid conversion of critical natural habitat of large primates. The resettlement action plan and rural development plan, drawn up to manage the resettlement of project-affected people, have taken account of the livelihoods and living standards of both farmers and pastoralists. The figure below presents the hydropower development of the Sanaga river downstream Lom Pangar.

### 7.9.2 | A public good to attract future private downstream projects

The financing of the project is interesting. The total cost of the project is $US 494 million, with a total Cofinancing of US$ 362 million and a total Bank Financing.

The financing source is described in the table below (source World Bank, 2012):

| BORROWER/RECIPIENT Pre-financing (associated infrastructure) | 101.00 |
| BORROWER/RECIPIENT | 98.00 |
| IDA: New | 115.75 |
| IDA: Recommitted | 16.25 |
| Others | 29.00 |
| African Development Bank (AfDB) | 29.00 |
| European Investment Bank (EIB) | 40.00 |
| French Agency for Development (AFD) | 79.00 |
| Central African States Development Bank (BDEAC) | 15.00 |
| Total | 494.00 |

The project development objective of the proposed Lom Pangar Hydropower Project is to increase hydropower generation capacity and reduce seasonal variability of water flow in the Sanaga River and to increase access to electricity. The project is divided in 4 main components, as described below:

| Component 1: Lom Pangar Regulating Dam | US$ 216 million |
| Component 2: Lom Pangar Power Plant and Transmission Line | US$ 62 million |
| Component 3: Environmental and Social Measures | US$ 73 million |
| Component 4: Technical Assistance and Project Management | US$ 42 million |

An important step in developing Cameroon’s largely unexploited hydropower potential is the construction of a regulating dam at the Lom Pangar site in the Sanaga river basin. The regulating dam will increase the guaranteed all-season hydropower capacity on the Sanaga River by approximately 40 percent. This will immediately translate into the addition of 120 MW at existing downstream hydropower plants as they will also generate electricity in the dry season. In the medium-term, the Lom Pangar dam will allow for further downstream development of large scale hydropower plants by ensuring firm all-season water flows. In this respect, the project is a typical public good. In addition, the Lom Pangar Hydropower Project powerhouse will generate 30 MW of electricity and will provide first time electricity services to over 2,400 rural households and improve reliability of supply to about 22,000 households in the Eastern Grid.

### 7.9.3 | A “water fee” to finance the Sanaga flow control

The Government of Cameroon (GoC) is in the final stages of introducing a water tariff for hydropower producers on the Sanaga River. The 2011 Electricity Law stipulates that the water tariff is defined through secondary legislation. The GoC has adopted a decree in 2012 (Decree 2012/0506/PM dated 22 February 2012) that sets the rules at the national level and has developed a final draft of an “arrêté”
(i.e. order) that defines the formula to recover the investment and operating costs of the Lom Pangar regulating dam as well as the three existing regulating dams on the Sanaga (those 3 existing regulating dams at Mapé, Bamendjin, and Mbakaou are currently operated by AES-SONEL, but the concession contract foresees them being transferred back to the GoC to be operated by EDC) before the Lom Pangar regulating dam is fully commissioned).

It is estimated that EDC will collect about US$ 29 million per year from water tariffs from the two existing downstream hydropower plants (265 MW generation at Edea and 384 MW generation at Song Loulou) and the 30 MW Lom Pangar power plant. Annual revenues will increase as more hydropower plants are developed on the Sanaga River. Such revenues will fully cover the investment and O&M costs of the Lom Pangar regulating dam (including the recurrent costs of the Deng Deng National Park) as well as the management of the river basin. The final drafts of the water tariff decree and arrêté were transmitted to the World Bank by the Prime Minister’s office on 20 February 2012. Signature of the decree and the arrêté is an effectiveness condition.

The Water fee, Decree and Arrêté for the Sanaga River

This is a payment for water fees by plant operators (users) who will benefit from the “service” of regulating the flows of the Sanaga thanks to storage capacity of the Lom Pangar reservoir. This fixed fee is proportional to the rated power of the hydropower plants downstream of the Lom Pangar dam (i.e. the installed capacity). These gains are significant and justify the introduction of this fee. It should be noted that this is the State of Cameroon who “advances” the funds for the completion of the work, but the real funding is ensured by the operators who benefit from this regulating capacity. All stakeholders closely involved in the studies for and drafting of those water fees elements.

Article 15(2) of the 2011 Electricity Law specifies that the level, modalities, and distribution of water tariff will be established through a decree. In addition, the 1998 Water Law stipulates that the use of water for industrial and commercial purposes requires prior authorization and payment of a fee to finance sustainable water development projects. A working group, chaired by MINEE and including EDC, ARSEL (Agence de Régulation du Secteur d’Electricité, i.e. the Electricity Sector Regulatory Agency), and MINFI (Ministry of Finance), prepared a decree with general principles applicable at the national level and an arrêté with specific rate and conditions applicable for the Sanaga River. After consultations with current and future hydropower producers in the Sanaga basin, draft decree and the PM has signed the decree and the PM’s office finalized the draft arrêté.

The decree establishes the nation-wide principles of the water tariff:

- The tariff recovers investment and operation and maintenance (O&M) costs of regulating dams as well as costs related to basin management.
- The water fee is non-discriminatory, so all hydropower producers are treated equal.
- The water fee is calculated based on the installed capacity of each hydropower plant (in MW).
- Water fees are administered by the GoC’s asset holding company for the energy sector (EDC).
- Water fees are to be paid semi-annually. In case of late payment, users pay a penalty.

The arrêté defines the specific water tariff in the Sanaga basin (7 August 2012 (MINEE and MINFI):

- The water fee recovers investment and O&M costs of the Lom Pangar regulating dam (including the recurrent costs of the Deng Deng National Park) as well as the management of the river basin,
- The water fee also recovers O&M costs of the regulating dams at Mapé, Bamendjin, and Mbakaou after the transfer of operation of the dams from the current operator (AES-SONEL) to EDC, as well as the costs associated with this transfer,
- The water fee will be applied to existing plants whose firm generation capacity will be boosted as a result of the LPHP (Edea and Song Loulou) and to new downstream generation capacity that will be developed, including the power plant at Lom Pangar itself,
- Water fees are paid to EDC. Tariffs are due from the first year the Lom Pangar regulating dam is in operation,
- The water fee is calculated to ensure EDC can cover debt service and operational expenditure in any given year,
- The part of the water fee representing O&M is indexed to inflation,
- The tariff is set at 14,960,000 FCFA/MW.
The creation of the Sanaga basin commission: essential for sustainable development

The Lom Pangar Project is at the heart of the process of institutionalizing a River Basin Commission for the Sanaga River Basin: the Sanaga Basin Commission. AFD is providing technical assistance for its implementation.

The overall objective of the establishment of an Integrated Management Framework of Water Resources (IWRM) in the Sanaga basin is the sustainable development of the basin for the benefit of its people and more generally for the benefit of Cameroon as a whole. Issues related to the implementation of this framework are considerable, especially for the energy sector. Cameroon is indeed facing an electricity shortage for several years, in contrast to the country’s vast hydroelectric potential. Most of the hydroelectric potential of Cameroon is located in the basin of Sanaga, both in terms of production (53% of the power potential) and control/regulation.

Main lessons learnt

An important step in developing Cameroon’s largely unexploited hydropower potential is the construction of a regulating dam at the Lom Pangar site in the Sanaga river basin. The regulating dam will increase the guaranteed all-season hydropower capacity on the Sanaga River. The Lom Pangar dam will allow for further downstream development of large scale hydropower plants by ensuring firm all-season water flows. In this respect, the project is a typical public good. The potential hydropower sites downstream of Lom Pangar are among the most attractive power assets in Cameroon.

An additional key element of the Lom Pangar HPP is the introduction of payment for water fees by the users of the water of the Sanaga river (currently only 2 existing ones, but, over time, it is anticipated, other hydropower producers as this regulating dam may attract private developers and investors). This water fee mechanism, that is being put in place makes all hydropower producers pay for the investment and recurrent costs of the Lom Pangar regulating dam and other regulating dams in the basin, was developed among all main stakeholders on a cooperative and consultative approach, and a closely dialogue. The water is paying the water.

Hydropower projects bring significant direct and indirect development benefits at the national and local level. Integrated project development in the context of a national, regional and communal development plan is important to maximize development benefits beyond project-level risk mitigation. Good dams require good governance.

The Sanaga basin commission, IWRM approach, will thus play a key role for the sustainable development of the Sanaga river in Cameroun.

References


7.10 | Pancheshwar (Nepal – India, Asia)

The Pancheshwar multipurpose project case study was provided by EDF. All information is in the public domain and was compiled by Emmanuel BRANCHE (EDF).

7.10.1 | Project description

The Pancheshwar Multipurpose Project (PMP) is a bi-national hydropower project to be developed on the Mahakali River bordering Nepal and India. Development of PMP is a mutual interest project between two countries, and is covered under the integrated Mahakali Treaty signed between Nepal and India according to which, two underground power houses, each of 3,240MW will be constructed on each side of the Mahakali river in India and Nepal. Moreover, the PMP also offers benefit of regulated water for irrigation to a vast area of agricultural land both in Nepal and India along with benefits of downstream flood control.

The Mahakali River basin, upstream from the proposed Pancheshwar High Dam site has a drainage area of 12,100 km² (80% in India, and 20% in Nepal). PMP has been identified as a huge storage scheme to be developed so as to maximize peak power benefit in the order of 6,720 MW (Pancheshwar High Dam-6480 MW and Rupali Gad Re-regulating Dam-240 MW) with an annual average energy production of 12.3 TWh. The Poornagiri re-regulating dam is an alternative to the Rupali Gad Re-regulating Dam from which an additional 1000 MW of power will be generated (PACO report, Additional Service, section 3, June 1992).
The PMP lies in the Mahakali zone of the Far Western Development Region of Nepal covering some parts of Darchula, Baitadi and Dadeldhura districts bordering India. At present, the Project site can be accessed by vehicle only through India. However, it can be accessed through Nepal by two days walking from Patan, Baitadi. The figure below (adapted from PMP) provides an overview of this project:

**Pancheshwar Multipurpose Project**

Pancheshwar High Dam project has been conceived as a huge storage scheme having a 315 m high rock fill dam with a central earthen core. With the “Normal Maximum Water Level” of 680 m elevation the reservoir area extends to 65 km upstream in Baitadi and Darchula districts. The crest length and the crest elevation of the dam would be 860 m and 695 m respectively. The “Normal Maximum Water Level” would provide live storage of 6.56 billion m³ of water and be capable of generating 10.7 TWh of energy. Two identical underground powerhouses, one on each bank in Nepal and India with a capacity of 324 MW have been proposed comprising 6 generating units of vertical Francis turbines (540 MW capacity each). Total installed capacity of the high dam project will be of 6480 MW. A re-regulating dam at Rupali Gad is conceived as an integral component of PMP to minimise social and environmental impacts due to high fluctuations of water levels and flow downstream when the high dam power plants operate at peak load. Poonagiri Re-regulating Dam has been identified as an alternative to Rupali Gad RRD.

The Rupali Gad Re-regulating Dam would be an 83 m high concrete gravity dam on the Mahakali River near Samniya settlement. The re-regulating dam site would be about 25 km downstream from Pancheshwar High Dam and about 1.75 km downstream from the confluence of the Rupali Gad and Mahakali Rivers in Dadeldhura District. At a maximum water level of 420 masl, it would store about 70 million m³ of water as live storage and produces 240 MW power with 1662 GWh of annual energy.

The Poornagiri Re-Regulating Dam would be located about 64 km downstream from the High dam. The DPR study of 1995 proposed two options; (a) 117 m high rock fill dam, and (b) 124 m high concrete gravity dam. These are for re-regulating the water of the high dam. The power production of the dam would be 1000 MW for both options. This proposed ‘storage’ dam would be built on the Indo-Nepal border in Champawat district. According to the State government data, the dam would submerge 60 villages.
and would affect 19,700 people in Uttarakhand, India. In Nepal, the dam would submerge 14 villages, affecting a population of 11,466.

A website is dedicated to this project development: http://www.pmp.gov.np/

7.10.2 | The Mahakali Treaty: an opportunity for meaningful Nepal/India cooperation

This information is issued from UNEP Dams and Development Project.

In the spirit of furthering cooperation within the Mahakali River area, the Governments of India and Nepal entered into a Memorandum of Understanding (MOU), commonly referred to as the Tanakpur Agreement, on December 6, 1991. The Agreement provided for the construction of the left afflux bund (the retaining wall) on Nepalese territory for which the Nepalese provided 2.9 hectares of land. Unlike the Sarada Treaty, the Tanakpur Agreement did not provide for an even exchange of land from India. The Agreement, instead, provided for the installation of a head regulator (main part of the reservoir regulating the water flow) at the Tanakpur Barrage with a capacity of 1,000 cusecs, and required India to construct a canal so that 150 cusecs of water could be delivered to Nepal. India was further required to provide Nepal with 10 megawatts (MW) of electricity. The Tanakpur Agreement also stated that when there was an increase in the water supply at the Pancheshwar Reservoir, the supply of water to Nepal would also be increased. The provision of water and electricity by India to Nepal was seen as the quid pro quo to Nepal for providing India with 2.9 hectares of its land needed to construct the afflux bund.

It is important to point out that the Mahakali Treaty emphasizes an integrated approach to the development of water resources and, more importantly, attempts to validate past activities taken to develop water resources on the Mahakali River. Because of the contemporary political climate, the need to validate past activities carried out under the Tanakpur Agreement and the need to improve the Mahakali water sharing arrangements became pressing. It is important to understand that the Mahakali water sharing arrangements were governed primarily by the Sarada Treaty, which was entered into when the political status of India and the needs of the two countries were different. Indeed, while India was under British rule at the time, the population of Nepal was small in size with a relatively low demand for water, and as such, water sharing did not get the same priority that it does today.

Considering the embedded views of both sides on the Tanakpur controversy, it took five years of negotiations after the Tanakpur agreement was concluded before the foreign ministers of India and Nepal were able on January 29, 1996, to initial a Treaty between the two countries for the integrated development of water resources on the Mahakali River. Two weeks later, on February 12, 1996, the Mahakali Treaty was signed by the Prime Ministers of India and Nepal.

An interesting feature of the Mahakali Treaty is the establishment of a joint Indo-Nepalese commission, called the Mahakali River Commission. This Commission is guided by the principles of equality, mutual benefit and no harm to either of the countries. The joint nature, both from an organizational as well as financial standpoint, is well reflected because the Commission will be composed of an equal number of representatives from both countries and its expenses also are to be borne equally by both India and Nepal.

The Commission has been given a relatively broad mandate. Among other things, the Commission has been directed to: (i) seek information on and, if necessary, inspect all structures included in the Mahakali Treaty and make recommendations for necessary steps to implement its provisions; (ii) make recommendations for the conservation and utilization of the Mahakali River as envisioned by and provided for in the Treaty; (iii) provide expert evaluation of projects and make recommendations thereto; (iv) coordinate and monitor plans of action arising out of the implementation of the Treaty; and (v) examine any differences arising between the two countries concerning the Treaty's interpretation and application.

The Mahakali Treaty absorbed the regime established by the Sarada Treaty, validated the controversial Tanakpur Agreement, and endorsed the idea of a new multipurpose project, the details of which, at the time of its conclusion, still needed to be worked out.

The Mahakali Treaty specifies that both India and Nepal have equal entitlement to utilize the waters of the Mahakali River without prejudice to their respective existing consumptive uses. This Treaty further specifies that both countries agree to implement the PMP in accordance with the Detailed Project Report (DPR) being jointly prepared by the countries. The Mahakali Treaty also added, in this context, that India would supply 350 cusecs of water for the irrigation of Dodhara-Chandani area in Nepal.

Maintaining the flow and level of water in the Mahakali River is one of the general principles established by the Treaty. India and Nepal each agreed not to use, obstruct, or divert the waters of the Mahakali River, so as to adversely affect the natural flow and level of the river. While the notion of adverse effect is not defined in the Treaty, and thus leaves room for controversy, this requirement does not preclude the use of the waters of the Mahakali River by the local communities living along both sides of the River as long as such use does not exceed five percent of the average annual flow at Pancheshwar.
Furthermore, the Mahakali Treaty does not preclude either country from planning, surveying, developing and using any of the tributaries originating from the Mahakali River, as long as such activities take place in each country's own territory and do not adversely affect the flow of the Mahakali River.

The Mahakali Treaty entered into force on June 5, 1997. It will remain valid for a period of 75 years. The provisions of the Treaty must be reviewed by both countries at 10-year intervals or earlier if requested by either country and amendments thereto will be made, if necessary.

The first part of the Mahakali Treaty deals with the Sarada Barrage. Accordingly, Nepal shall have the right to a supply of 1,000 cusecs of water from the Sarada Barrage in the wet season (15th May to 15th October) and 150 cusecs in the dry season (16th October to 14th May). Moreover, India is required to maintain a flow of not less than 350 cusecs downstream of the Sarada Barrage in the Mahakali River to maintain and preserve the river ecosystem.

The second part of the Mahakali Treaty deals with the Tanakpur Barrage. According to the decisions taken in the Joint Commission dated December 4-5, 1991, and the Joint Communique on October 21, 1992, India and Nepal agreed to carry out the construction of the eastern afflux bund of the Tanakpur Barrage at Jimuwa and tying it up to the high ground in the Nepalese territory at an elevation level of 250 meters. For this purpose, Nepal agreed to let India use a portion of its territory at the Jimuwa Village and a certain portion of the no-mans land on either side of the border. The Mahakali Treaty explicitly states that this land continue to remain under the sovereignty and control of Nepal.

In lieu of construction of the eastern afflux bund of the Tanakpur Barrage at Jimuwa, Nepal obtained the right to a supply of 1,000 cusecs of water during the wet season and 300 cusecs of water during the dry season. For this purpose, as well as for the purpose of supplying water from the Sarada Barrage, India agreed to construct the head regulator(s) near the left undersluice of the Tanakpur Barrage and to build waterways with appropriate water capacity all the way to the Indo-Nepalese border. Such head regulator(s) and waterways are to be operated jointly by India and Nepal.

Regarding electricity, Nepal is entitled to an annual supply of 70 million kilowatt-hours on a continuous basis free of cost, from the effective date of the Mahakali Treaty. For this purpose, India agreed to construct a 132 kV transmission line all the way to the Indo-Nepalese border from the Tanakpur Power Station. The Letter further clarified that the annual supply of 20 million kilowatt-hours of electricity, free of cost, to Nepal from the Tanakpur Power Station, as provided for in the Mahakali Treaty, shall be reconciled with the energy procured or to be procured by Nepal from India under the existing power exchange arrangements.

The Mahakali Treaty also described the arrangements that would be made at the Tanakpur Barrage at the time of development of any storage project(s) including the PMP upstream of the Tanakpur Barrage. Accordingly, additional head regulators and necessary waterways up to the Indo-Nepalese border would be constructed to supply additional water to Nepal.

Moreover, Nepal would have additional energy equal to half of the incremental energy generated from the Tanakpur Power Station on a continuous basis from the date of augmentation of the flow of the Mahakali River. Under the Treaty, Nepal was obligated to bear half of the additional operational costs and, if required, half of the additional capital costs at the Tanakpur Power Station for the generation of this incremental energy.

Although the newly conceived PMP is a very important part of the Mahakali Treaty, it remains a controversial aspect of the Treaty. The Tanakpur Barrage has, at the time of its completion, an installed capacity of 120,000 kilowatt generating 448.4 million kilowatt-hour of energy annually on 90 percent dependable year flow. In this context, it is also useful to note that India and Nepal on June 5, 1997, signed an agreement to promote private sector participation in the hydropower projects.

The Mahakali Treaty establishes four main principles for the design and implementation of the PMP. The first principle is that the PMP will be designed to produce the maximum total net benefit for both countries in the forms of power generation, irrigation use and flood control. The second principle regarding the construction of the PMP is that both countries are working together in an integrated manner to develop and share their water resources. Indeed, the PMP will be implemented as a joint effort including the erection of power stations of equal capacity on each side of the Mahakali River. The two power stations will be operated together, and the total energy generated will be shared equally between India and Nepal. The third principle is that both countries will share the cost of the project. As specified in the Treaty, India and Nepal will share the cost of the PMP in proportion to the benefits accruing to each, and will jointly endeavour to mobilize the financing required to implement the PMP. The fourth principle is that a portion of Nepal's share of energy will be sold to India. The quantum of such energy and its price shall be mutually agreed upon between the parties.

Nevertheless, both India and Nepal continue to reserve their rights to deal directly with each other on all matters, notwithstanding the competence of the Mahakali River Commission. In addition, both the parties can form, if they wish, specific joint entities for the development, execution and operation of new projects including the PMP in the Mahakali River for their mutual benefit.
The dispute resolution mechanism envisaged by the Mahakali Treaty is relatively elaborated and advanced. In case the Mahakali River Commission fails to come up with a recommendation after examining any disparities between the countries within three months, or if either party disagrees with the Commission’s recommendation, then a dispute shall be deemed to have arisen and shall then be submitted for arbitration. In so doing, either country is required to give three months’ prior notice to the other country.

A tribunal composed of three arbitrators conducts all arbitration. One arbitrator is to be nominated by Nepal, one by India, and neither country is allowed to nominate its own national representative. The third arbitrator is to be appointed jointly by the two arbitrators, who shall preside over the tribunal. In the event that the two countries are unable to agree upon the third arbitrator within 90 days after receipt of a proposal, either country may request the Secretary-General of the Permanent Court of Arbitration at The Hague to appoint an arbitrator. The Treaty states that the decision of a majority of the arbitrators shall be considered to be the decision of the tribunal. Both countries are obligated to accept the decision as final, definitive and binding.

7.10.3 | The Pancheshwar Development Authority as an appropriate governing body

Nepal and India signed the Mahakali Treaty in 1996 but there was very little action taking place over the following two decades. Implementation of Pancheshwar Multipurpose Project is the centre piece of this Treaty. Required field investigations for the Pancheshwar Multipurpose Project have been completed by a Joint Project Office (JPO-PI) in 2002 (except for some confirmatory tests). But mutually acceptable DPR of Pancheshwar Project could not be finalized due to differences on certain contentious issues. During the 3rd meeting of Joint Committee on Water Resources (JCWR) held from September-October 2008 at Kathmandu (Nepal), it was decided to set up a Pancheshwar Development Authority (PDA) at the earliest for the development, execution and operation of Pancheshwar Multipurpose Project. The constitution of PDA has been notified vide this Ministry’s Office Memorandum No. Z-14012/2/2013-Ganga/2302-14 dated 7th August 2014.

According to the Terms of Reference (ToRs), the PDA shall take immediate measures to finalize the Detailed Project Report of Pancheshwar Multipurpose Project. Thereafter, the Authority shall undertake the execution, operation and maintenance of the Project, including the re-regulating dam at Rupaligad site in an integrated manner. All powers of the Authority shall be vested in the Governing Body. The Governing Body may delegate all or any of its powers to the Executive Committee. The Executive Committee shall comprise of the Chief Executive Officer (CEO), Additional Chief Executive Officer (ACEO), Executive Director (Legal), Executive Director (Technical), Executive Director (Administration), Executive Director (Environment), Executive Director (Resettlement and Rehabilitation) and Executive Director (Finance) selected by the Authority having equal representations from each Party. The CEO will be appointed every three years on rotational basis between Nepal and India. Both the countries have agreed to appoint the first CEO from Nepal. As provided by the charter, when the CEO is from Nepal, an additional CEO and finance director will be from India, and vice versa. The Authority shall open a bank account for the Pancheshwar Development Fund. The annual requirement of funds shall be worked out by the Executive Committee and approved by the Governing Body in accordance with the schedule of construction and its progress. Major procurement of works, goods and consulting services for the Project shall be made through competitive bidding.

The first meeting of the governing body of the PDA was convened on September 22nd and 23rd 2014. The meeting observed as to how Pancheshwar Multipurpose Project was halted for a long period and now the impetus of the two (2) prime ministers during Prime Minister Narendra Modi’s visit to Nepal in August 2014 has led to this first meeting which will pave way for developing the project. At the meeting, the Indian delegation was led by Alok Rawat, Secretary in Ministry of Water Resources while the Nepalese delegation was led by Rajendra Kishore Kshetri, Secretary in Nepal’s Ministry of Water Resources. According to the agreement, the share of water and energy will be equally divided between both countries. Wapcos Ltd. from India was appointed to upgrade data for the integration of detailed project reports prepared separately by Nepal and India. The costs and benefits of the project would be analysed once the detailed project report was finalised.

It should be noted that this project has aroused strong opposition from environmentalists and anti-dam activists (situation in a fragile zone and could have major ecological and social impacts, in particular people directly and indirectly affected by the project; unresolved issues of the 1,000 MW Tehri dam within the Indian State of Uttarakhand has raised questions about the feasibility of large dams in this area in India, etc.). The on-going studies, which will update the detailed project report/ feasibility study report, are expected to address this issue in a sustainable way to better have in view of the changes in socio-economic data, availability of additional hydro-meteorological data, and increase in construction cost. All the benefits of the Pancheshwar Multipurpose Project should be assessed.

Similar lessons can be learnt from Paraguay/Brazil’s 14,000 MW Itaipu Binational Hydroelectric Project. Indeed in 1973 Paraguay signed the Itaipu Treaty with her large next door neighbour, Brazil, to construct the world’s (then) largest 12,600 MW Itaipu Hydroelectric Power Plant on the border river, Parana. The first 700 MW unit was commissioned in 1984 and the last 18th unit in 1991. The initial estimated
cost of US$ 2 billion increased to US$ 18 billion by the time of completion. The Itaipu dam was heralded as a triumph of cross-border cooperation on water resources development between a large and small neighbour.

7.10.4 | Main lessons learnt

The project, to be developed on the Mahakali River on the Nepal-India border, is expected to generate 6,720 MW of power, and irrigate 93,000 hectares of land in Nepal and 1.6 million hectares on the Indian side. It will also protect both countries from flood events. According to the agreement, the share of water and energy will be equally divided between both countries.

The Mahakali Treaty emphasizes an integrated approach to the development of water resources and, more importantly, attempts to validate past activities taken to develop water resources on the Mahakali River. This Treaty stressed the need for negotiation/departing situation, by reviewing of an old agreement, desire for a common approach to developing joint resources between Nepal and India. The international community (UN bodies, donors, multilateral development banks, etc.) played a key role in its development and implementation.

Implementation of Pancheshwar Multipurpose Project is the centre piece of this Treaty. This binational project on the Mahakali River is seen as a landmark development in Nepal-India cooperation in hydropower sector. The governing body of seven members from each country will be co-chaired by the energy secretary of Nepal and the water resource secretary of India. A CEO will head the executive committee of the Pancheshwar Development Authority. An Indian consultant was nominated to upgrade data for the integration of detailed project reports prepared separately by Nepal and India. All water users and the environment are expected to be involved within the process. Once the authority becomes functional, work on finalising a detailed project report, financial closure and construction will be undertaken.

The cost and benefits of the Pancheshwar multipurpose project would be analysed once the detailed project reports (DPR) were finalised.

7.10.5 | References


PDA, 2014 “Terms of Reference of the Pancheshwar Development Authority” http://wrmin.nic.in/writereaddata/TORS-PDA.pdf


UNEP/DDP, 2005 Mahakali River example http://www.unep.org/dams/documents/
7.11 | Three Gorges project (China, Asia)

The Three Gorges project case study was provided by China Three Gorges Corporation (CTGC). All information is issued by CTGC and public information; this was compiled by Emmanuel BRANCHE (EDF).

7.11.1 | Project description

The Three Gorges Reservoir is located in Sandouping, Yichang, Hubei Province. It is the backbone project of Yangtze River’s flood control system and it will control a drainage area of $1.0 \times 10^6 \text{ km}^2$. The normal water level elevation of the complex reaches 175 m, with the total storage capacity of 39.3 billion m$^3$. The drawdown level in dry season is 155 m, with the corresponding storage capacity of 22.8 billion m$^3$. The regulating storage capacity is 16.5 billion m$^3$. The flood control level is 145 m, with corresponding storage capacity of 17.15 billion m$^3$. The reservoir flood control capacity is 22.15 billion m$^3$.

The total installed capacity is 22,500 MW, with 32 sets of 700 MW turbine generator and 2 sets of 50 MW generating units in the power supply station.

The regulation of the Three Gorges Reservoir is not for the sole purpose of functionality. Instead, it involves decision-making for multiple purposes so as to formulate the optimal balancing solution that makes the most of the reservoir’s comprehensive benefits.

The Three Gorges Reservoir was conceived as a multipurpose infrastructure from the original design stage. Its major benefits are flood control, power generation and navigation.
The main purposes of the Three Gorges Reservoir are flood mitigation, hydropower and navigation. Other purposes include i) sediment management in the downstream river course, ii) barrier to saline water intrusion and iii) drought alleviation.

As with all large infrastructures, this project has environmental and social impacts. For instance, Three Gorges dam/reservoir has resettled around 1.2 million people as several cities and towns were flooded.

Economic approach

By design, the economic benefits of the Three Gorges Reservoir include flood control, power generation, and navigation. According to a comprehensive assessment by the Chinese Academy of Engineering for the five years between 2008 and 2012, the actual economic benefits of the reservoir are mainly the following:

- **Flood control:** The Three Gorges Reservoir has demonstrated remarkable flood control benefits. For the reservoir, flood submergence would have resulted in a total economic loss of about 74 billion RMB between 2008 and 2012. Before the project’s completion in 2007, a single disastrous flood event in 1998 passed through the site, causing economic losses to the region of USD 26 billion, equivalent to the total investment cost of the entire Three Gorges Dam project. When a similar flooding event took place in 2010, the dam was able to fully absorb the increased water flow, avoiding billions of dollars of economic damage, not to mention protecting the local communities living in the basin.

- **Navigation on the Yangtze River:** the navigation lock built around the dam allows the Three Gorges reservoir to be utilized as a shipping lane, bringing valuable goods upstream to the previously inaccessible municipality of Chongqing and others to the south-west. Navigation has increased by more than four times and the overall cost of transportation has decreased by a third. The Three Gorges Reservoir has significantly lowered shipping costs by cutting fuel consumption. The average energy consumption per unit of ships has dropped from 7.6 kg/kt•km to 2.9 kg/kt•km. This has created conditions for the rapid development of shipping on the Yangtze River. In 2012, as many as 150 thousand people were directly employed by the shipping industry just in Chongqing, one of the areas drained by the Yangtze River. Of these people, 80 thousand people were in the Three Gorges Reservoir area. Chongqing had over 500 thousand people working in industries that rely on the shipping industry, such as coal mining, tourism, and road transportation. Altogether, the shipping industries and associated industries created jobs for over 2 million surplus workers in the reservoir area, playing an essential role in economic and social development.

- **Electricity generation:** The designed annual electricity generating capacity of the Three Gorges Reservoir is 88.2 billion kWh (88.2 TWh/year). The reservoir generated an impressive total of over 500 billion kWh between 2008 and 2013. In particular, it hit a record of 98.8 billion kWh in 2014. Compared with the regulation method formulated in the design phase, that actually used in the operation phase has brought about noticeably higher electricity generating volume and economic benefits. Meanwhile, the reservoir has enhanced the economic competence of areas it supplies electricity to. Large quantities of cheap hydroelectricity have lowered the costs of many industrial products, especially high-energy-consumption products, making them more competitive in both domestic and overseas markets.
The most direct economic benefit of the Three Gorges Reservoir is electricity generation. Electricity generated by power stations is transmitted to the state power grid, which in turn distributes the electricity to different areas. Reservoir benefits of other functions like flood control and navigation are independently shared among state authorities and local governments. There are no financing relations. It is noteworthy that ships are not charged for passing the Three Gorges Project’s ship locks. The maintenance costs of the ship locks are included in the electricity generation costs.

The major indirect economic benefits of the Three Gorges Reservoir is the promotion of regional economic development. According to the assessment mentioned above, the Three Gorges Reservoir, after starting to store water, provided 19 counties, cities, and districts in the reservoir area with adequate basic energy, increasing local tax revenues, creating good opportunities and conditions for development, improving the navigation capacity, and driving tourism forward. The Three Gorges Reservoir area is poised to transform into a riverside economic belt that opens up to the outside and registers an annual GDP growth of around 20%.

Flood season (10th June-30th September):

<table>
<thead>
<tr>
<th>Flood season</th>
<th>Design</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flood Control Level (m)</td>
<td>145</td>
<td>between 144.9-146.5</td>
</tr>
</tbody>
</table>

**Flood Control**

When the big flood occurs, the reservoir need to dispatch the flood for the lower reaches, the reservoir water level allows being above 145 m to intercept and store flood. When the flood passed, the water level needs to decrease to 145 m.

In the case of small and medium floods, flood retention can be performed without compromising safety in flood control.

<table>
<thead>
<tr>
<th>Impoundment</th>
<th>Design</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start Date</td>
<td>1st October</td>
<td>10th September</td>
</tr>
<tr>
<td>Start Level (m)</td>
<td>145 m</td>
<td>150-155 m</td>
</tr>
<tr>
<td>Minimum discharge flow in September (m³/s)</td>
<td>---</td>
<td>10000</td>
</tr>
<tr>
<td>Minimum discharge flow in October (m³/s)</td>
<td>5000</td>
<td>8000</td>
</tr>
</tbody>
</table>
Dry season:

<table>
<thead>
<tr>
<th>Dry season</th>
<th>Design</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum discharge flow from January to April (m$^3$/s)</td>
<td>5000</td>
<td>6000</td>
</tr>
<tr>
<td>Water level of 25$^{th}$ May (m)</td>
<td>155</td>
<td>155</td>
</tr>
<tr>
<td>Water level of 10$^{th}$ June (m)</td>
<td>145</td>
<td>146.5</td>
</tr>
</tbody>
</table>

The various uses have certain priorities. If divided according to the time of the year, the priorities order is as follows (table presented below):

<table>
<thead>
<tr>
<th>Three Gorges project – Priority for Water uses according to the season</th>
<th>Dry season (December to 10$^{th}$ June of the following year)</th>
<th>Flood season (10$^{th}$ June to 30$^{th}$ September)</th>
<th>Water storage period (10$^{th}$ September to December)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1$^{st}$ priority</td>
<td>Navigation</td>
<td>Flood control</td>
<td>Navigation</td>
</tr>
<tr>
<td>2$^{nd}$ priority</td>
<td>Power generation</td>
<td>Navigation</td>
<td>Flood control</td>
</tr>
<tr>
<td>3$^{rd}$ priority</td>
<td>Flood control</td>
<td>Power generation</td>
<td>Power generation</td>
</tr>
</tbody>
</table>

Even if the Three Gorges Project is the world largest hydropower plant (in terms of maximum installed capacity 22.5 GW, and annual energy generation 98.8 TWh/year in 2014), whatever the season of the year, the power generation is never the first priority!

High level runoff forecasting system and scientific dispatch plans are the basis for Three Gorges Reservoir multipurpose scheduling decision-making. Three Gorges Reservoir has its own completely automatic hydrologic tele-metering system. With more than 600 telemetric stations in the upper stream and controlling 500 thousand km$^2$ drainage area, water and rainfall information of all stations can be automatic collected, transmitted and analyzed within 10 minutes, which highly increases the forecast period and precision of Three Gorges Reservoir’s hydrologic forecasting. In the meantime, the result of a series of research on Three Gorges Reservoir optimal dispatch is used in dispatch practice. The practice verifies the optimizing management mode of the research. In addition, in practical term, Three Gorges Reservoir establishes a scheduling consultation mechanism with the upper and lower reaches hydrological departments to provide effective support for the Three Gorges reservoir dispatch decision-making through the collaborative consultation and scientific computing by different departments.

To maximize the operation period of the Three Gorges Reservoir, an operation method was designed which can be summarized as “impounding clean water and discharging muddy water”. In this method, the reservoir discharges as much sediment as possible when the amounts of water and sediment are high during the flood season and stores water when the amounts of water and sediment are low outside the flood season. This method was concluded to be one that could keep most of the reservoir’s usable capacity for a long term, including its flood control capacity and its capacity for comprehensive benefits. In the operation phase, the actual amount of accumulated sediment was just one-third of the value estimated in the design phase. Since sediment was no longer the key issue that confronted reservoir regulation, the objective and method of regulation could be optimized and changed.

7.11.3 Governance models for this multipurpose reservoir

China Three Gorges Corporation (CTG) takes full responsibility of the Three Gorges Project’s construction and operation. CTG is a state-owned enterprise, with its main business being hydropower project construction and management, power production, international investment and project contracting, new energy development, and the relevant professional and technical services.

Flood control regulation is performed under instructions and supervision from flood control authorities. Electricity generation regulation complies with the whole plan for the entire power grid. Navigation regulation is in the charge of Changjiang River Administration of Navigational Affairs
under the Ministry of Transport. Regulation for the protection of water resources and the water eco-environment is organized and coordinated by flood control authorities.

Flood control regulation takes precedence over regulation for comprehensive benefits. Electricity generation regulation and navigation regulation require mutual coordination and must both give way to water resources regulation. Efforts are made to balance comprehensive benefits with water resources, the water environment, the protection of the water eco-environment, and the long-term use of the reservoir. Reservoir regulation follows supervision and instructions that come from super-ordinate authorities with administrative power and compulsion.

During the operation phase, measures are taken to reduce the amount of sediment so as to extend the service life of the reservoir in a sustainable manner. Sediment peak releasing to downstream regulation and reservoir tail sediment flushing regulation carried out step by step in recent years have been quite successful.

The main trade-offs are the contradiction between flood control and benefit, between flood control and navigation, between flood control and power generation, and between water storage and water supply needs.

Take impoundment at the end of the flood season as an example, as the demand for water grows stronger in areas downstream of the reservoir, there is a conflict to be resolved between ahead-of-schedule impoundment and flood control. Better runoff forecasts and a scientific study proving risks associated with ahead-of-schedule impoundment for flood control to be controllable, and made possible a method to store water earlier than the designed time. This alleviates the impact of the discharged flow reducing during impounding period and guarantees the possibility of the reservoir being filled with enough water, laying a solid foundation for water supply for areas downstream of the reservoir during the dry season.

On condition of safe operation, regulation priorities are applies to ensure that no damage or acceptable damage is done. This could be shown a consensus between all stakeholders.

In order to maximize the utility of the Three Gorges Dam and cut down on sedimentation from the Jinsha River, upstream of the Yangtze River before reaching Yibin in Sichuan, authorities plan to build a series of dams downstream of Jinsha, including Wudongde Dam, Baihetan Dam, along with the now completed Xiluodu, and Xiangjiaba dams. The total capacity of those four dams is around 38,500 MW. The figure below presents the longitudinal profile of the Yangtze River upstream of Three Gorges dam, and those hydropower projects (source Calvingao).
7.11.4 | **Main lessons learnt**

The Three Gorges Reservoir is a multipurpose infrastructure from original design stage. Indeed, **the world’s largest hydropower station** is, in fact, not primarily a hydropower station. China’s Three Gorges Dam, well known for its sheer size of the powerhouse at 22.5 GW, was built to control floods on the Yangtze River. Each year the river is subject to extreme floods, with major events occurring up to four and five times per year.

**One opportunity for improvement is to modify the operation method and objective decided in the design phase.** This should be adapted according to changes in the operation conditions such as the amounts of water and sediment from upstream and water conservancy projects upstream so as to further exploit the comprehensive functions of the reservoir. For example, to utilize floodwaters as resources, regulation for small and medium floods has been performed during the flood season, and water is impounded ahead of schedule to a higher level at the end of the flood season so as to guarantee the possibility of the reservoir being filled.

**Another opportunity is to consider more potential functions for the reservoir**, such as drought relief, ecological regulation to promote fish breeding, etc., so as to match economic development and meet the needs of the society and people. The operation method of the reservoir should be optimized under scientific guidance to achieve a higher standard of management that facilitates the fulfilment of the reservoir’s objective.

7.11.5 | **References**

7.12 | Arthurs Lake (Australia, Oceania)

The Arthurs Lake project case study was provided by HydroTasmania. All information is issued by HydroTasmania and public data; this was compiled by Emmanuel BRANCHE (EDF).

7.12.1 | Project description

Arthurs Lake was created by Hydro Tasmania in the 1920s by damming the Upper Lake River, and Blue Lake and Sand Lake—as well as the Morass Marsh. It is located in the Central Highlands of Tasmania, east of Great Lake. The multiple purposes that Arthurs Lake can deliver are hydropower, recreation, a fishery and irrigation.

Hydro Tasmania is Australia’s leading renewable energy business. It generates hydropower in Tasmania and trades electricity and energy-related environmental products in the Australian market. Hydro Tasmania is the largest water manager in Australia. It is owned by the Government of Tasmania and currently employs over 900 people.

The main purpose of Arthurs Lake is hydropower. Arthurs Lake augments the Hydro Tasmania generating system by increasing the water available to Great Lake, and hence into the 300 MW Poatina Power Station. The Poatina Power Station provides approximately 12% of Tasmania's electricity generation needs. Water is pumped from Arthurs Lake up to Great Lake, and the 1.7 MW Tods Corner Power Station
recovers part of the energy used in pumping the water. The balance, and more, of the pumping energy is recovered when the water is used at Poatina Power Station.

In addition to generating hydropower, Arthurs Lake is Tasmania’s most popular trout fishery. Arthurs Lake is used by more anglers than any other water in the State. Arthurs Lake is known for its good catch rate for its wild stocks of brown trout. There was no distinct decision to change from a single purpose to a multi-purpose storage in relation to the accommodation of recreational trout fishing, but Hydro Tasmania did agree to maintain higher minimum water levels in the lake to enhance the trout fishery. Some in-house analyses of costs associated with maintaining water levels to suit recreational users have been undertaken but not publicly released. No charges for cost recovery have been made in relation to lake level management for recreational trout fishing at Arthurs Lake, because these were able to be accommodated by Hydro Tasmania without significant implications for the generation potential. The Tasmanian Inland Recreational Fishery across the State is a highly valued resource of national and international significance. Reportedly, it attracts over 25,000 anglers each year, injecting some $40 million into the State’s economy through tourism alone and is a vital asset for regional communities where other recreational, social and economic opportunities are limited.

Arthurs Lake offers a number of facilities to support recreational uses and accessibility. There are three main roads used to access Arthurs Lake and numerous shacks and camping areas. Four main boat ramps are available, and the lake is popular for boat-based fishers.

A further multiple use of the Arthurs Lake water was created by the commissioning of the Midlands Water Scheme in August 2014. Water for the Midlands irrigation district is sourced from Arthurs Lake. This project, developed and operated by Tasmanian Irrigation Pty Ltd, is the largest irrigation development in Tasmania’s history and
is recognised as an outstanding engineering feat both in Tasmania and nation-wide. Water supplied in the irrigation district is sourced from Arthurs Lake. Water flows under gravity via the supply line and a mini-hydro electric generator before being taken into storage at Floods Creek. Water is delivered throughout the district by distribution pipelines and a number of natural water-courses supplied by the pipelines. Farm Water Access Plans are all in place and will ensure the environmental sustainability of the scheme. Annual audits are conducted to monitor compliance. A decision was made within the Hydro Tasmania business to provide storage water to the Midlands Irrigation Scheme, including further increasing the minimum lake level above that agreed to enhance the trout fishery. As the water is abstracted and no longer available for use at hydro-generation facilities owned and operated by Hydro Tasmania, a fee is payable for this water to Hydro Tasmania following a transparent pricing system.

Although not a multiple “use”, threatened fish species are also a significant influence on operations, and are recognised in the storage operating rules for Arthurs Lake. There are two endangered Galaxiid fish species in Arthurs Lake, Galaxias tanycephalus and Paragalaxias mesotes. Another threatened native fish species, Galaxias tanycephalus, inhabits Woods Lake which is downstream of Arthurs Lake. Water release may be required from Arthurs Lake to minimise potential adverse environmental conditions in Woods Lake.

The Hydro Tasmania generating system is an integrated system. Water is managed according to a sophisticated system of hydrological monitoring, inflow forecasting over various timescales, and scenario analyses.

The storage operating rules are the Hydro Tasmania management tool to recognise and accommodate multiple uses or constraints for individual storages. In these rules, Arthurs Lake is primarily a diversion storage for Great Lake. Its power generation potential at Tods Corner power station is a by-product of diverting pickup to Great Lake via Arthurs Lake pump. The operating range at Arthurs Lake is between the Full Supply Level (FSL) of 952.82 m and the Normal Minimum Operating Level of 943.05 m. Regarding storage operation, normally the Arthurs Lake pumps are operated whenever the lake level is above the agreed minimum lake level; however, during periods of low system storage position or low Great Lake level the lake may be drawn below the agreed minimum. In addition, during periods when system capacity is constrained, the pumps may be turned off to reduce demand on the system.

No structural modifications have been required to the main Arthurs Lake Dam across the Lake River for recreation and fishing purposes. Improved amenities for fishing and camping have been constructed at key locations on the perimeter of the storage (e.g. boat ramps, road access, waste and sanitary facilities).

A modification to a subsidiary dam was required to enable off-take of irrigation water. This required a pipe to be constructed through the dam so that water could be accessed by the irrigation scheme. The water is delivered from Arthurs Lake to the Midlands Irrigation Scheme through 35 km of high pressure gravity pipeline to a mini hydro-electric power station at Floods Creek at the base of the Western Tiers to the west of Tunbridge. The water then enters a dam at Floods Creek for water storage prior to its distribution for irrigation. The distribution system utilises 119 km of medium to low pressure pipes and 210 km of existing water courses from Floods Creek to the Isis Valley, Tunbridge, Oatlands, Mt Seymour and Lower Marshes (Jericho). Electricity from the Floods Creek mini hydro powers two pumping stations in the Tunbridge area as well as being fed into the main power grid.

7.12.2 | The Farm Water Access Plans: a sustainable water assessment tool

In Australia, water is managed by each state and territory in accordance with the Intergovernmental Agreement on a National Water Initiative. In Tasmania, water is governed by the Water Management Act 1999 (“WMA”). Under the WMA all water resources in Tasmania are vested in the Crown. The Minister for Primary Industries and Water may grant rights to take water under a system of water licences. Water licences are currently administered by the Department of Primary Industries, Parks, Water and Environment (“DPIPWE”). Where an irrigation district is established, the rights arising under a water licence (or an agreement deriving from a water licence) may be broken into individual shares and issued as irrigation rights. Irrigation rights are administered by entities (such as Tasmanian Irrigation) who are responsible for operating irrigation districts. Water licences and irrigation rights are statutory water entitlements. They are transferable and separable from land. The irrigation schemes owned, operated and developed by Tasmanian Irrigation use irrigation rights as the statutory basis for water entitlements.

Tasmanian Irrigation is a state-owned company responsible for developing and operating irrigation schemes in Tasmania. As at March 2014, Tasmanian Irrigation owns and operates eight irrigation schemes, owns the infrastructure of two locally managed schemes, has three schemes under construction and is at various stages of developing a further five schemes. The irrigation schemes currently being developed by Tasmanian Irrigation are designed to last 100 years, deliver water at an average annual reliability of at least 95% and are built to satisfy demand in each region, with a threshold level of private commitment required before construction begins.

Water entitlements are either irrigation rights or delivery rights. Irrigation rights in the irrigation district are issued under the Irrigation Clauses Act 1973 (“ICA”) and are
subject to the terms of the agreements titled “Irrigation Right: Midlands Irrigation District”. Irrigation rights confer entitlements to have an allocation of water made available for delivery during each irrigation season. The entitlement arising under irrigation rights is defined as a volume and denominated in mega-litre (ML) units. The allocations made to irrigation rights for an irrigation season are calculated by multiplying: i) the entitlement held under irrigation rights on the opening day of the season; and ii) the allocation percentage notified by Tasmanian Irrigation before the start of the season and any revision made to the allocation percentage during the season. Irrigation rights do not provide secure rights to have water delivered but do so when held in conjunction with delivery rights. Delivery rights in the irrigation district are subject to the terms of agreements titled “Zoned Flow Delivery Right: Midlands Irrigation District”. Delivery rights confer entitlements to a share of the capacity of the scheme to deliver water within a zone during the summer delivery period (150 days) and/or winter delivery period (215 days) of each irrigation season. The entitlement arising under delivery rights is defined as a flow rate and denominated in mega-litre per day (ML/day) units.

Irrigation rights and delivery rights are tradable within the irrigation district in accordance with the ICA and the Trading Rules for the irrigation district. Trades are made by transferring volume between irrigation rights and flow rate between delivery rights. To take effect, a transfer must be approved by Tasmanian Irrigation and recorded in the water entitlements register for the irrigation district.

The water entitlements issued in the irrigation district are separate from land. To access water from the irrigation district, a connection to a pipeline of the scheme or an off-take from a watercourse used by the scheme to deliver water needs to be in place and associated with water entitlements through a connection agreement.

The purpose of Farm Water Access Plans (WAP) is to identify where Tasmanian Irrigation water will be applied and manage any potential risks that may arise from the application of this water.

A Farm Water Access Plan must be in place for every property that receives water from the irrigation district. Farm Water Access Plans are management tools demonstrating that the use of water is sustainable and complies with Australian and Tasmanian Government requirements. The plans contain soil, water and biodiversity modules and specify management actions where environmental risks associated with irrigation are identified.

The assessable area under a Farm WAP includes all land to which Tasmanian Irrigation water will be applied as well as dams and the irrigation infrastructure that will be directly impacted by the use of Tasmanian Irrigation water now and into the future. A Farm WAP is not a property management plan and does not necessarily have to cover an entire property. It must be completed by prequalified consultants in accordance with the approved soil, water and biodiversity modules and contain management actions to be implemented if risks of applying Tasmanian Irrigation water are identified. The figure below presents the Farm WAP process.

---

**Farm Water Access Plan Process**

1. **Stage 1** – Baseline Resource Assessment by TI. Data collection, mapping and a short meeting with irrigator.
2. **Stage 2** – Farm WAP completed by consultants including land capability and biodiversity assessments.
3. **Quality Assurance** – TI ensures Farm WAP meets prescriptions and modules.
4. **Verification** – by Irrigator and consultants.
5. **Auditing** – annual random audit.
Hydro Tasmania Water Price Supply in the irrigation district is underpinned by a water supply agreement between Tasmanian Irrigation and Hydro Tasmania. The agreement recognises that water taken from Arthurs Lake would have otherwise been used to generate electricity at Poatina Power Station and Trevallyn Power Station. Accordingly, Tasmanian Irrigation is required to pay Hydro Tasmania for the water it takes from Arthurs Lake equal to an estimate of the value of revenue that would have been made by Hydro Tasmania if that water was used for power production. The estimated value of lost generation is based on the price of wholesale electricity, and renewable energy certificates and incorporates an annual adjustment to avoid large upward fluctuations in the price during periods of extended drought.

Numerous indirect economic impacts are intended from the creation of the Midlands Irrigation Scheme. For example, 130 direct jobs were created during the two year constructing period. Where possible the construction contracts were awarded to local Tasmanian companies. This scheme is intended to create new economic opportunities by significantly boosting food production and employment throughout the region. Based on experiences elsewhere around Tasmania, it is expected to create up to 300 on-farm jobs over time. Up to 38,500 megalitres per annum of high reliability irrigation water from Arthurs Lake is distributed to farms within an irrigable area of 55,680 ha. This area stretches from just north of Campbell Town to south of Kempton and comprising about 350-400 properties and seven communities. Over 15,000 ML will be available during a 150 day summer period with the balance available during a 215 day winter supply period. The climate in the district is comparatively dry, with an average rainfall of approximately 500 mm spread relatively uniformly throughout the year. Current production in the area includes poppies, cereals, canola, pasture seeds, lucerne, potatoes, and pasture for livestock finishing with also now potential for dairy conversions and perennial horticulture, such as grapes on some sites, depending on the incidence of frost. A reliable water supply is intended to give farmers the confidence to invest and diversify their businesses.

### 7.12.3 | Appropriate governance models for multipurpose water uses of reservoirs

The Arthurs Lake project is a local project. Hydro Tasmania and the Inland Fisheries Service (IFS) have a Memorandum of Understanding (MoU) for recreational activities for Arthurs Lake, and meet regularly at officer level and through the Inland Fisheries Advisory Committee as well as through more formal bilateral meetings. This MoU aims to achieve a minimum lake level for Arthurs Lake of 948.0 m on 1 June each year and a minimum level of 949.0 m on 1 November each year. With an active Midlands Irrigation Scheme the agreed minimum lake levels under the MoU are 1 m higher, being 949.0 m on 1 June and 950.0 m on 1 November each year. During periods of low system storage position or low Great Lake level, Arthurs Lake may be drawn below the agreed minimum levels. The Director of the IFS needs to be notified if it appears that the water level of Arthurs Lake will drop below the agreed levels.

Hydro Tasmania has a Water Operations Advisor role that has a direct responsibility to maintain relations with the irrigation sector, in particular in relation to water allocation and sharing issues. Arthurs Lake is a secondary irrigation storage for the Lake River irrigation area. Supplementary water for Woods Lake may be released via a riparian valve and/or the siphons. A Water Supply Agreement exists between Tasmanian Irrigation (TI) and Hydro Tasmania to achieve a minimum level in Arthurs Lake of 949.0 m on 1 June and 950.0 m on 1 November each year. During periods of low system storage position or low Great Lake level the lake may be drawn below the agreed minimum levels. TI needs to be notified if it appears that the water level of Arthurs Lake will drop below the agreed levels.

Hydro Tasmania operationalises these agreements for Arthurs Lake, as they relate to system control, through its storage operating rules.

Beyond regular meetings with these core stakeholders, Hydro Tasmania considers lakes such as Arthurs Lake and how it can improve activities to better reflect evolving environmental and community values through its Water Management Review programme. This proactive voluntary basin-scale outreach and review initiative of Hydro Tasmania has successfully helped the business understand and respond to evolving values around its waterways successfully since it was initiated in 1999, first focused on the South Esk-Great Lake scheme of which Arthurs Lake is a part. Hydro Tasmania is presently reviewing this programme and seeking to broaden it to be more clearly on a sustainability assessment platform, introducing elements of international sustainability assessment approaches such as the Hydropower Sustainability Assessment Protocol.

Trade-offs for Hydro Tasmania with regards to Arthurs Lake relate to constraints on reservoir operations. Hydro Tasmania has put an economic value on its water resources and is compensated for any foregone hydro-generation revenues if the water is used by another water user. As the major water manager in Tasmania, Hydro Tasmania considers other users of water resources when generating renewable hydro-electricity. Over time, a range of agreements have been entered into with other water users. Some agreements to transfer water are a result of pre-existing historical rights while others are statutory obligations. Water can also be transferred during flood events. If there is extra water which Hydro Tasmania cannot use, it wants others to be able to use it. Water transfers can also be subject to negotiated agreements. Where applicable,
some water transfers may include the payment of a fee to Hydro Tasmania that is calculated annually. Hydro Tasmania makes sure that the way in which this price is calculated is clear and transparent. The annual prices are for water “taken” during the coming 12-months from 1 July to 30 June. This time aligns with a normal water licence period. Three (3) water prices are quoted: i) winter ‘dam fill’ price, charged for water typically taken between 1 July and 30 November, and 1 May and 30 June to fill dams; ii) summer ‘direct take’ price, charged for water typically taken between 1 December and 30 April to irrigate crops; and iii) annual price, charged for water that could be taken at any time throughout the coming financial year. The table below presents the Hydro Tasmania water price for the 2014/2015 season for selected lakes:

<table>
<thead>
<tr>
<th>Reservoir or River</th>
<th>Generation forgone MWh/ML</th>
<th>Annual price per ML (Jul14-Jun15)</th>
<th>Summer price per ML (Dec14-Apr15)</th>
<th>Winter price per ML (Jul14-Nov14 + May15-Jun15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arthurs Lake</td>
<td>1.8969</td>
<td>$93.57</td>
<td>$94.19</td>
<td>$92.94</td>
</tr>
<tr>
<td>Great Lake</td>
<td>2.2278</td>
<td>$109.88</td>
<td>$110.62</td>
<td>$109.15</td>
</tr>
<tr>
<td>Ex Poatina or S.Esk</td>
<td>0.2794</td>
<td>$13.78</td>
<td>$13.88</td>
<td>$13.69</td>
</tr>
<tr>
<td>Parangana (via mini)</td>
<td>0.7950</td>
<td>$39.21</td>
<td>$39.48</td>
<td>$38.95</td>
</tr>
<tr>
<td>Cluny Lagoon</td>
<td>0.1072</td>
<td>$7.86</td>
<td>$7.86</td>
<td>$7.86</td>
</tr>
<tr>
<td>Lake Meadowbank</td>
<td>0.0675</td>
<td>$7.86</td>
<td>$7.86</td>
<td>$7.86</td>
</tr>
<tr>
<td>Lake Paloona</td>
<td>0.0731</td>
<td>$7.86</td>
<td>$7.86</td>
<td>$7.86</td>
</tr>
<tr>
<td>Minimum Fee</td>
<td></td>
<td>$7.86 per ML</td>
<td></td>
<td>Up-dated 5 May 2014</td>
</tr>
</tbody>
</table>

Difficulties to be overcome in balancing competing needs typically relate to local-scale land and recreation use management issues, e.g. managing conflicts between competing recreational groups, how to manage camping, waste, boat traffic, safety, signage etc. For example, the Arthurs Lake Camping Ground is leased to a local community group and they manage it on behalf of Hydro Tasmania. Hydro Tasmania has developed Recreational Principles to guide interactions with external stakeholders across its hydro generation network, so that the business focus can be on generation and the community focus can be on enjoying recreational opportunities. Hydro Tasmania has, and will, continue to develop and implement management plans for key sites that have high recreational use values for communities. Hydro Tasmania makes available near real time water information for Arthurs Lake. This assists recreational users to determine if the conditions are favourable prior to leaving home.

### 7.12.4 | Main lessons learnt

The **Australian legislative framework provides a good framework for water management** in the different States. Arthurs Lake is a very good example of multipurpose water uses of reservoirs in Tasmania.

As the major water manager in Tasmania, Hydro Tasmania considers other users of water resources when generating renewable hydropower. The Arthurs Lake experience provides evidence that providing access to water for other users results in increased value for Hydro Tasmania. Not only does the business get payment for foregone generation from the irrigation scheme, but expanded irrigation capacities require more energy to run pumps and provide downstream processing which increases electricity demand in the State. Accommodation of recreational purposes has little consequence for electricity generation, but provides business value in the way of good stakeholder and community relations and a positive view of the company.
Hydro Tasmania has developed many agreements and/or tools to set-up participative and constructive models around multiple uses of its waterways. Important tools include Memorandums of Understanding between key agencies, water supply agreements, and storage operating rules.

Considering the economic and financial benefits (and costs) was a key step when considering changes to the storage operating rules. With respect to both accommodating recreational fishing and irrigation needs, Hydro Tasmania evaluated the implications on electricity generation and revenues. The water pricing principle developed by Hydro Tasmania, in a transparent way, is an effective way for water sharing.

Communication mechanisms are important to success. These include written documentation, website information, regular meetings with stakeholders, notification procedures in case of changed operations, and mechanisms for easy contact in case of any issues of concern.

7.12.5 | References

Hydro Tasmania, 2014 “Case study for EDF-WWC framework on multipurpose– Arthurs Lake, Hydro Tasmania”, Helen Locher and Greg Carson, July 2014


7.13 | **Bronte Lagoon (Australia, Oceania)**

The Bronte Lagoon project case study was provided by HydroTasmania. All information is issued by HydroTasmania and public data; it was compiled by Emmanuel BRANCHE (EDF).

---

### Identity Card

**Type:** Basin / project

**Status:** preparation / operation

**Purposes:**
- Hydropower
- Flood control
- Water supply
- Irrigation
- Fisheries
- Recreation
- Navigation
- Water flow management

### SHARE topics

- Sustainability approach
- Higher efficiency
- Adaptability for solutions
- River basin perspectives
- Engaging stakeholders

---

#### 7.13.1 | Project description

Bronte Lagoon is a lake that was created by Hydro Tasmania in the 1950s, along with Bradys Lake, Lake Binney and Tungatinah Lagoon as the head water storages for the Tungatinah Power Station on the Nive River. Bronte Lagoon is located in the Central Highlands of Tasmania south of the Lyell Highway, connected to Bradys Lake by Woodwards Canal. It is an area where holiday shacks were built along the shore, and camping is permitted. The best-known purposes that Bronte Lagoon can deliver are water for hydropower generation and recreation (trout fishing, canoeing, kayaking and camping).

Tungatinah hydropower station is the second on the Nive/Derwent scheme. The station has five machines and was commissioned from 1953 to 1956. Each machine is made up of a Boving francis turbine coupled to a GEC generator. Tungatinah Power Station is located on the bank of the Nive River upstream from Tarraleah Power Station. The headworks are quite complex with several dams, a tunnel, canals, pipelines, flumes, associated control gates, and a pump station. Water is diverted from Tungatinah Lagoon by a short tunnel with surge shaft, and then drops 290 metres through five steel penstocks to the power station. Water passes through the five 25 MW Francis turbines and discharges into the Nive River, where it combines with the water from Tarraleah Power Station to supply the six Lower Derwent stations. The tunnel intake structure is provided with a radial,
gravity close intake gate designed to operate under full flow and abnormally high flow. Each of the five steel penstocks is provided with a hilltop valve designed to close automatically on abnormally high flow. Each turbine has a semi-embedded spiral casing, and water flow is controlled via a spherical rotary inlet valve and a relief valve designed to prevent spiral casing over pressure. A single 100 tonne overhead crane is provided which can handle a fully assembled stator or rotor with poles. Tungatinah Power Station has an extensive modernisation strategy in place, being undertaken from 2008 to 2014. It is part of Hydro Tasmania’s ongoing maintenance and planned technical upgrades which help retain world class standards for its assets.
Bronte Lagoon has developed as an excellent fishery rewarding fly and lure anglers with well conditioned trout. In 2012/13 Bronte Lagoon was the fourth most popular angling lake in Tasmania. The fishery in Bronte Lagoon is managed by the Inland Fisheries Service as a Premium Wild Trout Fishery. Natural recruitment of brown trout and periodic stocking of both rainbow and brook trout maintains the quality of the angling experience.

In addition Canoe Tasmania has developed an internationally recognised white water canoe course on Bradys Canal, the waterway that links Bronte Lagoon and Bradys Lake (Canoeing and Rafting). Woodwards Canal (also known as Bradys Canal) is used as a white water canoe course. The optimal flow for canoeing is approximately 21.2 cumecs.

Bronte Lagoon is a diversion storage with an operating range between Full Supply Level of 665.98 m and its Normal Minimum Operating Level of 662.33 m. Bronte Lagoon discharges into Tungatinah Lagoon via Woodwards Canal.

Hydro Tasmania makes reasonable endeavours to maintain the water level in Bronte Lagoon between 664.50 mASL and 665.5 mASL for the period 1 October to 30 April inclusive. Rapid level changes should be avoided where possible, but is it acknowledged that recreational events in the white water course will necessitate such releases. If the water level is drawn below 663.90 mASL then the draw-down should proceed as slowly as practicable. Water level recovery will be dependent on inflows and generation requirements.

When the lagoon is drawn below 663.82 m, notice should be given to local residents and the Bronte Chalet because their domestic water supply may be affected. If the water level of Bronte Lagoon drops below 663.90 mASL, Hydro Tasmania will, at the earliest opportunity, notify the Director of the Inland Fisheries Service of the expected duration of the low water level and any measures Hydro Tasmania proposes to take to address the low water level. Hydro Tasmania will notify the public by means of public notices in regional papers and appropriate websites, in advance of significant planned water level draw-downs (i.e. infrastructure maintenance) that may impact negatively on the fishing experience of anglers.

7.13.2 | An adaptative operation for new purposes and data sharing

From a single purpose to a multi-purpose reservoir

Bronte Lagoon is a storage dam jointly used for hydropower and recreational activities (i.e. trout fishing and canoeing). However Bronte Lagoon was originally designed and built in the early 1950s as one of a series of storages for the nearby Tungatinah Hydropower Station. Whilst originally developed as a hydro-generation storage, Bronte Lagoon evolved into a multipurpose infrastructure during its lifetime.

The recreational value of the lagoon and associated canal have been increasingly recognized over the past 25 years, alongside a gradual promotion through the Inland Fisheries Service (IFS) and the Tasmanian arm of Canoe Australia.

The steep elevation drop of 14.7 metres over approximately 300 metres between Bronte Lagoon and Bradys Lake has been developed by Canoe Tasmania into a world class white water canoe course. On request, and assuming sufficient water is available in the storage and that generation requirements are suitable, Hydro Tasmania can manually release water to facilitate events on the course. Releasing water can be a balancing act to meet the potentially conflicting requirements of angling (e.g. maintaining preferred water levels) and canoeists (e.g. swift water releases).

Drivers for the evolution to a multi-purpose water storage dam have been:

- Economic development associated with tourism around recreational trout fishing and canoeing at the State (Tasmania) and local (Tasmanian Central Highlands) levels; and
- Evolved societal expectations and values, relating to an increase in the ability to pursue recreational activities, the appreciation of outdoor and natural resource-based recreational pursuits, and an interest in local food sources and self-sourcing.

There was no distinct decision to change from a single purpose to a multi-purpose storage, and no specific economic analysis of the costs and benefits of changing operating rules to enable and enhance the multiple uses. As the change in use was gradual there was no driver to do such an analysis. Use of the lagoon for angling and water releases for canoeing events impose limited additional costs on hydro-generation activities, as water released for canoeing still gets used for power generation further downstream. Over the years the State has promoted recreational trout fishing as an economic development opportunity, and as a government business enterprise Hydro Tasmania assists and works with the State government to help implement their policies where these do not impose a significant cost or constraint on hydro-generation activities. In practice Hydro Tasmania does this through forming partnerships, Memorandums of Understanding (MoU) and other formal and informal agreements with relevant agencies. Hydro Tasmania accepts that these are shared water resources and that it has a stewardship role to help manage these resources for shared values including hydropower generation. For Hydro Tasmania, there are indirect economic benefits in terms of maintaining community support for hydropower and Hydro Tasmania as an institution. These benefits include an improved ability...
through partnerships to understand and manage community expectations, and continued social licence to operate and positive regulator relations.

As the largest manager of water in Australia, Hydro Tasmania knows just how vital water is. Hydro Tasmania has a responsibility for 45 of Tasmania’s major lakes and at least 1200 km of natural creeks and rivers influenced by its hydropower operations in some way, and Hydro Tasmania is committed to the sustainable use of this shared resource. The integrated power system in Tasmania uses water from six major river catchments, authorised under water licence. Hydro Tasmania has water management guidelines for managing the system as a whole. These guidelines require establishing long-term storage targets, following storage operating rules, managing storage risks, and developing and implementing protocols for communication with stakeholders.

- Long-term storage targets: those targets are established using system modelling which makes use of current and historical water level and flow data. Hydro Tasmania uses this modelling to manage the volatility in inflows, balancing the risk of shortfall against the risk of spill. This modelling incorporates the latest climate change predictions from CSIRO (i.e. Commonwealth Scientific and Industrial Research Organisation) and the Bureau of Meteorology.

- Individual water bodies in a system: for each of the water bodies managed by Hydro Tasmania, storage operating rules have been developed. These describe how water levels and releases from the storage are to be managed. In developing the rules, the attributes of the particular lake are considered – physical, climatic, multiple-use, social, environmental and operational requirements – as well as key stakeholders and communication and notification requirements.

Adjustments to rules are made when conditions surrounding these attributes change significantly. Consultation with stakeholders is undertaken where appropriate to do so. For example, Hydro Tasmania and the Inland Fisheries Service (IFS) have water level arrangements in Memorandums of Understanding (MoUs) for seven (7) lakes.

**Data sharing and stakeholder engagement**

Sharing the information is important, so Hydro Tasmania provides water level and flow data to other stakeholders. It also publishes river and lake levels, where available in near real-time, on this website. Formally, it prepares and presents annual compliance monitoring reports to the Tasmanian Minister for Primary Industry and Water on monitored data, environmental issues and mitigating actions. Going beyond compliance requirements, on a voluntary basis Hydro Tasmania further monitors water bodies to address key issues, such as recent research into the ecology of threatened fish species.

The Tasmanian Inland Recreational Fishery is a highly valued resource of national and international significance. It attracts over 25,000 anglers each year, injecting some $40 M into the State’s economy through tourism alone and is a vital asset for regional communities where other recreational, social and economic opportunities are limited. The Tasmanian Inland Recreational Fishery Management Plan establishes a 10 year-vision (2008-2018) for the State’s inland recreational fishery (the Fishery) with the goals of nurturing, developing and managing the inland recreational fisheries in harmony with the natural environment and realising its full potential for the Tasmanian community and future generations. Key issues to managing the State’s Fishery identified within the Plan are stakeholder engagement, fisheries management and planning, recreational salmonid stocking, development and enhancement, bio-security, and aspects of conservation and protection.

Difficulties to be overcome typically relate to balancing recreation requirements on the local-scale land and water use, e.g. managing conflicts between competing recreational groups, how to manage illegal camping, waste, boat traffic, safety, signage etc. Hydro Tasmania primary business is electricity generation and is not the management of local and multiple use pressures. In response to this difficulty, Hydro Tasmania has developed Recreational Principles to guide its interactions with external stakeholders, so that the business focus can be on generation and others can be on enjoying recreational opportunities.

**Economical and financing issues**

No significant financing has been required for Bronte Lagoon for multipurpose water management. Small funding has been required for improvements of amenities, e.g. for boat ramps, etc. This is typically funded within the beneficiaries’ operational budgets, and if needed, shared funding arrangements are made. All operational and management costs associated with reservoir management are met by Hydro Tasmania. Minor amenity costs are handled directly by the lead agency (e.g. trout stocking by the Inland Fisheries Service (IFS), signage and boat ramp maintenance by Marine and Safety Tasmania (MAST)). Where needed, costs are discussed and agreed amongst the beneficiaries.

**7.13.3 | Main lessons learnt**

The Australian legislative framework provides a good framework for water management in the different States.

Bronte lagoon is a very good example of multipurpose water uses of reservoirs in Tasmania.
As the major water manager in Tasmania, Hydro Tasmania considers other users of water resources when generating renewable hydropower. The Bronte Lagoon experience provides evidence that providing access to water for other users results in increased value for Hydro Tasmania. **Accommodation of recreational purposes has little consequence for electricity generation**, but provides business value in the way of good stakeholder and community relations and a positive view of the company.

Hydro Tasmania has **developed many agreements and/or tools to set-up participative and constructive models around multiple uses of its waterways**. Important tools include Memorandums of Understanding between key agencies, water supply agreements, and storage operating rules.

**Communication mechanisms** are important to success. These include written documentation, website information, regular meetings with stakeholders, notification procedures in case of changed operations, and mechanisms for easy contact in case of any issues of concern.

### 7.13.4 References

- **Hydro Tasmania, 2014** “Case study for EDF-WWC framework on multipurpose– Bronte Lagoon, Hydro Tasmania”, Helen Locher and Greg Carson, July 2014
About the author:

Emmanuel BRANCHE, is a Senior Economist Engineer working since 1999 at Electricité de France (EDF). He has working first as a Research Engineer in transmission network planning and as an analyst in power markets across Europe. After his experience within the R&D Division, he joined the Corporate Strategy Division as an Economist in the field of power and environmental public policies (renewable energy sources, energy efficiency and CO$_2$ markets). Then he moved at the Hydropower & Engineering Division for developing carbon finance associated to international hydroelectric projects, and to manage water-energy nexus projects. In particular he is the project manager for World Water Council and EDF Framework “multipurpose water uses of hydropower reservoirs”. He is also in charge of implementing the Hydropower Sustainability Assessment Protocol for EDF, and he is an active member of IHA for many years.

He is representing France at EURELECTRIC Working Group on Hydro, at the IEA Implementing Agreement on Hydropower, and at ICOLD Committee on multipurpose water storage.

He was a Contributing Author and Expert Reviewer for the IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation (May, 2011). He also contributed to the IRENA’s (International Renewable Energy Agency) “Renewable Energy Technologies Cost Analysis series: Hydropower” (June, 2012 and February, 2013) and IEA’s (International Energy Agency) “Hydropower Roadmap” (October, 2012). He also published several articles in the Hydropower & Dams journal.