Strategy for Water Resources

National Adaptation Plan to Climate Change

8 Strategy for Water Resources

8.1 Presentation

This Strategy was developed within the scope of the Water Network (Rede Água) which comprises a group of experts and researchers of various research institutions under leadership of the National Water Agency (ANA) and with the support of the Secretariat for Water Resources and Urban Environment (SRHU/MMA), the Secretariat for Climate Change and Environmental Quality (SMCQ/MMA), and the Centre for Management and Strategic Studies in Science (CGGE). Contributions were also received from a public consultation to which a previous draft of this document was submitted. ANA is the agency responsible for implementation of this strategy.

This Strategy examines the impacts of climate change on water resources and on the main categories of water users. It identifies adaptation measures for improving capacity to respond on the part of water-resources management bodies and for governance of the sector, in a context of greater climatic variability.

It presents the main foreseen impacts of global climate change on water resources on Brazil's macro-regions, provides guidelines for adaptation using water-resources management instruments, and identifies the main water-user sectors. It also names potential institutional players for drafting and implementation of action plans and specific activities.

Implementation of this National Adaptation Plan (NAP) should take into account guidelines provided by the National Water Resources Policy[35], the National Water Resources Plan (PNRH) and other related policy coordination instruments.

8.2 Introduction

Alterations in temperature and rainfall patterns brought on by climate change are likely to cause significant impacts on water availability (volumes and distribution) affecting the multiple uses of water and the general population as a whole. Extreme water-related climate events (flooding and drought) are likely to become more intense. In view of the indispensability of water, water-related issues are likely to be among the first impacts of global climate change felt by populations.

Increasingly, flooding and drought have caught the attention of the public, not merely as a consequence of their economic and social impacts, but also because of mass media coverage. It should, however, be remembered that impacts of extreme events attributed to climate change may also be exacerbated by other pressures on water resources, including inappropriate land-use and settlement in river basins, increasing demand for urban water supply, agriculture and power generation;

[35] Law No. 9433/1997. Available in <http://www.planalto.gov.br/ccivil_03/leis/L9433.htm>.

the intensification of processes that impair water quality, higher exposure of populations, and increased anthropogenic intervention.

Aside from Increased in the variability of hidrological extreme events, one of the potential effects of climate change is a shift in hydrological data series[36] patterns, nowadays considered stationary. Such a shift in stability would affect planning and operation of water-resources infrastructure for multiple uses, since such planning was based on the assumption that historical statistical series would be indicative of the future availability. The planning of water infrastructure and allocation must take into account that the historical hydrological series may not be a reliable guide to future water availability, and may vary in ways not yet completely understood, thereby raising uncertainties as to the design of adaptation measures to be adopted.

To address such uncertainties and reduce information gaps, further investment is needed for climate projections and for studies of potential impacts of climate change on water availability in Brazil.

The question this raises is: how to plan for future water-infrastructure needs, taking into account potential changes in hydrological variables patterns and the high degree of uncertainty of these projections? Such changes may make it necessary to embark upon large civil engineering projects for reservoirs, canals, pumping stations, etc. In seeking to address this situation, society must learn to live with natural climate variability, including its extremes, as a first step towards adaptation to climate change. At the same time, while accepting the possibility of an increase in the frequency of extreme weather events phenomena, water-resources managers must be prepared for potential effects of variability in long-term average flow.

Uncertainties with respect to measurement of the impacts of future climate on the water balance, scarcity of financial resources and implementation gaps in water-resources management indicate a need to adopt no-regrets[37] adaptation measures. Such measures are targeted at problems linked to current climate variability, and hence strengthening resilience to future climate change. i.e., addressing current problems in a more robust manner and thereby increasing the capacity of society, of ecosystems, and of the economy to cope with expected changes.

The main interfaces between water resources and climate change relate to adoption of adaptation measures, targeted at increasing capacity to respond and reducing the vulnerabilities of populations and ecosystems to expected

[36] A data series is considered stationary when it maintains a constant average over time, reflecting some form of stability. (Analysis of Temporal Series, MANOEL IVANILDO SILVESTRE BALOCH, 2006. Available in <http://www.ebah.com.br/content/ABAAAe8xcAD/apostila-analise-series-temporais>.

[37] No regrets adaptation measures are those targeted at problems linked to current climate variability and that, at the same time, seek to strengthen adaptive capacity to future climate change. The benefits of no regrets measures will be perceived regardless of the degree of climate change. - Mainstreaming Adaptation to Climate Change in Agriculture and Natural Resources Management Projects (World Bank, 2010. Available in <http://siteresources.worldbank.org/EXTTOOLKIT3/Resources/3646250-1250715327143/GN5.pdf>.).

adverse climate-change effects. This should be the main focus of an adaptation plan for the water resources sector to complement and reinforce significant Brazilian and international efforts to reduce greenhouse-gas emissions.

8.3 Impacts of Climate Change – Vulnerability

8.3.1. Climate changes Scenarios and its impact on Water Resources

River-basin level simulations carried out in Brazil (NÓBREGA *et al*., 2011; TOMASELLA *et al*., 2009; CAMPOS and NERIS, 2009; MEDEIROS, 2003) generally corroborate studies conducted on a global level (MILLY et al., 2005; UK MET OFFICE, 2005) and on a national level (SALATI et al., 2008) with respect to signs of climate change, i.e., temperature and rainfall variations, etc.

Based on studies of climate-change impacts on water resources at the global level, projections indicate that the various regions of Brazil will be affected differently by the climate change.

The main impacts of climate change on Brazilian water resources can be broken down into four major trends:

More critical water balances in river basins of the Northeast Region, but there is no consensus about rainfall dynamics.
Rapid decline in flow levels, in about 2100, in basins in the western part of the Northeast and Western-Atlantic hydrographic regions;
A decline in availability of surface water in almost all regions of Brazil (lower rainfall may impact river flows in basins that generate hydroelectricity);
Increased rainfall and, consequently, flows in Brazil's South region.

Compounding these effects on surface water, climate change is likely to affect groundwater replenishment rates. One study (Doll & Florke, 2005) estimates that groundwater replenishment capacity in the Northeast region will drop by roughly 70%, by 2050. Likewise, for the Guarani Aquifer System, almost 70% of the climatic scenarios predict variations in the water-table, dropping below those detected by monitoring between 2004 and 2011 (MELO, 2013).

However, knowledge about groundwater levels and its recharge is still incipient. Few studies exist on the impact of climate change on groundwater or on the relationship between surface waters and aquifers (KUNDZEWICZ et al., 2007).

8.3.2. Expected impacts of climate changes on major user sectors

Changes in the water cycle arising from altered rainfall patterns will significantly affect the availability and temporal distribution of river flows. Moreover, impacts on the hydrological regime and increases in demand from various user sectors are to be expected, both as a function of population growth, and of the demands of economic development.

8.3.2.1. Urban Water Supply

Human water supply relies directly upon the availability of quantities of water of appropriate quality, on demand. Regions where demand for human water supply is greatest will be the most heavily impacted by changes in the hydrological cycle. Aside from burgeoning demand arising from population growth and urbanisation and universalization of water-supply services, water stability is likely to be affected by increased consumption stemming from rises in average global temperatures.

Many years of low investment in public water-supply services exacerbate vulnerability to the effects of climate change.

The National Basic Sanitation Plan (PNSB) estimates the costs of repressed demand for investment in universalization of the four components of sanitation services (water-supply, wastewater, urban solid wastes and storm drains)[38] at roughly R$ 508 billion. ANA's 2011 Atlas Brazil on Urban Water Supply[39] presents the results of an evaluation of the status of water sources and water production systems for towns throughout Brazil. The study has enabled verification of the current vulnerabilities which, in a scenario of changing availability and higher frequency of extreme events, will tend to worsen.

Guidelines for urban water supply sector

Orient sectoral planning toward:

1. Consideration of additional vulnerabilities associated with water availability changes.
2. Integration of water resources planning with that of other sectors.
3. Reduce losses; stimulate rational use and quantitative and qualitative monitoring of water sources.
4. Increase investment in wastewater collection and treatment, especially in basins subject to water scarcity, so poor quality does not pose an additional obstacle to use of water resources.

8.3.2.2. Irrigation

It is likely that, in a critical water-availability scenario, conflicts will arise between irrigation and other water-user sectors, including urban water supply and power generation. In critical periods, effective measures will have to be deployed to ensure priorities established in law and to balance the interests of different user sectors.

The irrigation sector currently accounts for 54% of abstracted flows and 72% of effectively consumed flows, making irrigated farming Brazil's largest water-user sector (ANA, 2015). The area under irrigation in Brazil, in 2012, was estimated

[38] Available at <http://www.tratabrasil.org.br/saneamento-no-brasil, accessed on 25/3/2015.>.

[39] Available at <http://atlas.ana.gov.br/Atlas/forms/Home.aspx>.

at 5.8 million hectares, or 19.6% of a potential 29.6 million hectares, according to data from the 2006 Agriculture Census[40] and projections of the National Transport Logistics Plan 2002- 2023. Moreover, aside from the trend for expansion of irrigated farming, changes in rainfall patterns in different regions of Brazil, including some areas traditionally unaffected by drought, may lead to increased demand for complementary irrigation.

In regions with greater water scarcity and, consequently, with greatest limitation on abstractions, two trends may be observed: (1) reduced demand for irrigation water in certain areas as a consequence of introduction of newer technologies or crop substitution, motivated by water scarcity or implementation of water-use charges and other economic instruments; (2) an increase in water-use conflicts, leading to difficulties in enforcement of the decisions of basin committees and constraints of different types.

It should also be remembered that irrigated farming is a highly elastic form of water use. In view of the array of water-saving irrigation techniques now available and the possibility of switching to crops that are less demanding in terms of water, the irrigation sector could, with relative ease and in specific cases, reduce volumes abstracted to adjust to current availabilities.

Guidelines for the irrigation sector

Possible adaptation measures for the irrigation sector include:

1. Capacity building and mobilisation of users for formulation and implementation of contingency plans.

2. Improvement in short and medium-term predictions of water availability for irrigation.

3. Replacement of irrigation technologies by more efficient methods of water and energy use.

4. Adoption of efficient management of irrigated areas.

5. Infrastructure to guarantee integrated supply with other uses and with water resources planning.

6. Strategies for soil conservation with an impact on water production, such as no-tillage, maintenance and restoration of Permanent Preservation Areas (APPs), promotion of conservation, and increased infiltration in aquifer recharge areas.

[40] IBGE, 2010. Available at: <http://www.ibge.gov.br/home/estatistica/economica/agropecuaria/censoagro/default.shtm>.

8.3.2.3. Energy

Brazil is a leading producer of hydroelectric power, accounting for 10% of worldwide generation capacity. According to data from the Brazilian Electricity Regulatory Agency (ANEEL) hydroelectricity accounts for roughly 61% of Brazil's energy mix[41]. This system is highly dependent on medium and long-term availability of water for energy generation and to ensure stability of electricity supplies. Such dependence implies a high degree of vulnerability to changes in the water regime.

Various studies predict, somewhat inconclusively, a decline in rainfall and, hence, of water availability in the Northeast region where significant volumes of hydroelectricity are produced, and in the North where most future generation capacity is likely to be harnessed. For some key Brazilian hydroelectric generation areas, including the Southeast region and the Tocantins river basin, there is no consensus on the part of climatic models as to which future flow-level trends will prevail, and as to whether rainfall levels will rise or decline. For the South region, however, increased rainfall is likely to result in higher flows; however, their use will depend upon storage capacity and allocation decisions.

The option in recent years for run-of-river hydroelectric plants (i.e., without large reservoirs) with a lighter environmental footprint increases vulnerabilities in the event of scenarios with longer and more severe dry periods since, with little storage capacity, such plants rely exclusively on current river flow levels. This may impact operation of reservoirs of other plants that supply the National Interconnected System (SIN) since production levels may not necessarily correspond to the interests of stakeholders in basins in which they are located, thereby intensifying local water-use conflicts.

Hydroelectric plants coupled to large reservoirs offer greater possibilities for management and are less vulnerable to river flow-level variations. A study by CEBDS[42] shows that hydroelectric power plants are subject to different types of impacts, depending on their installed capacity and that, consequently, different strategies for reducing vulnerabilities must be pursued, including switching to other energy sources in the months of water deficit. Moreover, greater storage capacity and the ability to regularise flow levels in water bodies can reduce vulnerabilities for other water-use categories, especially human water supply.

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41 Available at: <http://www.aneel.gov.br/aplicacoes/capacidadebrasil/operacaocapacidadeBrasil.cfm, accessed on 12/3/2015>.

42 Available at: <http://cebds.org/publicacoes/gerenciamento-of-riscos-hidricos/#.VddBD4tRGUk>

Guidelines for the electric-power sector

Possible adaptation measures for the electric-power sector include:

1. Increase inter-annual storage capacity of new hydropower investment Projects.
2. Better management of multiple uses of reservoirs.
3. Increased investment in local electricity generation solutions so as to complement the National Interconnected System.
4. Increased investment in conservation measures and recovery of APPs, with a view to reducing silting of reservoirs and extending their lifespans.

8.3.2.4. Industry

Industry accounts for 17% of total abstractions and for 7% of water consumed, according to a report on the status of water resources in Brazil (ANA, 2015). That the hydrographic regions with highest industrial demand for water are the Paraná, the South-Atlantic and the Southeast-Atlantic demonstrates that this category of use is highly concentrated.

Impacts vary by type of industry and geographic location. Changes in the water regime and the impacts of extreme hydrological events may affect industrial activity (e.g., situations of water scarcity and consequent total or partial lack of supply). The adaptation capacity of industries depends upon size and volumes of resources available for investment.

Guidelines for the industrial sector

Possible adaptation measures for industry must take into account the specific characteristics of each industrial activity:

1. Increase investments in water storage capacity.
2. Stimulate rational use and reuse of water.
3. Use alternative or new energy sources and relocate industrial plants.
4. Invest in technologies to increase water use efficiency for all types of industry.
5. Prepare contingency plans for extreme hydrological events; e.g., define procedures and mechanisms to be adopted in situations of prolonged drought.

8.3.2.5. Water quality and the environment

Climate change may significantly alter water quality and associated ecosystems. It is, however, not easy to quantify these changes, owing to uncertainties relating both to climate projections and to the complexity of interaction among the various factors that affect water quality (hydrology and chemical, physical and biological processes).

Higher water temperatures are expected to be among the most immediate manifestations of climate change. Such temperature rises may causes changes in chemical and biological processes, affecting the water quality. One of the principal impacts will be reduced concentrations of dissolved oxygen that will interfere with the self-purification of water bodies and their ability to sustain aquatic biodiversity.

Warming of surface waters of lakes and reservoirs also increases vertical stratification in these water bodies, thereby reducing the mixing of surface and deeper waters.

Lower flow levels also impact the quality of surface waters. Reduced river flows hamper the capacity to dilute pollution loads, resulting in increased downstream pollution levels.

Longer duration and higher intensity rains can increase non-point pollution caused by sediments, nutrients and pesticides. Higher nutrient levels cause proliferation of algae, which can significantly alter aquatic ecosystems, leading to mortality of fish and food-chain alterations. Cyanobacteria, which produce toxins, generally undergo a greater proliferation at higher temperatures (above 25ºC) when they exert a competitive advantage in relation to another species.

Deterioration of water quality implies higher treatment costs for domestic water supply and industrial uses. It reduces the feasibility of irrigation systems, damages aquatic biodiversity and fish stocks, raises incidences of waterborne diseases, and reduces the attractiveness of landscapes and their value for tourism.

Guidelines for water quality and environment

Possible adaptation measures include:

1. Implement systematic water-quality monitoring.
2. Implement water safety plans, water-quality control and surveillance procedures for human water supply.
3. Invest in technologies to reduce discharges of pollution loads into water bodies.
4. Increase investment in treatment of effluents.
5. Ensure effectiveness of instruments for classification of water bodies in accordance with main categories of use.
6. Invest in recovery of Permanent Protection Areas (APPs).

8.4 Water-resources management adapted to climate change

8.4.1. Guidelines for Water Resources Governance

Good governance of water resources, regardless of the impacts of climate change, depends upon the capacity of federal, state and municipal authorities to make appropriate and timely decisions to ensure compliance and coordinate with stakeholders in the system. In view of uncertainties as to future availability and demand for water and prospects of more frequent and severe extreme hydrological events, there is an increasing need for technical capabilities, appropriate planning instruments and inter-sectoral cooperation among federal, state and municipal bodies, and for new arrangements to strengthen the capacities to respond to situations that stretch the envelope of normality.

This can be a challenge in view of the complexities of Brazil's Water Resources Management System, with its multiplicity of levels and authorities, overlaps and gaps that cause high transaction costs that hamper adoption of more agile and flexible arrangements, undermining the feasibility of timely decision-making. At times, current legislation hinders adoption of more streamline and flexible decision-making arrangements (e.g., formation of dedicated temporary or standing management groups for specific locations and issues).

As important as the structure of the management system is the ability of the institutions to adapt to changing circumstances. This greatly influences the effectiveness of water-resources and of management for multiple use. Recent flooding and drought events have posed challenges to the capacity of the system and to its component institutions, thus revealing the magnitude of the problem of adaptation to critical situations.

Guidelines for governance of water resources systems

Potential adaptation measures are targeted at:

a. Increased capacity of institutions to respond to uncertainties and changing future scenarios:

1. Information and knowledge: generate and disseminate reliable and timely information and knowledge on natural and human systems, taking into account uncertainties (reliable updated water-user registries, climate forecasts, monitoring, appropriate hydrological series, etc.).

2. Conflict management: create or adapt mechanisms for settlement of potential conflicts, including specific suitably empowered bodies, contingency plans and allocation of water in situations of drought, etc.

3. Compliance with rules: setting of well-defined well-publicised rules for use of water resources, consistent with local realities, with mechanisms to ensure compliance and appropriate and enforceable sanctions for violations.

4. Adequate physical infrastructure: (reservoirs, canals, aqueducts, wells, etc.), technology (computer models, climatic-forecast models, weather radars, sensors, etc.) and an institutional framework (institutional diversity, user participation, legislation, etc.) capable of withstanding potential effects of climate change.

5. Learning and adaptation: institutions should be designed to foster transformations needed to address new problems and changing contexts, in a constant process of learning and adaptation. To this end, mapping and assessments should be conducted by the public sector and by sectors of the Brazilian economy.

b. Increase coherence and consistency among the public policies for water resources and other related sectors:

1. Strengthen governmental management; establish the necessary coordination to ensure that water-resources management is incorporated into on-going public-policy planning processes for related sectors, including environment policies.

2. Strengthen participation of municipalities in the SINGREH, in view of its key role in planning of land-use and settlement, management of urban solid wastes, local environmental licensing, and sanitation issues.

3. Clarify concepts and principles relating to water-resources legislation, notably for treatment of critical events, which may entail rationing, suspension of licences and/or reallocation of available flows.

c. Increase the effectiveness of river-basin governance:

1. Prioritise local approaches to problems, through compatible institutional arrangements.

2. Apply the principle of subsidiarity and strategic territorial approaches, for critical/priority regions.

3. Consider targeted management models for the Amazon, semi-arid areas and the South, Southeast and Central-West regions.

4. Expand initiatives for integration of water-resources management among the three levels of government and for increasing the capacities of state-level management systems (especially management agencies) by means of shared goals and incentives.

5. Seek alternatives so that different institutions can perform water resources management tasks, e.g., by means of agreements, management contracts or public-private partnerships.

6. Reduce the distance between collegiate deliberative structures and water-resources management agencies, thereby increasing administrative capacities.

7. Ensure transparency and accountability.

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[43] Subsidiarity is the principle that any decision that can be made locally and does not affect third parties and/or broader issues shall not be submitted to higher hierarchical levels.

There follows a listing of goals relating to the specific objectives of this NAP:

Objective 3. Identify and propose measures to promote adaptation to and reduction of climate risk

Sectoral and Thematic Strategy: Water Resources		
Goal 3.9	**Initiatives**	**Responsible**
Incorporate measures for adaptation to climate change into actions carried out by the National Water Agency.	Identify/propose "no regrets" adaptation measures, targeted at enhancing capacity to respond of the National Water Resources Management System and at reducing vulnerabilities of the main water-user sectors, populations and ecosystems to foreseen adverse effects.	ANA
Indicator/Monitoring:	Progress in deployment of water resources management projects and instruments.	
Impact:	Enhanced the capacity of ANA and of other component bodies of the National Water Resources Management System (SINGREH) to respond to challenges posed by climate change.	

Sectoral and Thematic Strategy: Water Resources		
Goal 3.10	**Initiatives**	**Responsible**
Develop integrated climatic and hydrological models and assess their impact on water resources management.	Use of new modelling techniques with dynamic and statistical methods borrowed from other Global Climatic Model (GCM) families, thereby increasing the number of projections available for analysis of the impact of climate change on water resources.	ANA
	Develop studies using Economics of Climate Adaptation (ECA) methodology, based on the Piracicaba-Capivari-Jundiai River Basin project.	
	Support development scientific and technological researches, by means of a specific call for proposals to be drafted jointly with CNPq, targeted at the climate-change/ water-resources interface.	
Indicator/Monitoring:	Progress in the development of projects.	
Impact:	Enhanced capacity of component bodies of SINGREH to respond to challenges posed by climate change.	

8.4.2. Management Instruments foreseen in the National Water Resources Policy

The main objectives of the National Water Resources Policy (Law 9433/1997) are to ensure availability of water resources for integrated and rational use by current and future generations for purposes of sustainable development, and to promote prevention and defence against natural and anthropogenic critical hydrological events. The Law provides the following instruments for achievement of these objectives:

Water Resources Plans, developed for multiple spatial and temporal scales;
Classification of water bodies into classes, according to prevalent categories of use;
Grating of water right;
Water use charges; and
The National Water Resources Information System (SNIRH).

The main challenge, in the context of expected climate change, is to ensure effective deployment of management instruments that can be adapted to varying conditions, i.e., providing managers and decision-makers with adequate and flexible means of responding to a dynamic system, with a view to improving resilience of the water-resources management system and to addressing the long-term prospects of climate change.

8.4.2.1. Water Resources Plans

Water Resources Plans must seek to identify potential threats to future water availability caused by climate change and indentify their impacts on future demand for water, as like as set guidelines for operation of the water-resources management system under new conditions. To facilitate understanding of the problems involved and ensure uniformity and compatibility of information, an analysis of prospective scenarios should be conducted, encompassing expected climate-change impacts and drawing upon well-established methodologies and a robust database platform.

Contingency plans (especially for droughts and flooding) need to be drawn up and periodically reviewed within the scope of long-term planning to orient actions of the different players involved during extreme weather events, and guide preparations to mitigate the adverse effects of such events. In parallel, a plan for financing the necessary investments must be prepared. Furthermore, planning must encompass definition of structural and non-structural measures and strategic guidelines for allocation of water in basins where conditions are considered most critical.

During elaboration, implementation and review of national, state and basins-level water resources plans, the guidelines provided in this NAP must be considered.

8.4.2.2. Classification of water bodies

Many decision-makers and water-resources managers have not yet understood that classification essentially serves as a river-basin planning tool for setting of water-quality targets with acquiescence of local stakeholders. Climate change may have significant repercussions on water quality and flow levels, and on reducing the capacity of water bodies to dilute pollution loads, thereby exacerbating point and non-point sources of pollution.

Adoption of a single reference flow level as a basis for classification creates a constraint for management, since quality targets are usually set on the basis of extremely limited reference flows, making such targets hard to meet. Moreover, adoption of a single reference flow level for decision-making fails to allow for adjustments in changing scenarios, thereby increasing uncertainties stemming from such restrictions. One alternative entails adoption of a 'probability of occurrence' approach to water-quality parameters. Under this approach, a certain degree of risk of not meeting water-quality targets is accepted, taking into account the cost of depollution measures needed to ensure compliance with classification goals. This type of approach enables greater flexibility for management, since the risk of non-compliance is not tied exclusively to a progression of classification goals, but also takes into account changing climate scenarios.

Adoption of the following practices would help achieve effective deployment of water-body classification:

Integrate classification goals with municipal sanitation plans.
Expand funding mechanisms for deployment of depollution actions.
Expand and standardise water-quality monitoring to accompany effects of climate change and attainment of classification goals.
Take into account climate-change scenarios and uncertainties when setting water-quality targets and classification criteria.
Coordinate activities of different institutions to obtain environmental license and grant water-use rights according to classification criteria.

8.4.2.3. About Grating of water right

Climate-change projections indicate that the status of water resources in certain basins will become critical in both quantitative and qualitative terms. This situation demands strong institutional arrangements and more flexible water-use licensing criteria to enable management of the water balance, allocation among water users and different categories of use. Endowing licensing instruments with sufficient robustness and flexibility to respond to different possible scenarios implies adoption of less conservative service parameters, specific procedures for critical areas and transparent mechanisms and criteria for cancellation, curtailment or suspension of water rights.

A new set of procedures should encompass less conservative reference flows and allocations to different users, collective grants and temporary licenses, risk and economic-value assessments for decision-making, and reallocation of volumes. Such special situations require reliable information, more technical training, greater coordination and communication with the water users, and higher supervision capacity.

The following alternatives are suggested for adapting water-resources licensing instruments to address the impacts of climate change:

Examine the possibility of licenses that establish limitations in the event of critical flow levels in atypical water-availability situations; this implies proportional curtailment or interruption of permitted abstractions, duly explained in contingency plans or allocation agreements and with prior acquiescence of users, drawn up on the basis of technical studies that demonstrate the need for such actions.
Draw up negotiated water-allocation agreements for areas where critical levels have been reached or in cases of extreme hydrological events.
Consider risk assessments and stakeholder preferences when examining alternatives for addressing risks, taking into account the capacity of water users to absorb such risks.
Introduce more flexible service parameters: when adopting criteria for setting abstractions limits of licenses, possibly in association with reference-flow variations.
Verify institutional and legal security (criteria and sequencing of actions) for suspension of water-use rights in situations of extreme hydrological events.
Seek more effective compliance with licensing conditions.

8.4.2.4. Water use charges

Water use charges play an important role in acknowledgment of water as an economic good, for indicating its value to users, encouraging rational use, and securing funding for defrayal of water-resources management actions. In view of the expected impacts of climate change on availability and demand for water resources, incentives for rational use and investment in specific actions become more urgent.

When viewed as a revenue source for river basins, such charges serve as an important instrument for deployment of strategies for adaptation to climate change, within the context of water-resources plans and contingency plans and when setting investment priorities. Investment of such resources in programmes and activities that effectively result in a reduction of risks stemming from climate change may assuage the perception of users that such charges are just another tax.

Flexibility may be called for when investing proceeds of water-use charges and should include participation of private-sector stakeholders, with a view to attracting further investment and ensuring the effectiveness of interventions.

In view of projected scenarios that point toward increased hydrological risks, water use charges may be used to defray deployment of other management tools. Such tools might include insurance for users that suffer losses owing to unfulfilled demand and rewards for users that reduce their abstraction volumes, thus mitigating the risks of failure to meet local river-basin priorities.

On the other hand, the main purpose of water use charges is to make users aware of the monetary value of these resources, with the proviso that, in critical situations (i.e., scarcity) the rates should increase. To this end, it is important that the sums charged reflect the status of the local water balance, and that charges should rise in situations of scarcity and for more extravagant forms of use, with a view to stimulating greater efficiency and rational water use.

Alternatives for maximising the positive effects of water-use charges in a scenario of climate change include:

Prioritise actions under basin plans and contingency plans, defrayed by proceeds of water use charges.
Increase transparency and accountability with respect to investment of the proceeds of water use charges.
Conduct economic analysis in support of water use charge increases, when justified.
Allow flexibility of charges to reflect the status of the water balance (higher charges in times of scarcity) and the efficiency of water use.
Allocate part of the proceeds of water use charges to preparation of adaptation projects, enabling access to specified funding.

8.4.2.5. The National Water Resources Information System (SNIRH)

Adaptation of water resources management to uncertainties brought on by climate change requires the best possible information, provided in a timely and practical manner, to assist with decision-making. Therefore, the adaptation of the SNIRH must entail endowing it with the capacity to provide current and readily-accessible data to stakeholders, based upon a robust database platform.

To meet such demand, and to provide real-time availability (especially during flooding events) more automated data-gathering and processing capabilities will be needed, including standardised methodology and information formats, with the aim of applying the latest methods for setting up a good communication and dissemination strategy.

The national hydro-meteorological network is in need of some water-resources management enhancements to address changing behaviour of hydrological scenarios. The main challenges are:

Increase the availability of information from rainfall monitoring stations and flow-level measurement posts in urban areas.
Increase the number of flow-monitoring stations in small river basins.
Expand monitoring of evaporation and evapotranspiration, sediments and water quality.
Increase availability of flow-level data series for rivers subject to eddy and tidal or reflux effects.
Strengthen early-warning networks and deployment of situation rooms in regions with histories of extreme events.

Investments in science, technology and innovation are needed for modelling and monitoring water resources availabilities, as will be discussed in more detail in Section 8.6.

8.4.3. Complementary water-resources management instruments

In view of new foreseen water-resources management challenges and in addition to instruments already provided for in current legislation, new regulations and approaches could afford solutions or minimise potential losses caused by climate change, including as yet unforeseen consequences. Listed below are some examples of new tools that could be adopted:

Implement Decision-making Support Systems (DSS): the growing need to manage ever increasing amounts of water-resources management information requires the use of analytical tools capable of quantifying cause-and-effect relationships and orienting decision making. DSSs are ideal tools for such functions, since they offer flexibility and facilitate communication with users and decision makers.
Stimulate and regulate deployment of an insurance system for extreme hydrological events targeted at each user sector and category of use.
Define and reach agreement upon offset mechanisms among user sectors for each type of situation where restrictions apply to certain categories of use, in order to protect other categories.

Consider permanent or temporary adoption of other economic instruments, targeted at promoting sustainable use of water, such as subsidies, taxes and fees, including for effluent discharges.
Increase the range of fiscal incentives to expedite objectives of water-resources plans.
Support payment for environmental services, whereby beneficiaries earn financially rewards for initiatives that quantitatively and qualitatively enhance water availability.
Consider Payment for Environmental Services (PES) as an instrument for recovery and conservation of river basins

Other management measures that could be adopted include: water user organisations, rules for water rationing, compliance monitoring of water rationing, and establishment of funds for damage mitigation.

8.5 Conflict Management

Burgeoning demand from an array of water-user sectors and the prospect of increasing water scarcity may cause or aggravate water-use conflicts. To handle such potential conflicts, the management system must be capable of issuing clear guidelines and offer compensation mechanisms for sectors that are required to reduce their water consumption.

Adaptation measures proposed in water resources plans or in other instruments and programmes must be perceived as firm commitments to be fulfilled within foreseen timeframes. Thus, goals and targets need to be negotiated between the representative bodies appointed by SINGREH and those responsible for execution of said programmes and actions, with a view to ensuring their effective deployment and appropriate coordination.

To this end, it is essential that negotiation mechanisms clearly identify potential or actual points of conflict stemming from the effects of climate change. It is desirable that basin-level entities have experienced negotiators, capable of drafting agreements among the parties concerned. The role of water resources management bodies in such processes is essential, and they need to be prepared to manage conflicts over allocation of increasingly scarce water resources.

Conflict management groups, comprised of water-resources managers and stakeholder representatives, should participate in water-resources management discussions when and wherever necessary. Water resources plans and other management instruments should adopt procedures, criteria, and priorities for management of conflicts.

Risk management plays an important role in reducing conflicts and in preparations for addressing them. To this end, joint efforts should focus on reducing all factors that contribute toward increasing risk, by means of the planning and preparation of responses. In practice, it entails raising awareness about risks and deepening studies and simulations to define methodologies/ parameters for achieving an adequate risk-sharing balance among the various water-user sectors. Indeed, a good risk-transfer agreement can significantly minimise potential conflict situations

Finally, it is important that open communication channels be maintained among the various user sectors and water-resources managers, with a view to preventing or managing potential conflicts.

8.6 Science, Technology and Innovation

There are a number of evident weaknesses and knowledge gaps that hamper or undermine the feasibility of actions for addressing vulnerabilities and potential impacts on the water-resources sector of effects associated with climate change.

Such difficulties include: insufficient research on climate and water resources; though basic hydro-meteorological information is available, the degree of detail does not meet the needs of small basins; there is a lack of hydro-meteorological information and of climate-change projections broken down by biome; and consistent data is not always available within required timeframes. The following suggestions aim to overcome these weaknesses:

Award priority to the development of the following lines of research: climatic and hydrological processes, prognosis of hydro-climatic variables, impact assessment of hydro-climatic scenarios and respective strategies for adaptation and mitigation of impacts, correlation between land use and changes in flow patterns of water courses and of water quality.
Prepare an evaluation study to modernise the physical and hydrological database, with a view to improving the current hydro-meteorological network (new technologies, remote and hard-to-access areas, provision of information and data series, seasonal and short-term forecasting).
Ensure that outputs of monitoring and scientific research are suitable for application to water resources, especially in terms of (1) temporal and spatial resolution; (2) information update time; (3) standardisation of data and of network operations.
Promote technology transfers and capacity-building, in line with the UNFCC’s Capacity Building principles.
Ensure the systematic monitoring of key hydrological variables to enable characterisation of risks and uncertainties involved in three types of networks: (1) systematic observation; (2) reference river basins; (3) early warning.

8.7 Communications

The expected impacts of climate change on water resources raise questions for decision-makers, water users and the general public, relating to factors such as: lack of consensus among the most prominent models; uncertainties of impact projections, especially on regional and local levels; and incompatibilities between the scales on which climate studies are conducted and the appropriate scale for water-resources planning and management. A good communications approach for the theme must provide a unified outlook for addressing the phenomena and risks involved, and express them clearly to all players, so as to provide the best information available and indicate approaches for coping with expected impacts.

Communication between scientists and decision-makers

There is a disconnection between providers and users of information. It is thus necessary to strengthen consensus on the need for active involvement and understanding and for actions and links between scientists and water resources policy makers. To this end, communication channels for disseminating scientific knowledge must be strengthened, using tools that enable sharing of results with society and decision-makers, expressed in clear language and applying of said knowledge to practical problem solving. Scientists should provide inputs for decision makers, based on the best technical possible information so that it can be evaluated alongside the policy components and the appropriate decision made.

Understanding and incorporation of risk

Notwithstanding their inherent uncertainties, climate-change projections contain valuable information, provided it is efficiently communicated to water users. Decision-makers are accustomed to dealing with uncertain and incomplete information, but they need a better understanding of the sources and degrees of uncertainty involved. A clear characterisation of possible climate risks and of the confidence levels of their projections can provide a better basis for planning and decisions as to the need for adaptation measures. There is thus a need to consider communication strategies for conveying the risks to water-user sectors, clearly communicating potential impacts associated with climate change on water availability and the possibility of supply failure, so that they can prepare to cope with such risks.

More transparent communication with the public

Appropriate and timely communication is essential, so that society can appropriately prepare to confront impacts associated with climate change, especially in relation to extreme hydrological events. To prepare the public, channels for constant dialogue must exist between government and the public, and especially the more vulnerable segments of the population. Such channels endow government actions with transparency and enable more efficient communication with the business sector, academics and civil-society organisations.

Another challenge entails standardisation of a common language, to be adopted so as to avoid divergent interpretations among user sectors. To this end, the climate change agenda will require an institutional structure of working forums, comprised of representatives of different user sectors and of government.

8.7.1. Institutions responsible and timeframe

The guidelines discussed in this chapter feature elements to enable identification of potential institutional players to participate in the drafting of relevant plans of action (Table 14). Some of these elements are crosscutting, entailing coordinated networking among two or more institutions and thus greater complexity in terms of execution. The table below indicates potential partner institutions to lead implementation of this plan over the coming years. ANA, as the body responsible for implementation of the National Water Resources Policy, will have varying degrees of responsibility over all these actions, and thus does not appear on the list. However, since no agreement has yet been reached as to the specific attributions of these institutions, the list should be regarded as merely indicative.

Table 14. Potential institutions for elaboration of plans of action

INSTITUTION RESPONSIBLE	
Item/Guideline	**Partner institution**
WATER-RESOURCES MANAGEMENT ADAPTED TO CLIMATE CHANGE	
Governance	SRHU, state-level institutions and authorities representing the SINGREH (committees and councils)
Adaptation of current instruments	SRHU and state-level institutions
Conflict management	SRHU, state-level institutions and authorities representing the SINGREH (committees and councils)
SCIENCE, TECHNOLOGY AND INNOVATION	
Develop priority lines of research	MCTI/MEC/SRHU
Studies for evaluation to modernisation of the physical and hydrological database, with a view to integrating the existing network	ONS/CPRM
Promote the suitability of outputs of monitoring and scientific research	MCTI/MEC/SRHU
Ensure systemic monitoring of key hydrological variables and development of key indicators.	MCTI/MME/SRHU
COMMUNICATION	
Communication between scientists and decision-makers	MCTI/MEC/SRHU
Communication with society should be more transparent	MCTI/MEC/SRHU/MI