Climate Changes Water Demand Management

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Abstract

Climate is a fundamental driver of the water cycle. It determines how much water is available (supply) and it is also an important factor determining how much water is needed (demand) in the short and long term for people, food and ecosystems. By 2020, between 75 and 250 million people are projected to be exposed to an increase of water stress due to climate change. Globally, water demand will grow in the coming decades primarily due to population growth and increasing affluence; regionally, large changes in irrigation water demand as a result of climate changes are expected. If nothing is done, both trends will adversely affect livelihoods and exacerbate water-related problems. With growing evidence to the contrary, all governments must begin by re-evaluating the adequacy of their infrastructural facilities as well as their legal, technical, and economic, policy and institutions approaches for water management and water services in the light of predicted impacts of climate change. Supply and Demand Measures: Adaptation measures to ensure water supply during average and drought conditions can be distinguished as demand-side and supply-side measures. The former improve water-use efficiency, *e.g.*, by new technologies such as drip irrigation, restrictions on use, water conservation campaigns and pricing. Supply-side strategies generally involve increases in storage capacity, abstraction from water courses, and water transfers. Integrated water resources management provides an important framework to achieve adaptation measures across socio-economic, environmental and administrative systems. This article presents a brief introduction on supply and demand management and selected examples.

Key words: climate change, demand management, supply management, integrated water resources management.

1. Introduction

1.1 Water for People: Population Pressures

At the end of 2007, following the United Nations Conference on Climate Change in Bali, little doubt remained that the world's 6.7 billion people are under serious threat from global warming, and that urgent international action must be taken. The message was that humans are climate changers - directly or indirectly the main cause of climate change. In short, demographic growth is one of the drivers of climate change[1]. Had efforts been made to stabilise human numbers in 1975, when the planet was inhabited by 4 billion climate changers, there would be fewer than 6.7 billion climate changers now and the image would be far less bleak.

Continuous population growth, fuelled by an expected increase of 2.5 billion people on the planet up to 2050, is multiplying the impacts of climate change and will increasingly be ecologically unsustainable. World population is still growing by some 80 million a year. A larger global population means a larger demand for everything--most urgently, energy.

1.1.1 Urbanisation

The principal non-climatic factor affecting water demand is the growth of human population. The pace of population growth, including (over)consumption, is so profound that it is expected to outpace any potential environmental benefits from industrial modernization and improving technologies. Urbanization, economic structure, and age of a population are other factors that have relatively little effect[2]. Increased urbanization however, raises the demand for industrial, residential, and agricultural water use, leading to an increase in hydrological droughts and masking the effect of potential changes in the Earth's climate. In addition, increased urbanization results in more impervious surfaces, and channelization of streams and rivers, which in its turn lead to an increase in both hydrological droughts and floods.

Both the growth of population and increased urbanization lead to steep increases in demand for services. Combined with many old systems that spill water, the overall resultant of a growing population is increased water stress. This stress can be resolved by either building more efficient infrastructures or by making the services more efficient and control water use.

1.2. Water for Food: Irrigation Pressure

Agriculture of any kind is strongly influenced by the availability of water. Changing temperature and precipitation patterns will lead to different water needs for irrigation. The demand for water for irrigation is projected to rise in a warmer climate, bringing increased competition between agriculture, already the largest consumer of water resources in semiarid regions, and urban as well as industrial users. Both changes in total precipitation and in seasonality are important. Falling water tables together with a higher demand due to higher evaporation will make irrigation more expensive. When land is taken out of irrigation, following a trend that has already begun, considerable prior investment will be lost. Peak irrigation demands are also predicted to rise due to more severe heat waves. Additional investment for dams, reservoirs, canals, wells,

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[1] From the UN Framework Convention on Climate Change which came into force on 21 March 1994: "While the world's climate has always varied naturally, the vast majority of scientists now believe that rising concentrations of greenhouse gases in the earth's atmosphere, resulting from economic and demographic growth over the last two centuries since the industrial revolution, are overriding this natural variability and leading to potentially irreversible climate change."

[2] Dietz *et al*., 2007

pumps, and piping may be needed to develop irrigation networks in new locations. Intensified evaporation will increase the hazard of salt accumulation. In general, crop varieties with greater drought tolerance become more interesting for farmers. However, what happens to the agricultural economy in a given region, or country, will depend on the interplay of the set of dynamic factors specific to each area.

In addition to the increasing hydrological problems, an increasing world population needs more food, thus more land and water. The same holds true for energy. These increasing demands can be managed by either greater water or land supply (if available), or by making the production of food and energy more water efficient.

1.3. Climate Change increases water stress

Impacts of climate change on water resources will be felt in virtually every aspect of natural resources management. All decisions about long-term water planning, the design and construction of new water supply infrastructure, the type and acreage of crops to be grown, urban water allocations and rate structures, reservoir operation, and water-supply and demand management depend on climatic conditions and what humans do to respond and adapt to those conditions. Many uncertainties remain about the timing, direction, and extent of these climatic changes, as well as about their societal implications. Indeed, the most important effect of climatic change for water systems will be increasingly the overall uncertainty managers face. These uncertainties greatly complicate rational water resource planning and have contributed to the ongoing debate over how to respond.

Globally, the negative impacts of future climate change on freshwater systems are expected to outweigh the benefits. By the 2050s, the area of land subject to increasing water stress due to climate change is projected to be more than double that with decreasing water stress. Areas in which runoff is projected to decline face a clear reduction in the value of the services provided by water resources. Increased annual runoff in some areas is projected to lead to increased total water supply. However, in many regions this benefit is likely to be counterbalanced by the negative effects of increased precipitation variability and seasonal runoff shifts on water supply, water quality and flood risks.

2. Managing water stress on supply side and demand side

2.1. Managing water related stress: a case of supply and demand management

A characteristic of water demand is its inexorable rise over many years; continued growth is projected over coming decades. Meeting this increasing demand from existing resources is self-evidently an uphill struggle, particularly in water stressed/scarce regions in the developed and developing world alike. There are typically two potential responses:

1. Supply-side: meeting demand with new resources
2. Demand-side: managing consumptive demand itself to postpone or avoid the need to develop new resources

Table 1: *Supply and demand side strategies for different sectors. Table adapted from IPCCC, 2001.*

SUPPLY SIDE	DEMAND SIDE
MUNICIPAL WATER SUPPLY	
Increase reservoir capacity Extract more from rivers or groundwater Alter systems operating rules Inter-basin transfers Desalinisation	Incentives to use less (pricing) Legally enforceable water use standards Increase use of grey water Reduce leakage Development of non-water-based sanitation systems Seasonal forecasting
INDUSTRIAL AND POWER STATION COOLING	
Increase source capacity Use low-grade water	Increased water-use efficiency and water recycling
HYDROPOWER GENERATION	
Increase reservoir capacity	Increasing efficiency of turbines: encourage energy efficiency
NAVIGATION	
Build weirs and locks	Alter ship size and frequency
POLLUTION CONTROL	
Enhance treatment works	Reduce volume of effluents to treat Catchment amangement to reduce polluting runoff
FLOOD CONTROL	
Increase flood protection Catchment source control to reduce peak discharges	Improved flood warning and dissemination Curb floodplain development
IRRIGATION	
Increase irrigation source capacity	Increase irrigation-use efficiency Increase drought-tolerant varieties Change crop pattersn

There is considerable pressure from the general public, regulatory agencies, and some governments to minimize the impacts of new supply projects (*e.g.,* building new reservoirs or inter-regional transfer schemes), implying the emphasis should be shifted towards managing water demand by best utilizing the water that is already available.

2.2. A total approach: Umgeni Water Supply

An interesting example of a combined or total approach, entailing measures on both the demand and the supply side, is that of Umgeni Water. Umgeni Water is one of Africa's most successful organisations involved in water management and the largest bulk water supplier in the province of KwaZulu-Natal, South Africa. It is one of the largest catchment-based water utilities in Southern Africa, supplying safe drinking water to almost 4.8 million people annually. Climate change has been identified as an inherent risk and is therefore incorporated into the Corporate Risk Register[3]. It is recognised that investigations are required to establish a better understanding of the potential impacts of climate change at a local scale, such that appropriate control measures can be instituted to bring the residual risk to a level that the organisation is willing to accept. Based on the outcomes of this project, Umgeni Water will need to develop adaptive sustainable strategies to mitigate against the risks associated with these potential impacts. Water resource development plans, system operating rules and disaster risk management plans will contain the means of implementing these strategies. As such, Umgeni Water is systematically including climate change risk on both the supply and demand side of the water supply equation.

[3] Umgeni Annual Report 2007-2008

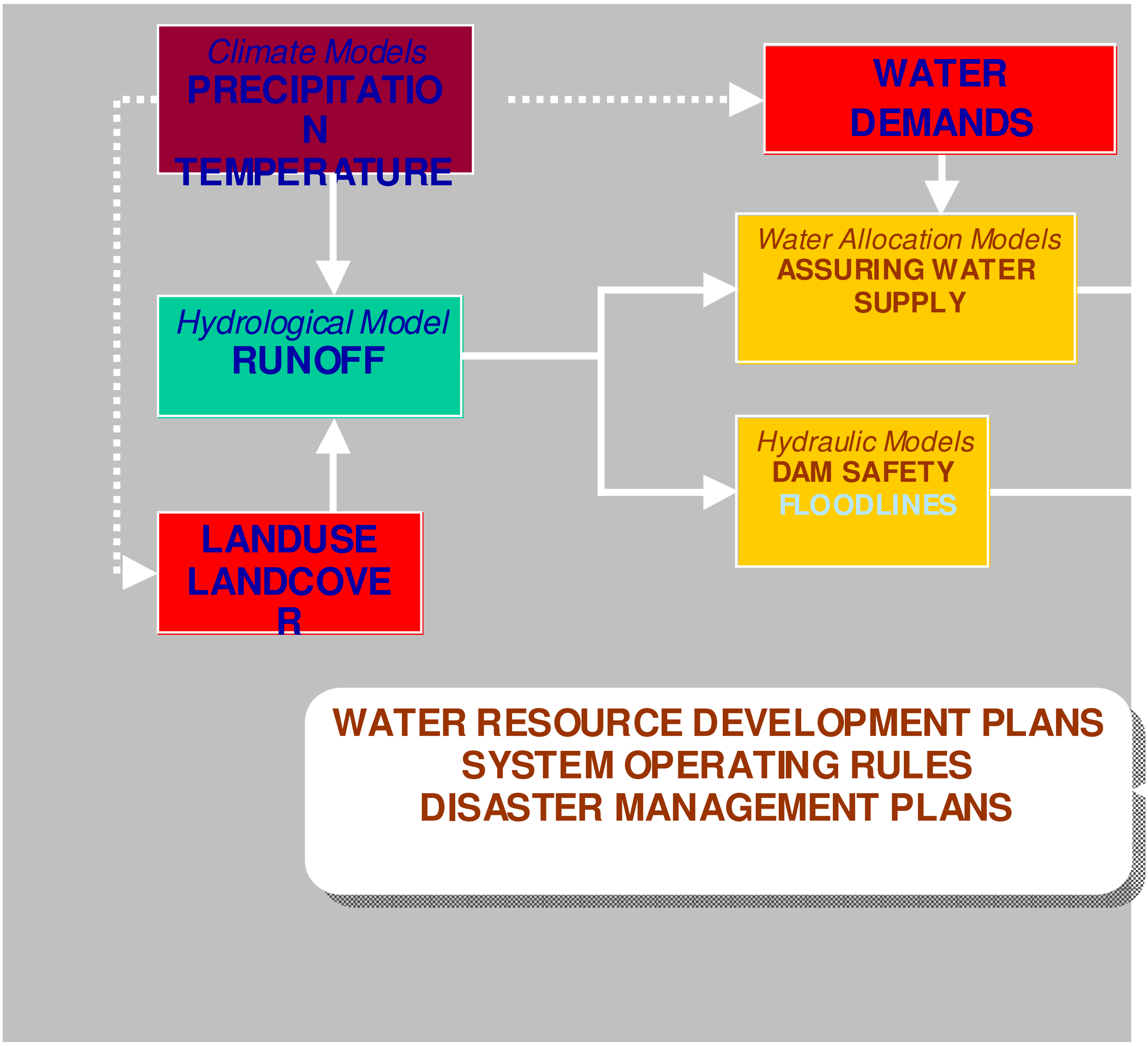

Figure 1. *The Umgeni water strategy: catchment based impact scenario assessment process.* Source: Steve Gilham, Umgeni Water, South Africa.

2.3. Specific supply side measures

Water supply can be seen as the process of self-provision or provision by third parties of water of various qualities to different users. As a fundamental driver of the hydrological cycle, climate determines how much water is available (supply) in the short and long term.

Below, a few examples illustrate how countries deal with a decrease in water by implementing measures on the supply side.

Ethiopia: construction of dams

Ethiopia is a landlocked country in the eastern Horn of Africa. The need for water in Ethiopia is severe; their access to water supply is one of the lowest in the world. Along with limited food supply, during times of drought, water-related diseases are rampant. Surface water sources such as springs and ponds dry up. What limited water sources remain become heavily contaminated by environmental waste, such as human and animal excreta which is washed in when the limited rains do come. The stagnant water serves as a breeding place for mosquitoes. Projected future climate trends are decreases in rainfall amount exacerbated by higher evaporation rates associated with the increasing temperatures. Projections of precipitation are more uncertain than projections on temperature and considerable regional variations exist. According to the country's First National Communications to the UNFCCC, precipitation is expected to decrease in the northern regions, while southern areas could see an increase of as much as 20%. Solutions for Ethiopia lie on the supply side via dam constructions, but it should be noted that investments to reach water security require 144 years at 5 percent of GDP.

Australia: desalination

Australia is mainly going for supply side management by introducing desalination technologies. The city of Perth is facing a serious water shortage. Over the past 10 years or so, the city has seen a 21 percent decline in rainfall, but the stream flow into dams — the actual amount running into storage — dropped about 65 percent. The Water Corp. turned to the nearby Indian Ocean to help solve the water shortage problem. The Kwinana Desalination Plant south of the city opened in November of 2006. The facility, the first of its kind in Australia, covers just a few acres in an industrial park next to the ocean. It is located just south of Perth, and turns water from the Indian Ocean into about 150 million litres of drinking water per day, roughly 20 percent of Perth's daily consumption. That makes the plant the single largest source of water for the city. Some predict that desalination will account for at least half of Perth's water in the next 30 years. Other water-stressed seaside cities in Australia are taking a serious look at desalination, as traditional water sources dry up because of lack of rain. Sydney, on Australia's southeast coast, gave concept approval for the desalination project and project approval for the desalination plant at Kurnell, an even larger plant than Perth's.

United States of America: Rethinking big dam policies because of climate change

The era of massive dam construction in the West — which tamed rivers, swallowed towns and created irrigated agriculture, cheap hydropower and persistent environmental problems — effectively ended in 1966 with the completion of Glen Canyon Dam in Arizona. But the population of the Western states grew nearly 20 percent in the 1990s, to more than 64 million, and continues to swell. Demand for water from growing cities, industry, agriculture and struggling fish runs is already high. Increasing the pressure are fears that climate change will cause rain instead of snow to fall in winter, reducing the snowpack that provides water in summer months. So once again, governments began studying dams, this time to create huge reservoirs to capture more winter rain and spring snowmelt for use in dry summer months.

2.4 Water demand management

Water demand is interpreted as demand for services, including drinking water, irrigation, hydro, navigation, and even protection in case of storms. Essentially the concept in water management is water security. Countries or basins are considered highly stressed if the per capita water availability is less than 1,000 m^3 per year based on actual run off (Falkenmark, 1989). This amount includes water for drinking, food production, industry, hydropower etc. Estimates of the population living in such severely stressed basins range from 1.4 billion to 2.1 billion (Kundzewicz *et al.*, 2007).

Box I: Critical words on desalination

Desalination offers the potential of an unlimited source of fresh water purified from the vast oceans of salt water that surround us. The public, politicians, and water managers continue to hope that cost-effective and environmentally safe ocean desalination will come to the rescue of water-short regions. While seawater desalination plants are already vital for economic development in many arid and water-short areas of the world, many plants are overly expensive, inaccurately promoted, poorly designed, inappropriately sited, and ultimately useless[4]. The potential benefits of ocean desalination are great, but the economic, cultural, and environmental costs of wide commercialization remain high. A study by the WWF found that desalination uses large amounts of energy, emits greenhouse gasses and destroys marine life in some coastal areas (WWF, 2007). The building of desalination plants can thus actually accelerate greenhouse gas emissions and increase climate change.

In many parts of the world, alternatives can provide the same freshwater benefits of ocean desalination at far lower economic and environmental costs. These alternatives include treating low-quality local water sources, encouraging regional water transfers, improving conservation and efficiency, accelerating wastewater recycling and reuse, and implementing smart land-use planning.

Source: Cooley et al., 2006

Water demand management can be defined as any method - whether technical, economic, institutional, financial or social- that will accomplish one (or more) of the following five tasks:

1. Reduce the quantity or quality of water required to accomplish a specific task;
2. Adjust the nature of the task or the way it is undertaken so that it can be accomplished with less water or with lower quality water;
3. Reduce the loss in quantity or quality of water as it flows from source through use to disposal;
4. Shift the timing of use from peak to off-peak period;
5. Increase the ability of the water system to continue to serve society during times when water is in short supply

Water demand management strategies and tools therefore enable water-use efficient, equitable and sustainable practices and policies. Essentially, it requires a change in behaviours and practices in the way in which water is used, particularly in the agricultural sector where most of the water is consumed.

Water demand management is a strategic and effective adaptive no-regret strategy to the current challenge of water scarcity and will become more so as climatic variability and climate change impacts intensify. It increases social resilience and contributes to

[4] At present, the only significant seawater desalination capacity is in the Persian Gulf, on islands with limited local supplies, and at selected other locations where water options are limited and the public is willing to pay high prices.

preparedness policies. There are several difficulties to consider in this process: first, the impacts of climate change on the water sector are complicated and to a large extent unpredictable. Second, many impacts may be non-linear and chaotic, characterized by surprises and unusual events. These difficulties complicate the development of measures.

Examples of demand management measures include:

- Campaigns for water economy at household and industrial level (Atlanta). For instance, cards in hotel rooms asking 'Our State is experiencing severe water shortage. Please join us in our efforts to conserve this precious resource';
- Economy in water use (economic shower heads, water free toilets, water economic washing machines);
- Pricing;
- Restrictions on users, for instance lawn watering only at night (Australia, UK, USA);
- Restrictions on allocations, for instance contracts with utilities, farmers (Philippines and North East Brazil, elaborated in the two examples below that demonstrate how tailored climate information can help water managers allocate water), and
- Regulations on building codes and settlements (in flood prone areas) connected with insurance (USA).

Below, more detailed examples of demand management measures in practice can be found.

Example 1: Metro Manilla, Philippines - allocation managing demand using climate forecasts

The reservoir that supplies water to Metro Manila is increasingly vulnerable to hydrologic variability, both drought and flood. A large irrigation area also relies on water from the reservoir in this shared water system. In times of water scarcity, questions of where the water should be allocated become critical and often contentious. Research institutions work with the urban water supply service, irrigators and national level agencies to create anticipatory strategies for managing water crises[5]. Together, they are exploring economic mechanisms such as option contracts and index insurance and building capacity in the use of climate information and forecasts in order to allocate water efficiently and equitably.

Example 2: Ceará, Brazil - allocation water through demand management

Drought is a major challenge for those who rely on water in Ceará, Northeast Brazil, such as farmers and irrigators, as well as the Fortaleza metropolitan area. Scientists have developed a long-range forecast (up to 18 months in advance) of the inflows to the major reservoir system. Simulations have shown the potential for improved reliability of water deliveries for all users when forecasts are integrated with reservoir releases. Continuing work focuses on capacity building with local stakeholders in order to operationalize forecast use.

[5] http://portal.iri.columbia.edu/portal/server.pt/gateway/PTARGS_0_5280_2009_0_0_18/water.pdf

Example 3: Spain[6] - inter-basin transfers?
Spain has to deal with unevenly distributed rainfall and large arid areas, while at the same time experiencing a growing consumption (13 % per year) despite having highest retention already (El Pais, June 2005). In 1985, Spain passed the Water Act, which established a framework of integrated water management. It made the river basin agencies, still dominated by the central government but with broader participation than in the past, the primary institutions responsible for water planning. This act broadened the emphasis on supply augmentation to include additional goals of environmental protection, water quality improvement, and water use efficiency. In 1999, this law was amended to introduce the elements for voluntary exchanges of water rights among users— water markets. The changes are a significant improvement, although they have not "solved" the country's water problems. Water deficits are still a problem in the more arid parts of the country, and tensions between urban and agricultural water users are growing. Major inter-basin transfers are under consideration, despite active opposition by environmental and other groups. Other measures include demand management, e.g., reduction of losses by linking investments to performance (leak reduction).

3. Conclusion: Diversify risk with portfolio approach

Many water utilities have begun to respond to climate change through "adaptation" measures to modify plans and operations to minimize impacts. These adaptation efforts fall into two broad categories. The first consists of vulnerability analyses that are intended to identify the most near-term priorities in places where impacts could be felt the soonest. The second is long-term planning, or more formally, Integrated Resource Planning (IRP) that adopts the broadest possible strategic view of how a utility can plan to cope with such systemic changes over the longer term. In addition, utilities are responding through adoption of measures to help mitigate the onset of climate change by reducing energy consumption that contributes to the production of greenhouse gases.

3. 1 The Portfolio Approach

The long-term response that is most prevalent in discussions of climate change is fortunately one that is familiar to many water utilities – IRP, often called Integrated Resources Planning, or Integrated Water Resources Management (IWRM), although it is sometimes undertaken without being explicitly labelled as such. A hallmark of this approach to long-term planning is the adoption of a very broad view of the problem that "integrates" all facets of it – environmental, socioeconomic and engineering – as a basic strategy for keeping a wide range of options open and providing a maximum of flexibility. All of the advice on adaptation to climate change begins with the same message: employ a portfolio approach – maintaining a maximum degree of flexibility and resiliency. The continued improvement and refinement of best practice in IRP will be of significant value to water utilities in coping with climate change.

An essential part of maintaining a broadly "integrated" approach is the continuous involvement of all stakeholders. IRP is most appropriate to problems of sweeping

[6] Kemper, Dinar, and Blomquist 2005; Fraile 2006.

proportions that involve complex trade-offs between multiple objectives and multiple constraints. The best solutions are made possible in such situations because IRP recognizes that stakeholders have the capacity to redefine some of the objectives and constraints when necessary to avoid an impasse. But this only works if stakeholders are fully involved.

The bottom line in water supply planning has always been a matter of coping with variability. With the coming changes in climate, there will be a heightened need to respond to increased variability. The net effect of the direct impacts of global warming will be to change the variability of key parameters affecting the quantity and quality of water that would normally be expected to be available at any specific time and place. In addition, the capability to store water in various forms and the demand for water will be changed.

Given the sweeping extent of these changes, the IRP approach of taking the broadest possible view of the problem is indeed an ideal adaptation strategy. Working within broadly established system boundaries, it is possible to approach optimization in a manner that first derives maximum advantages from flexible operating strategies to expand the number of ways in which supplies can be managed to meet demands. This can have the benefit of deferring irreversible capital projects that may present more risk in a changing environment. Water utilities already employ sophisticated modelling tools (RIVERWARE, BASINS, OASIS, WEAP) to design such operating strategies, and it seems likely that applying such modelling tools to the design of adaptation strategies will be as, or more, important a priority as the climate models previously discussed in the examples of Manilla and Ceará.

Significantly, the IRP approach also features comprehensive assessment of strategies that can be applied to manage the water demand side of the equation. Warming processes will lead to altered demand patterns as a result of seasonal shifts in precipitation, more evaporation, more frequent heat waves, and more extensive droughts. Conservation programs offer a bonus in reducing both water supply needs and energy use. Bolstering conservation incentives (and disincentives to outdoor water use) may become more essential if warming processes otherwise increase water demands, especially during coincident peak demand periods when both water supply and electric power capacities are stretched to their limits.

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