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ORIGINAL ARTICLE

A stakeholder driven process to reduce vulnerability to climate change in Hermosillo, Sonora, Mexico

Hallie Eakin · Victor Magaña · Joel Smith · José Luis Moreno · José Maria Martínez · Osvaldo Landavazo

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Abstract While there is a growing body of knowledge on potential impacts of climate change on water availability, there has been much less empirical research on exploring the viability of particular adaptation options. The participation of stakeholders in defining appropriate adaptation strategies is increasingly recognized as a critical element in the translation of climate change impact research into effective actions to reduce future vulnerability, yet the process by which stakeholders are included in such initiatives is not well-defined. This article presents the results of a pilot project in which a participatory approach was employed to identify and evaluate adaptation options to climate change scenarios for Sonora's capital city, Hermosillo. In an iterative process, stakeholders representing different water users and managers in the city met to discuss climate change

H. Eakin (✉)
Department of Geography, University of California, Santa Barbara, CA 93106-4060, USA
e-mail: eakin@geog.ucsb.edu

V. Magaña
Centro de Ciencias de la Atmósfera, Ciudad Universitaria, Universidad Nacional Autónoma de México, México, DF CP 04510, Mexico

J. Smith
Stratus Consulting Inc, P.O. Box 4059, Boulder, CO 80306-4059, USA
e-mail: jsmith@stratusconsulting.com
URL: www.stratusconsulting.com

J. L. Moreno · J. M. Martínez
El Colegio de Sonora, Calle Obregón #54, Col. Centro, Hermosillo, Sonora, CP 83000, Mexico

J. L. Moreno
e-mail: jmoreno@colson.edu.mx

J. M. Martínez
e-mail: josemaria@colson.edu.mx

O. Landavazo
Universidad de Sonora, Blvd. Luis Encinas y Rosales, Col. Centro, Hermosilo, Sonora, Mexico
e-mail: olanda@iq.uson.mx

scenarios, identify specific adaptation options, and evaluate a subset of options for possible future implementation. This process enabled the focus of the investigation on those adaptations that addressed not only concerns with the potential future impacts of climate change but also the immediate and pressing concerns about development patterns and water use in the city. Two of the adaptations to climate change identified by stakeholders would also reduce energy demand. The simplicity of the approach makes it a feasible model for adaptation initiatives in other regions of Mexico and in other countries in Latin America.

Keywords Adaptation · Mexico · Stakeholder participation · Water management

1 Introduction

Water availability will be one of the more pressing problems resulting from the alterations in the hydrological cycle anticipated under climate change. The impact of climate change on water resources is likely to be greater in the semi-arid and arid regions of the world, where climatic variability already has a determinant effect on water availability and where competition over water allocation to meet the needs of growing populations is already acute (IPCC 2001). Higher temperatures will increase actual or potential evapotranspiration, potentially reducing soil moisture and water supplies. Should climate change result in a decrease in precipitation, the impacts on water resources will be even more severe.

Although there is some disagreement over the sign and magnitude of precipitation change estimated by general circulation models (GCMs), the models tend to show that in the future Mexico will face higher temperatures, particularly in the northern region (Mendoza et al. 1997). Rising temperatures will increase already high soil moisture evaporation rates, which, unless combined with substantial increases in precipitation, will most likely result in reduced runoff and soil moisture levels (Nash and Gleick 1993).

Studies of potential climate change impacts show that northern Mexico's water users and ecosystems are vulnerable to these climatic changes (e.g., Mendoza et al. 1997). Population growth and the relative low level of economic development contribute to regional sensitivity to both climatic variability and climate change (U.S. EPA 2000). As in many semi-arid regions, water use in northern Mexico is higher than use in the country's more humid regions, straining water supply capacity and infrastructure for both surface- and ground-water systems. Already periodic deficits in precipitation have resulted in hydrological droughts in recent years and even in binational problems related to trans-boundary water allocations (Magaña and Conde 2003).

The city of Hermosillo, in the desert state of Sonora (Fig. 1), is one of the many rapidly industrializing cities in the developing world that faces problems with water availability. The shift in the regional economy from an agricultural base to an orientation towards service provision has attracted immigrants from other parts of the state and nation, placing new demands on the city's water resources. In the urban sector, daily per capita water consumption in Hermosillo is around 330 liters, one of the highest in Mexico.

In short, socioeconomic pressures and Hermosillo's exposure to climatic variability create a situation of increasing vulnerability to extreme climate conditions. This vulnerability is particularly acute in the water sector, where a combination of environmental and

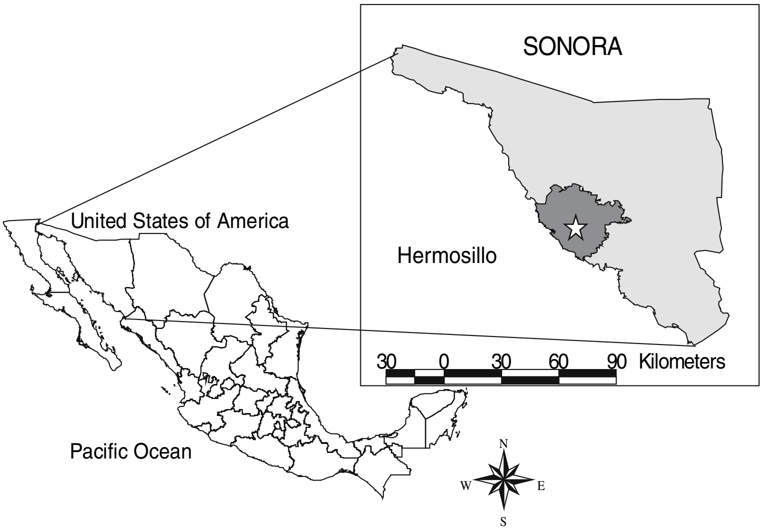

Fig. 1 Geographical location of Hermosillo, Sonora

socioeconomic changes will affect future water supplies and thus will require adaptation measures.

This article presents the process and results of one of the first projects to explicitly address adaptation to climate change in Mexico. The project was designed to examine a process of adaptation to potential impacts of climate change on water resources in the state of Sonora. One of the principal goals of the project was to involve stakeholders in the project's design and implementation and to coordinate the project's adaptation proposals with local policy priorities. Thus rather than beginning with the construction and evaluation of climate change scenarios, as is often done in vulnerability and impact studies (e.g., Carter et al 1994; Benioff et al. 1996), the project used work already completed on climatic change scenarios and variability for Sonora as the point of departure (Magaña and Conde 2003). In this light, the project reflects a new international focus on the process of adaptation as outlined in such initiatives as the Adaptation Policy Framework of the United Nations Development Programme (Lim et al., 2005). The project's focus was on identifying, evaluating, and setting priorities among options to adapt to the impacts of climate change. As it turned out, two of the three adaptations identified by stakeholders would also reduce energy demand (by reducing demand for water). Thus, the measures are both suitable for mitigation and adaptation.

A participatory approach was employed both to define the specific adaptations and to qualitatively evaluate and prioritize the options. While the proposed adaptations may, with further elaboration, prove to be important contributions to reducing the vulnerability of the city to climate change, the ultimate success of the project was in the stakeholder participation process. The process enabled the introduction of a new issue—climate change—into an ongoing and heated debate over Hermosillo's present and future water problem, in the context of the stakeholder workshops. To the extent that the participants represented decision-making agencies (for example Agua de Hermosillo, the National Water Commission and the National Institute of Ecology), the project may well have planted the necessary seeds for the incorporation of climate change adaptation into new policy initiatives. The pilot project thus represents a feasible model for adaptation initiatives not only in other regions of Mexico but also in other countries in Latin America.

2 Water, adaptation, and public participation

The relatively high uncertainties associated with climate-hydrological scenarios often challenge the formulation of concrete adaptation plans (IPCC 2001). Yet over the last decades, significant advances have been made in improving water resource planning to anticipate and reduce conflict over water use, guarantee quality and supply, and—perhaps most important—change public attitudes toward water management (National Research Council 1999). It is now widely recognized that achieving more sustainable water use practices can be best reached through policy processes that involve public debate, education, and the direct participation of a variety of stakeholders in policy formation and implementation (Downs 2001a; Ammons and Rawls Hill 2002).

While public participation in local development, planning, and priority-setting exercises and project implementation is not without its challenges (see Chess et al. 2000), there is a growing consensus that carefully managed processes of public participation not only enhance the relevancy of decision outcomes but also help ensure that the decisions are viewed as credible (Cash et al. 2002). The educational exchange among different stakeholder groups involved in participatory decision-making processes is a tangible benefit in its own right, often just as important as the decision outcomes.

The recently published United Nations guidelines on adaptation to climate change (Lim et al. 2005) identify stakeholder participation in adaptation policy formation as fundamental to the successful reduction of present and future vulnerability. Recognizing that most adaptations will be implemented by individuals and communities, adaptation policy is seen to be successful when originating from a diverse range of stakeholders from the initial planning stages (Lim et al. 2005). Adaptations that arise from and are thus consistent with an evaluation of current development needs and policy priorities are likely to be more readily accepted by both the public and by policy-makers. In addition, although the focus of adaptation is on the growing threat of climate change, it is now thought that adaptations may be most appropriate when they consider the particular climatic threats of the recent past and present (Lim et al. 2005). Participatory practices and research methods can ensure that proposed adaptations meet the above criteria.

3 Climate of Sonora, Mexico

The climate of northern Mexico is essentially semi-arid. Annual precipitation in Sonora is around 420 mm, but it varies from around 200 mm near the border with the United States to more than 600 mm at higher altitudes. In Sonora, the Mexican monsoon is associated with a short period of numerous, severe storms in July, August, and September. Winter cold fronts may result in precipitation as well. Annual mean temperature in Sonora varies between 15°C and 25°C. Maximum temperatures may be well above 30°C year-round, reaching 45°C in summer. In most of northern Mexico, evaporation exceeds precipitation and consequently there are low levels of soil moisture during most of the year.

Interannual climate variability is partially related to El Niño/Southern Oscillation (ENSO), with more winter rains during El Niño events. In most of northwestern Mexico, intense El Niño years with enhanced winter rains may well raise the levels in dams and consequently increase water availability. La Niña years result in fewer or no winter rains and consequently dry conditions for most of winter and spring.

The region also exhibits interdecadal patterns of climatic variability characterized by relatively long periods of negative and positive precipitation anomalies. In the 1970s and 1980s annual precipitation in Hermosillo showed a positive trend, reaching mean values of around 400 mm (above the long-term average 300 mm/year) (Fig. 2). This pronounced positive trend in precipitation was evident in most of northwestern Mexico (Magaña and Conde 2000) and resulted in increased streamflow in the region. In the 1990s a decline in annual rainfall to the average annual values of approximately 300 mm led to severe problems with surface water availability (Meza 2001). Although there was a return to normal values of precipitation at the end of the 1990s in the region, the government water agency interpreted the 1990s a period of severe drought.

One of the most interesting aspects of precipitation in Hermosillo is that periods of increased precipitation are associated with more extreme precipitation events. This means that more rainfall results from more severe storms (Fig. 3). In fact, there has a positive trend in intense precipitation events in most of the state of Sonora. Summer rains that result in flooding in the streets of Hermosillo are now more frequent than in previous decades.

4 Sonora: socioeconomic setting

Water demands in the state of Sonora have grown rapidly, driven largely by the agricultural sector and more recently by industrial and urban expansion. Increases in irrigation use coupled with rising demand in the urban areas have resulted in competition for access to the resource. Water scarcity in Hermosillo could well exemplify one of the more serious problems of northern Mexico. It is estimated that approximately 75% of available water is used in agriculture. Although the agricultural sector substantially reduced water consumption in the 1980s, the aquifer underlying the region's agricultural districts remain overexploited (Moreno 2000). In most cases, the irrigation methods used

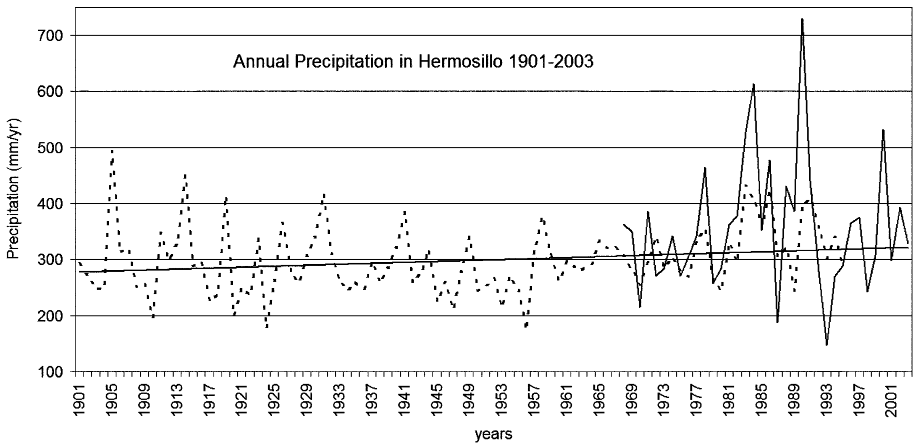

Fig. 2 Long term Trends in Annual precipitation in Hermosillo, Sonora, 1901–2003. Interpolated values (dashed line) from IPCC (2004), and observed values in Hermosillo (solid line) from Mexico National Water Commission (IMTA 2000)

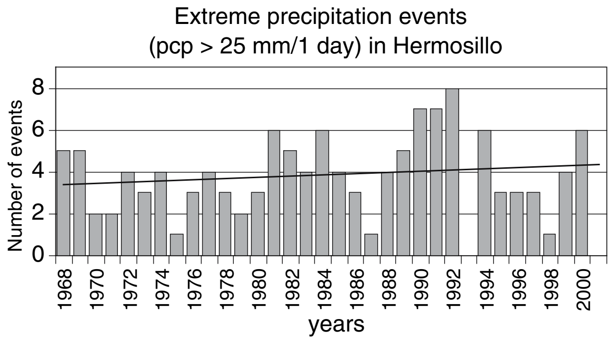

Fig. 3 Number of annual extreme precipitation events in Hermosillo, Sonora, with linear trend line (Méndez Pérez 2003)

are not considered highly efficient. Water for irrigation is practically free, and consequently little has been done to improve irrigation systems and water efficiency, particularly in agriculture's ''social sector''—the agricultural communities, called *ejidos*, that received land as part of the land distribution process initiated after the 1910 agrarian revolution. Water efficiency in the urban sector is also not high, and this issue has recently become one of the most important for the city and the state.

As in many of Mexico's northern states, scarce water supply and increasing water demand have become central political concerns in Sonora. This is particularly true for Hermosillo, the state's capital, where public officials are struggling to create sustainable policies to meet the growing demands of the urban and light industry sectors. According to the latest national population census, annual population growth in Hermosillo county (*municipio*) averaged 3.13% between 1990 and 2000, exceeding the national average by more than one percentage point (INEGI 2000). Today the county's population is over 600,000 and is projected to exceed 800,000 in less than three decades (Fig. 4). Much of the population growth over the last few decades has been fueled by the shift in the state's economy away from its historical dependence on agribusiness to an increased emphasis on manufacturing and light industry.

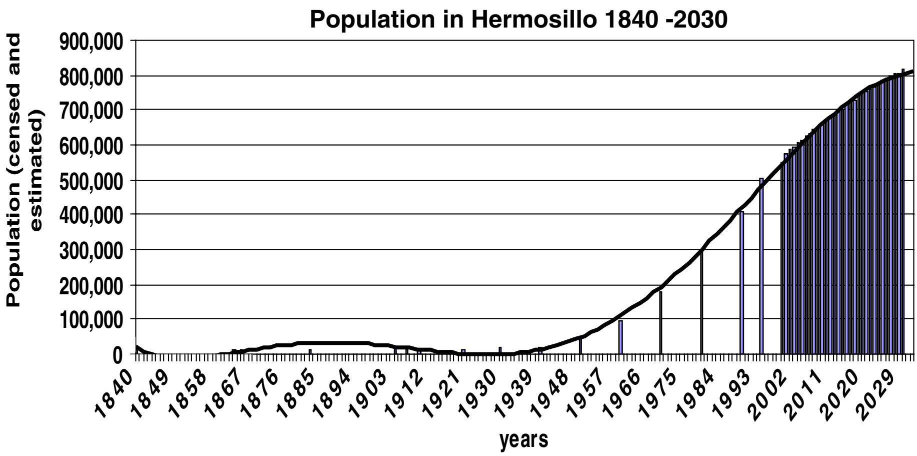

Fig. 4 Recorded and projected population in Hermosillo Sonora (elaborated from data of CONAPO 2004)

Hermosillo is home to the largest automobile assembly plant in the country, owned by Ford Motor Company. The factory is expected to expand in the future (Kachadourian 2003), generating new jobs and a potential population growth. Hermosillo has also has been an attractive site for other types of assembly plants and factories over the last decade. At the end of 2003, Sonora was home to 200 assembly plants of different kinds, employing over 70,000 workers (INEGI 2004). The services sector has also grown and today may be the second most important activity in Hermosillo. In addition, Mexican authorities are promoting a federal tourism development project called *Escalera Nautica* for the Gulf of California coast that may also have implications for future water use and demand in the Hermosillo municipality (León and Graizbord 2003).

Although agriculture remains the principal water user in the state in Hermosillo, urban and industrial uses are increasingly competing for access to water. The Abelardo Rodríguez dam's water supplies over half of Hermosillo's water, and during the last years of drought the city had to impose water rationing. The city also draws from 42 wells. Researchers working on the *Escalera Nautica* project estimate that approximately 36% of Hermosillo's water supply is unaccounted for—lost through leaks or other inefficiencies (León and Graizbord 2003).

The city's water demand is estimated to be about 96 Mm^3/year, with an annual deficit of 13 Mm^3/year (Lagarda Lagarda 1998). As a result of droughts and growing water demands, per capita supply has been declining (Piñeda Pablos 1998). The city's capacity for water treatment is low, and very little wastewater is recycled. The city also does not have any facilities to enhance rainwater capture and use.

As a result of the city's water crisis in 2001, the state governor and the city undertook a review of options to enhance water supply to the city, reduce its dependence on highly variable water sources, and meet anticipated increases in demand. They considered various options of piping in water from neighboring aquifers (Costa de Hermosillo, Pesqueira, Mesa del Seri and Willard) and dams (El Molinito and El Novillo) (COAPAES 1999). The result of this study, undertaken by the state Commission on Potable Water and Drainage (COAPAES), was a rejection of all options that required acquiring well rights from agriculture. Farm organizations are politically powerful in Hermosillo, and have aggressively opposed policies that would entail expropriating their water sources (Moreno 2000). Partly in consideration of this political pressure the city decided in favor of building a desalinization plant on the Hermosillo coast, 110 km from the city. Although it appears that the decision to build the plant has been made, there is some opposition from environmental groups and academics who feel that not enough other mechanisms have been explored (water markets, conservation mechanisms, infrastructure repair, education, and participation). This process of public debate provided an ideal opportunity to introduce the topic of adaptation into the discussion of water policy and planning.

5 Sonora: climate change challenges

The present problem of limited water availability and rapidly growing demand in Hermosillo implies that water will continue to be an issue in the region well into the future, regardless of significant climate change. In this project, two climate change scenarios that had been developed in the context of a previous research initiative were used to stimulate discussion with stakeholders in the city (Magaña and Conde 2003). These scenarios were developed on the basis of an analysis of trends in observed climate data from the region and a comparison of several general circulation model outputs.

This process revealed that temperature in the region does not exhibit a clear trend, given the relatively cool period in the 1960 and 1970s, which resulted in negative temperature anomalies for more than 20 years. However, the time series of precipitation data exhibit a weak positive trend toward higher values. This is particularly clear in the 1970s and 1990s, when extreme precipitation events appeared to increase in frequency. An extreme precipitation event is defined as 24 h of accumulated precipitation, high enough to have a 10% probability of occurrence (Méndez Pérez 2003). A positive trend in extreme precipitation is related to more severe storms, particularly during the summer months. In Hermosillo, extreme intense precipitation frequently results in flooding.

GCM outputs were used to examine possible future changes in precipitation and temperature by means of the Model for the Assessment of Greenhouse-gas Induced Climate Change (MAGICC/SCENGEN) tool (Wigley 2004). Simulations of current climate were estimated with the observed forcing, while radiative forcing from various emissions scenarios (such as SRES A1B, A2, etc.) were imposed for future-climate simulations. Most of the climate models project an increase in temperature (IPCC-DDC). The probability of higher temperatures in the Sonora region is greater than 95%. The expected changes in mean annual temperature are between 1°C and 2°C for 2050. However, there is substantial uncertainty about the changes in precipitation. The probability of increased annual precipitation over the period 2000–2050 is low, only between 15% and 50%, meaning that some of the models pointed to more precipitation (e.g., GFDL) while others pointed to less precipitation (e.g., ECMWF). The probabilities for climate change were obtained after estimating the dispersion in the probability density function resulting from various climate change experiments from various GCMs and emission scenarios. A scatter plot for temperature versus precipitation for the Sonora region shows that most GCMs project a temperature increase for the 2050 climatology, but a less defined signal for precipitation (Fig. 5).

According to a recent study by Arritt (2005, submitted), climate simulations for the 2070–2099 in the North American monsoon region (which incorporates the state of Sonora) indicate little change to precipitation in the monsoon core, but large inter-model

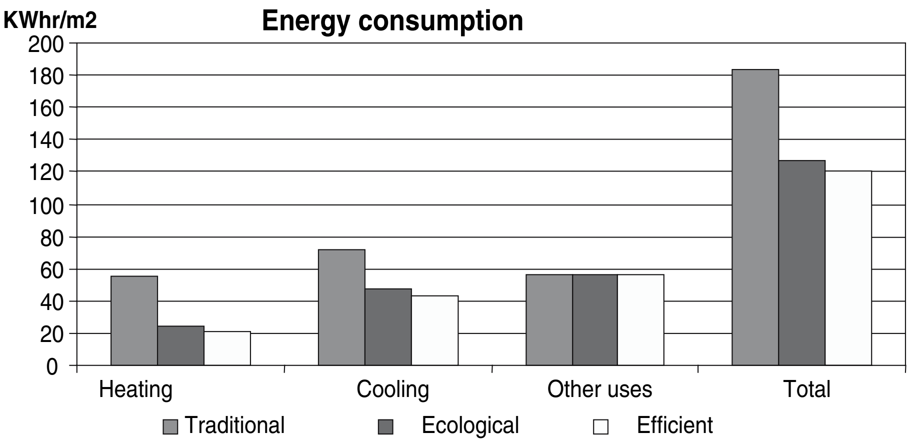

Fig. 5 Results of the Energy-10 model, comparing annual energy consumption of a traditional (modern) house in Hermosillo (traditional), house constructed of biodegradable materials (ecological) and the third with thermally efficient commercial materials (efficient)

variability suggests low confidence in predicted changes or lack thereof. For a semi-arid region like Sonora, higher temperatures with either more or less precipitation will result in a larger soil moisture deficit.

On the basis of the observed trend in extreme precipitation events, and the high probability of temperature increases and uncertainty associated with future precipitation in the GCM outputs, two scenarios were proposed for northwestern Mexico:

- warmer and drier conditions; and
- warmer and wetter conditions, with more precipitation associated with a larger number of extreme precipitation events.

6 Methods to define adaptation options

To ensure that a variety of stakeholders from the public and private sectors was involved throughout the study, the project was implemented in three phases. In the first phase, researchers from the National Autonomous University of Mexico (UNAM) and the *Colegio de Sonora* conducted an initial assessment of water/climate concerns in Hermosillo and possible adaptation options through a series of informal interviews with water managers, water user associations, representatives of different water-consuming sectors (e.g., agricultural unions), local environmental officials and nongovernmental agencies, and academics in May 2002. This process resulted in a preliminary list of adaptation options that were already under consideration or were of interest in the community, as well as key issues relating to water supply and the impacts of climatic variability.

A formal stakeholder workshop to present the topic of climate change and water to the community followed from this initial assessment. Invitations were sent to a wide variety of stakeholders who were known to be involved in issues of water management, use, or research, including those consulted in the initial interviews. Approximately 20 stakeholders attended the meeting, including water managers and representatives of urban water interests, nongovernmental organizations, and academics.

Very few of the agricultural sector participants attended the workshop, possibly because of the highly conflictive and political nature of the debate over urban-rural water allocation in the region. Representatives of farm organizations consulted independently at the start of the project perceived that they were often considered the culprits of the water problem. They argued that the water supply issue had been ‘‘overly politicized’’ and that the agricultural sector had already made substantial improvements in water efficiency that were not adequately recognized by urban decision makers. Rather than being exclusively a rural problem, the farmers viewed the issue as being inter-sectoral and related to the broader uses of the watershed, in which correcting urban water leakages and ‘‘reducing the insatiable demand’’ for water in the city needed to be made a priority. They argued that agricultural water usage be evaluated in light of its strong present and historical contribution to the region’s economy. While they called for technical (rather than political) solutions to the problem, they simultaneously expressed considerable skepticism about the credibility of previous technical studies of water supply and demand in the region.

The participants in the meeting were provided with both climatic and socioeconomic scenarios, based on general trends in urban and rural development and demographic patterns. In breakout groups, the participants discussed the various scenarios within the context of the present priorities and problems facing the city of Hermosillo, including concern over the possibility of more frequent events of intense rainfall in the future, as well as in respect to a preoccupation over general water scarcity from growing water use and demand, poor water storage, and a depleted aquifer. In a plenary session following the breakout groups, the various proposals were discussed and developed into five adaptations options for possible further consideration:

1. promote a ''culture of water'' among water users to reduce the demand-side pressures on the resource and improve public consciousness of water scarcity;
2. improve housing design and the use of construction materials to reduce water consumption and energy loss;
3. capture rainwater runoff and improve groundwater filtration;
4. inject captured excess runoff into the groundwater; and
5. reduce water demand in the agricultural sector.

In this first workshop, the participants did not set priorities among these options. The fourth and fifth options were dropped from consideration by the project team following the workshop. The technical complexity of groundwater injection was considered by the research team a substantial obstacle to its further elaboration in the context of the project, and to its practical realization in Hermosillo. The central ambition of this option—to enhance ground water supply—was incorporated into the evaluation of rainwater capture (Option 3). The fifth option was dropped as a result of the limited participation of agricultural sector representatives in the meeting and the resistance expressed by those who did attend to any adaptation measures that would require a reduction in irrigation water consumption. Many participants also concurred in the opinion that economic forces and poor water quality were resulting in a natural decline in agricultural activities that would be manifest in a substantial reduction in water consumption in the next ten years.

The remaining proposed adaptations illustrated the relatively holistic perspective that the participants had on the issue of adaptation: they were interested integrating climate change adaptation into a broader ambition of improving the general sustainability of living in the Sonoran Desert region rather than more narrowly addressing future water supply problems. Options 1 and 2 were notable in that they not only addressed adaptation to tightened water supplies, droughts, and a potential long-term drying of the climate but also would decrease energy demand (through either less use of heated water or reduced need for indoor air cooling) and reduce emissions of greenhouse gases to produce energy.

The adaptation options the group selected became the focus of the project in the months following the workshop. Consulting with stakeholders continued to form a central part of the process of elaborating each proposed adaptation option. The following sections present the results of the *Colegio's* elaboration of the three proposed adaptations as a form of feasibility analysis. Results from this part of the project were presented and discussed with stakeholders in a second workshop in Hermosillo in July 2003.

7 The adaptations

7.1 Culture of water

The objective of the ''culture of water'' adaptation option was to facilitate the consideration of water conservation measures by urban residents in Hermosillo, with the idea that under both ''warmer and wetter'' and ''warmer and drier'' scenarios the water demand of the growing population would most likely outpace supply, even if the region were to benefit from increased rainfall in the future. The emphasis of this adaptation thus was on demand-side management through new technology adoption and the active involvement of the public in conservation efforts. In addition, any efforts to improve water conservation would help mitigate the city's dependence on fossil fuels for water transport and storage. The elaboration of the details of the project component was based on a review of similar demand-side management projects in arid regions both in Mexico and elsewhere (focusing especially on the approaches employed in Monterrey, Mexico and Zaragoza, Spain).

To ground the elaboration of the adaptation option in the perceptions and behavior of local residents, in the spring of 2003 the *Colegio de Sonora* research team implemented a questionnaire in 280 households in 19 different neighborhoods in Hermosillo, stratified by socioeconomic class. This sample was not intended to be strictly statistically representative, but rather to complement a recent statistical survey of water consumption in the city (Acuña and León 2001) by focusing on public perceptions and attitudes about water and energy. The same general methodology was followed as in the Acuña and León study, but with a smaller sample in a representative subset of Hermosillo's neighborhoods. A review of previous research revealed that 50% of domestic water consumption in Hermosillo came from bathroom use rather than from watering lawns or using cooling systems as originally suspected by the workshop participants (Moreno 2003). The survey implemented by the study team found that the households surveyed recognized that water was an important problem in the city, and the majority (66%) attributed the problem to rainfall deficiency and resulting water scarcity in the city's dam. Ninety-five percent of the respondents were willing to conserve water and were receptive to adopting water-saving household technologies (e.g., low-flow toilets, shower heads, and faucets), particularly if such technologies would result in lower water utility payments.

Based on average water consumption data for typical households in Hermosillo and manufacturers' specifications of potential savings, the project team estimated potential water savings from the adoption of a package of water saving technologies that could be installed in residential bathrooms. The team believed that a focus on such a technology package not only would be an effective way to reduce per capita water consumption but also would involve the greatest number of residents in the water conservation process and thus also would serve as an educational tool. The potential water savings were compared across different categories of water consumers (as defined by the public water utility for charging its customers) to evaluate the potential for reducing water utility fees for each consumer category. The team found that the two highest water consumer categories were in the residential sector (i.e., households that consume monthly between 36 m^3 to 50 m^3 and those that consume monthly between 51 m^3 to 72 m^3) and would stand to gain most economically from the technologies, although in absolute numbers they are not the largest group of consumers (Table 1).

The team concluded that full adoption of the new technologies could contribute to overall water savings of up to 50% of current use. In 2003, the cost of the technology package ranged from 90 pesos to 120 pesos (roughly US$8 to US$11). With water savings to the city potentially reaching 15 million m^3 per year, the net savings (subtracting the cost of the new technology purchase and installation) would be approximately 78 million pesos (approximately US$7 million). Reducing water demand in homes would also save energy by reducing pumping and treatment of water, both of which consume energy. However, the purchase cost of the package is relatively expensive for many people in Hermosillo and thus is a barrier to widespread adoption. The total cost of the technology is expected to be about 20 million pesos (approximately US$2 million), assuming the cost of 90–120 pesos per set.

Table 1 Residential water consumption in Hermosillo

Consumer group (m^3/month)	Number of consumers	Water fee (pesos/m^3)	Current (2003) total consumption of consumer group (Mm^3/year)	Future consumption with new technology (Mm^3/year)	Savings as % of 2003 water expenditure*
0–10	14,003	34.13 (flat rate/month)	0.84	0.59	0
11–14	15,447	2.88	2.32	1.62	0–15%
15–35	106,423	4.01	31.93	22.35	30–50%
36–50	22,810	6.7	11.77	8.24	58%
51–75	2,391	22.99	1.81	1.27	30–88%
76 or more	680	24.81	.31	.22	30%
Total	161,754		48.97	34.28	

Source: Agua de Hermosillo, elaborated by Moreno (2003)

*The savings reflect an assumption of full adoption of water savings technologies, resulting in an average reduction of 33% in household water consumption, according to the specifications of the technology manufacturers. The degree of savings in water expenditure depends on whether the reduction in consumption changes the households' consumer group, and thus the fees paid per m^3

The team recommended a gradual implementation plan, coordinated closely with the city's program of water meter installation and the structure of water management and supply in the city. Selected homes in each of the city's water service sectors that have water meters would initially adopt the technology on a trial basis, and water consumption and costs associated with the technology would be monitored and evaluated. Any improvements necessary in the technology package and installation plan would be made based on the results from this trial period. After six months, these homes would be used as examples to facilitate broader adoption of the technologies over a two-year period. Mechanisms to cover the cost of the technologies would be developed concurrently with the trial phase of implementation, possibly involving a subsidy program administered by the water utility (recuperated over time in water fees) as an incentive program for adoption.

7.2 Housing design

The concept of adaptation by changing the type of building materials used in construction was a response to the recognition of participants at the stakeholder workshop that the popular conception of ''modern housing'' in Sonora was not compatible with the harsh environment of the Sonoran desert, and would become even less compatible under future climate change. In the last decade, the number of houses built in Sonora increased by 40% (COMPROVI 2002). The image of ''modernity'' manifested in this recent housing construction has been the extensive use of concrete, brick, and glass, cooled with a water cooler or air conditioning system, with little consideration of energy conservation. This housing style contrasts sharply with the houses that were common in the region up to the mid-20th century, built with materials such as adobe.

The workshop participants were unanimous in their opinion of the temperature advantages of the more traditional materials over those now commonly used in construction. It was thought by the stakeholders that the incompatibility of ''modern'' materials with the surrounding environment would only worsen with the high rate of population growth and projected climate change in the region. It was also recognized that the process of and materials used in housing construction were also sources of environmental contamination. Not only does the production of particular materials such as concrete, brick, glass, and plastics contribute to greenhouse gas emissions but also the energy use required to maintain a livable climate within structures of these materials can create a substantial demand for fossil fuel consumption (Natalini and Klees 2000; OECD 2003).

The stakeholders in the workshop believed that one of the primary sources of water consumption might be the water cooler systems most typically used in Sonoran households for air cooling during the summer months. By changing the design and insulation of houses, this consumption might be substantially reduced. Although the research was inconclusive about the proportion of water consumed by coolers (and there was considerable debate over this point in the stakeholder workshops), the research team thought that improving housing design could be an important adaptation to rising temperatures in terms of overall energy and water conservation, while also addressing the problem of greenhouse gas emissions in the energy consumed in both building construction and use. In addition, reduced energy consumption would reduce the need for cooling water at thermoelectric power plants.

Three experiments were conducted to evaluate possible adaptations in housing construction to the Sonoran climate (Martínez et al. 2003). The first entailed collecting data on construction costs and materials, energy and water consumption, and interior temperatures for a prototype ecological house that was constructed by the University of Sonora for a regional livestock association entirely of straw bales and adobe in the outskirts of Hermosillo in 2002. These data were compared with data on the average cost of construction for Hermosillo's houses (Table 2) and with data provided by a cement-processing firm on average interior temperatures of houses built of cement block (Ponce 2003). Results illustrated significant water savings (65%) as well as savings in heating and cooling over a calendar year from the more stable interior temperature of the prototype house.

Table 2 Comparison of costs related to typical house construction in Sonora and a prototype ecological house constructed by the University of Sonora

	Typical house in Sonora*	Prototype ecological house**
Construction time	4–5 months	2 months
Construction cost	US$155,000 (35 m^2 house)	US$95,000 (95 m^2 house)
Cost/m^2	US$4,428	US$1,000
Cooling method	System cooler or air conditioning	Fans or portable cooler
Labor	Specialized labor	Owners
Environmental cost	High: Production of CO_2, consumption of hydrocarbons, production of toxins	Minimal: Exclusive use of biogradable materials
Insulation factor	R5	R56
Sound insulation	Poor	High

*INFONAVIT and Fovisste (2002)

**University of Sonora and Regional Livestock Union of Sonora, 2003

The second experiment involved analyzing data from a typical brick house of 240 m^2 for which a straw bale wall had been erected over the exterior west wall, together with a covered garage. The house was inhabited by three adults in a middle-class neighborhood in Hermosillo. By comparing energy bills and temperature measurements of the year before (2001) and after (2002) the construction, the team found savings of 53% in energy bills and 47% in energy consumption during the warmest months of the year (July–October).

The third experiment involved using the Energy-10 model to compare the actual energy consumption (kWh/m^2) for a typical house of brick and cement built in the 1970s with two alternative hypothetical cases (one constructed of biodegradable materials such as straw bale, the other constructed with conventional materials but following insulation standards appropriate for the desert region). Costs for heating and cooling per meter square were 40% greater in the typical house. The team concluded that substantial energy savings could be made by using construction materials such as straw bale, and adobe, and improved insulation (Fig. 6). The actual costs of construction are often less than in modern homes and construction in many cases the construction may be faster.

The team also identified significant legal and regulatory obstacles to the use of these materials. The current codes for construction do not specify standards for energy or water consumption or conservation, nor do they provide standards for the use of alternative materials. The legal restrictions make such construction more difficult and prevent local suppliers from stocking the materials. The *Colegio* research team not only identified a need for an educational campaign and financial incentives for homeowners to seek out such housing designs but also need for a change in public policy in favor of prioritizing energy consumption and environmental considerations in public housing. These obstacles are not insurmountable, but they would require leadership from the public sector to bring together the relevant housing authorities, academic experts, and representatives from the

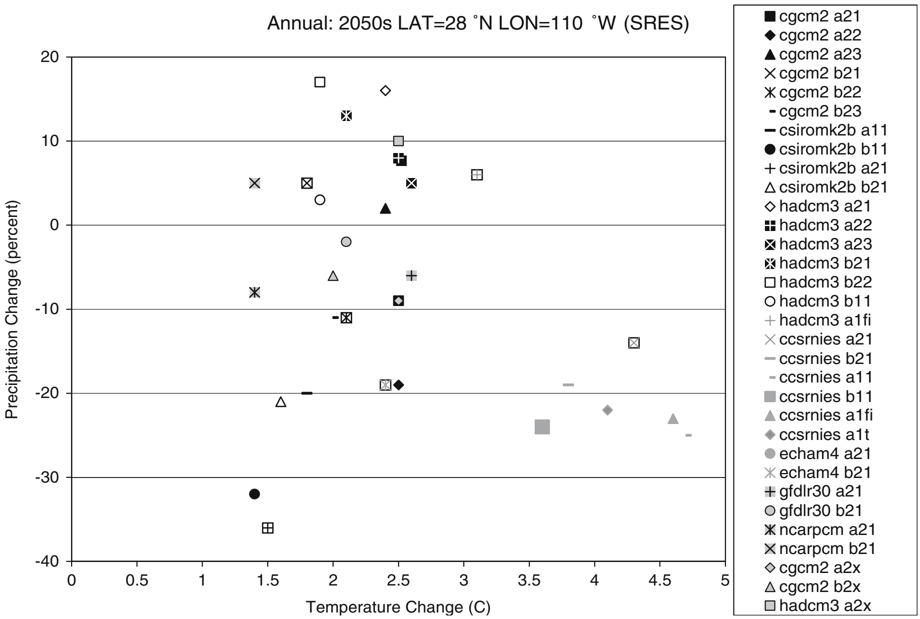

Fig. 6 Projections of temperature and precipitation change for the year 2050 in Hermosillo, according to diverse global circulation models and emission scenarios

construction sector to design the appropriate codes, standards, and incentives for this adaptation to have substantial impact in the medium- to long-term future.

7.3 Rainwater runoff harvesting and groundwater recharge

The proposed adaptation of capturing rainwater runoff was designed to address the current cyclical problem of localized flooding and water scarcity, which is likely to worsen as climate change increases the intensity of the hydrologic cycle. The solution proposed was to capture rainwater runoff in the desert arroyos that surround the city of Hermosillo by building series of small dams based on traditional, low-cost water harvesting methods employed for centuries by settlers in desert regions (Ciuff 1989; Gould 2000; Pandey et al. 2003). Rainwater capture and groundwater infiltration enhancement are increasingly components of contemporary urban water supply and flood management planning in Mexico (IMTA-CNA 1996).

The particular system envisioned for Hermosillo would involve building a system of small stone dams or dykes in carefully selected arroyos in pristine areas in the outskirts of Hermosillo (Landavazo 2003). Each dam would be approximately 18 m long and 2–3 m high. A well would be constructed behind each dam and filled with permeable soil, sand, or gravel. The water captured by the dam would then filter through this material into the underlying aquifer. Readily available local materials would be used to build the dams and fill in the wells. Ideally, rural residents would be involved in selecting the sites, building dams and wells, and monitoring the infrastructure over time—thus providing both employment and an opportunity for involving rural residents in environmental planning and development.

This system of rainwater harvesting has already proven successful in raising the water table in one rural agricultural community in Sonora, and similar rainwater harvesting projects have also shown to improve water recharge rates and control flooding in other regions (Boers and Ben-Asher 1982; Wesemael et al. 1998; Abu-Zreig et al. 2000). In the Sonoran case, farmers participated in the construction of small dams and wells at a total cost of US$2,500 per system (approximately 25,000 pesos). Recharge rates associated with such a dam range from 50 mm/h to 100 mm/h (compared to an average of 10 to 15 mm/h in an unmodified arroyo). Capturing runoff in this way was also thought to be a way of reducing the risk of localized flooding in downstream urban or peri-urban neighborhoods.

Although the technique for locating and constructing the wells is well established, additional research would be required to identify the appropriate sites for the wells to meet the broader objective of preventing localized flooding and recharging the aquifer to the direct benefit of the city of Hermosillo. Accurate assessments of the quality and location of groundwater supplies are lacking in the region (Moreno 2000). The effectiveness of the wells and dams in capturing runoff depends on the soils and topography of each site, so it is difficult to estimate how much water could be harvested. The runoff that enters the wells also needs to be uncontaminated, a requirement that poses additional challenges to finding appropriate sites for the projects. However the wells have an important advantage in their overall low-cost and low energy use compared to other options for enhancing water supply in Hermosillo (e.g., importing water from alternative aquifers and watersheds and desalinization). Although it is unlikely that alone this option would satisfy much of Hermosillo's water demand, in combination with conservation efforts, rainwater harvesting could reduce the city's dependence alternative options with higher fuel demand and reduce the risk of localized flooding.

8 Participatory evaluation of the adaptation options

Once the elaboration of each adaptation option was complete, another stakeholder workshop was organized in early July 2003 to present the detailed proposals to the public and to debate their particular merits and challenges on the basis of criteria proposed by the workshop participants. The participants in this workshop differed from those participating in the first workshop, in part because of personnel changes in the participating organizations and agencies and in part because the project had narrowed its focus to the three adaptation options and thus now had a more specific stakeholder audience. Participants included representatives from the tourism industry (hotel managers), public water utility representatives (the National Water Commission and Agua de Hermosillo), representatives from the construction industry (including merchants of construction materials), academics, and representatives from environmental nongovernmental agencies and public research groups. Although not all of the participants were able to attend the entire day's workshop, at any one time approximately 20 stakeholders were in attendance.

The climate scenarios for the region were again presented, followed by presentations on each of the proposed adaptation options. A question and answer period followed each presentation to clarify points and address concerns about what had been covered or left out of each evaluation. The participants were then asked to consider different evaluation criteria and, based on the criteria of their choosing, evaluate each option. The stakeholders proposed the following criteria: (1) the efficiency of the project in addressing future water concerns, (2) the time frame in which results could be expected, (3) the cost, (4) the general feasibility, (5) the actors who would need to take responsibility for implementation, and (6) other impacts (positive or negative) that might be expected from the project. The participants then collectively evaluated each option on the basis of these criteria, together deciding on the language to fill the cells of a matrix developed for this purpose (Table 3).

In addition to this qualitative evaluation, participants were also asked to rank the options according to which one was most important to implement, given the *current* water problems in Hermosillo. They were then asked whether their ranking would change according to each of the two climate change scenarios presented in the workshop (i.e., warmer and wetter, and warmer and drier). The results of this exercise are shown in Table 4. It is interesting to note that there was considerable initial resistance to the priority setting exercise: In general, the participants argued that all three adaptations were critical and complementary.

As Table 4 illustrates, the participants were most supportive of the culture of water program for addressing current problems in the city, reflecting the general perception that water is currently wasted and too little is being done to change attitudes. This priority setting also likely reflects the fact that during the workshop recess participants saw a demonstration of water saving household technology. Many participants returned to the discussion convinced of the feasibility of this option, while they associated greater uncertainties with the other two options.

Under warmer and drier future conditions, several of the participants changed their original rankings, placing far more importance on improving energy savings through alternative building materials. This may reflect a perception that in the desert of Sonora, warmer and drier conditions would significantly decrease comfort levels in houses in which both a demand for energy and water would increase. Under warmer and wetter conditions, the aggregated rankings were identical to the participants' evaluation of present conditions, although there was far less unanimity in the participants' individual responses, and thus less overall certainty in the rankings.

Table 3 Qualitative evaluation of adaptation options by stakeholders

Adaptation	Efficiency	Time to results	Cost	Feasibility	Actors	Other impacts
Culture of water (water saving technology)	High	1 to 3 years, depending on financing	Low (recoverable)	High	Agua de Hermosillo and water users, the National Water Commission, businesses	Energy and financial savings.
Home construction materials (water recycling)	Medium	20 years	Low (in comparison with other construction materials)	Medium	Promoters and public institutions, scientists, and water users	Substantial energy savings, less waste generation, better social welfare and human health.
Capture and control of rainwater	High	10 years	Low (depending on the machinery used)	Locally high, and medium regionally	Federal, state, and local governments, farmers, and rural residents	Flood control. Possible ecological impacts.

Table 4 Ranking of adaptation options (1 = highest priority, 3 = lowest priority)

	Culture of water	Rainwater capture	Building materials
Hermosillo today	1	2	3
Warmer and drier	2	3	1
Warmer and wetter	1	2	3

Finally, the participants were asked to list some of their remaining concerns related to the feasibility of each option and what additional information they believed would be required before any actions could be taken. Among other things, the participants stated that the ways in which water and drought issues were currently politicized in Hermosillo was a large obstacle to any rational consideration of alternatives. There was also concern that better understanding about the relationship between rising temperatures and water availability in the region would be needed. Although there was much interest in the housing design option, the general opinion was that more specific information would be needed before alternative materials would be adopted. The lack of accurate and reliable data on water supply and consumption in Hermosillo was emphasized as a problem for designing water management strategies for the future.

9 Conclusions

While there are numerous studies of the potential impact of climate change on water resources, water management, and water-dependent economic sectors, relatively few studies have attempted to bring the issue of climate change directly to water users for their consideration and action. The pilot project presented here was the first of its kind in Mexico. It illustrates that a variety of diverse stakeholders can be successfully engaged in a discussion and analysis of options to adapt to future climate stress, even in conditions of relatively little initial understanding or awareness of climate change scenarios.

The close integration of the stakeholders in the project's scope and focus ensured that the adaptations proposed would target problems that were of greatest concern to the stakeholders present. It is important to recognize, however, that although every effort was made to invite a representative diversity of participants to the workshops, it is nearly impossible to guarantee that their attendance accurately reflects the opinions and perspectives of the sectors and interests they represent. The absence of particular stakeholder groups—for example farmers' unions—speaks to the inevitable problem in projects reliant on stakeholder participation. Participation is voluntary; there is always a substantial risk that the population that may be most critical to the issue at hand will not be sufficiently represented. This is particularly the case for disempowered sectors of the population but also, as in our case, for potentially powerful groups who for political reasons may decline to participate. Thus even when considerable effort is made to involve the diversity of stakeholders, there exist the possibility that pertinent perspectives are not adequately represented in the project's development.

In the case of the Hermosillo study, informal interviews conducted prior to the first workshop helped triangulate the opinions presented in the workshop (particularly in relation to agricultural organizations), and the household surveys implemented by the researchers at the *Colegio de Sonora* facilitated the incorporation of the perspective of the unorganized stakeholders: the ordinary citizens who are water consumers but not members of community groups, nongovernmental organizations, and the particular industries in which water availability and energy consumption were of highest concern.

There are far more complex methods for formalizing the process of stakeholder consultation and for integrating stakeholder opinions and experience into planning (e.g., Bell et al. 2001). The process followed in this pilot study was simple, but transparent and cost-effective. The surprisingly compatible perspectives on the issue of water supply shared by the participants undoubtedly facilitated the success of the qualitative methods employed in the project. It is important to note, however, that the debate over water in Hermosillo is most heated between agricultural and urban water users. If there had been more representation in the stakeholder groups from the agricultural sector (and the study's scope expanded to include water concerns in the rural areas adjacent to the city), the project could have benefited from the use of multicriteria decision tools and methods that have proven helpful in achieving stakeholder consensus in resource management and planning (Bojórquez-Tapia et al. 2004).

The participants in the two workshops perceived climate change adaptation as a matter of sustainable development, and considered their vulnerability to fundamentally be a product of a general disconnect between living patterns, consumption, and the environment. In focusing on energy as well as water use in the built environment, the stakeholders managed to incorporate in the project's scope both adaptation and mitigation. The actions they proposed not only were designed to address the climate change scenarios presented to them but also reflected a desire to change the relationship of the population of Hermosillo to its surrounding environment.

The adaptations suggested were designed to address future climatic change as well as constructive and practical solutions to Hermosillo's present water supply challenge. The awareness of the stakeholders of the complexity of water concerns in Hermosillo and the previous experience of several participants in water management in the city ensured that the proposals were closely related to ongoing water management debates and initiatives in the region. This greatly enhances the probability that the adaptations will be integrated into current public policy initiatives.[1]

The process also allowed sufficient time and resources for expert analysis of the adaptation options, although additional analysis and demonstration may be required before any of the options can be implemented. On the whole, the process is one that could be replicated elsewhere in Mexico and in other countries to address adaptations to climate change. While the project did not intend to provide the definitive list of adaptations to climate change for the city, it did establish a foundation for further research on the specific adaptation options proposed for Hermosillo, and outlined the necessary steps required for such adaptations to successfully address particular aspects of the challenge of climate change in the region. Most important, the project introduced a discussion of adaptation into both local policy discussions and individual stakeholder resource planning, despite the uncertainties in the climate and hydrological scenarios for the region as well as the highly politicized nature of water management in the city.

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[1] The presentation of the adaptation options for Hermosillo to policy-makers and industry representatives at the federal level after the project's completion also generated substantial interest and resulted in a tentative proposal to link the options proposed for Hermosillo to national climate change adaptation policy development.

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References

Abu-Zreig M et al (2000) Rainfall harvesting using sand ditches in Jordan. Agri Water Manage 46: 183–192

Acuña F, León K (2001) Diagnóstico del consumo doméstico de agua en Hermosillo. Departamento de Ingeniería Industrial, Universidad de Sonora

Ammons N, Rawls Hill M (2002) Public participation necessary. Water, Envir Technol 12(9):79–84

Bell M et al (2001) An evaluation of multi-criteria methods in integrated assessment of climate policy. J Multi-Crit Decision Anal 10:229–256

Bellon MR (1995) Farmer's knowledge and sustainable agroecosystem management: an operational definition and an example from Chiapas, Mexico. Human Org 54(3):263–272

Benioff R et al (1996) Vulnerability and adaptation assessments: an international handbook. United States Country Studies Program, Dordrecht, Kluwer

Boers T, Ben-Asher J (1982) A review of rainwater harvesting. Agri Water Manage 5:145–158

Bojórquez-Tapia LA et al (2004) Environmental conflicts and nature reserves: redesigning Sierra San Pedro Mártir National Park, Mexico. Biol Conserv 117:111–126

Burton I (1996) The growth of adaptation capacity: practice and policy. In: Smith J, Bhatti N, Menzhulin G et al (eds) Adapting to climate change: assessments and issues. New York, Springer

Carter TR et al (1994) IPCC technical guidelines for assessing climate change impacts and adaptations with a summary for policy makers and a technical summary, London. University College London and National Institute for Environmental Studies, Japan

Cash D et al (2002) Salience, credibility, legitimacy and boundaries: linking research, assessment, and decision-making. John F. Kennedy School of Government Faculty Research Working Paper Series, Cambridge, MA

Chess C et al (2000) Adaptive participation in watershed management. J Soil Water Conserv 55(3):148–155

Ciuff CB (1989) Water harvesting systems in arid lands. Desalination 72:149–159

Comisión de Agua Potable y Alcantarillado del Estado de Sonora (COAPAES) (1999) Agua para el 2000: El reto de avanzar o paralizarse. Hermosillo, Sonora

COMPROVI (2002) Gobierno del Estado de Sonora, Coordinación de Promoción de Vivienda

CONAPO (2004) www.conapo.gob.mx

Downs TJ (2001a) Making sustainable development operational: integrated capacity building for the water supply and sanitation sector in Mexico. J Environ Planning Manage 44(4):525–544

Downs TJ (2001b) Sustainable health risk management and the role of cross-disciplinary professionals in developing countries: the Mexican experience. Environ Develop Sustain 3:61–81

Gokhale AA (2001) Environmental initiative prioritization with a Delphi approach: a case study. Environ Manag 28(2):187–193

Gould J (2000) Rainwater catchment systems: reflections and prospects. Waterlines 18(3):2–6

IMTA (2000) ERIC II. Servicio Meteorológico Nacional

IMTA-CNA (1996) Manual de métodos de recarga artificial de acuíferos, Cuernavaca, Mexico, Instituto Mexicano de Tecnología del Agua y Comisión Nacional de Agua

INEGI (2000) XII Censo General de Población y Vivienda. Aguascalientes, INEGI

INEGI (2004) Datos Económicos de Coyuntura, www.inegi.gob.mx/est/contenidos/espanol/tematicos/coyuntura/pubcoy/entidades/26/pcmaq.asp?c=4973&e=26

Infonavit y Fovisste (2002) Citados por Periódico El Imparcial. Domingo 06 de Octubre. Hermosillo, Sonora

IPCC (2001) Climate Change 2001: Impacts, Adaptation and Vulnerability, Geneva, Intergovernmental Panel on Climate Change

IPCC-DDC (2004) Data Distribution Center, website: http://ddcweb1.cru.uea.ac.uk/

Iyer-Raniga U, Treloar G (2000) A context for participation in sustainable development. Environ Manage 26(4):349–361

Kachadourian G (2003) Ford Futura to be built in Mexico. Automotive News, October, 27

Karl M (2000) Monitoring and evaluating stakeholder participation in agriculture and rural development projects: a literature review. SDdimensions 2004

Lagarda Lagarda C (1998) Alternativas de solución de agua para Hermosillo. In: Pineda N (ed) Hermosillo y el Agua. El Colegio de Sonora/Centro de Investigación en Alimentación y Desarrollo, Hermosillo, Sonora, Mexico

Landavazo O (2003) Control productivo de inundación-sequía como adaptación sustentable al cambio climático en sonora, México. Background paper for Vulnerability and Adaptation Support for Mexico, Project Summary Report, Stratus Consulting, Boulder, CO
León C, Graizbord B (coordinators) (2003) Panorámica del agua en el noroeste de México. Vínculo y límite de las actividades humanas, informe final. Bases para el Ordenamiento Ecológica de la Región de Escalera Náutica (Componente Social y Económico), Colegio de México, México, DF
Lim B, Spanger-Siegfried E, Burton I, Malone E, Huq S (eds) (2005) Adaptation policy frameworks for climate change: developing strategies, policies, and measures. Cambridge University Press, New York
Magaña V, Conde C (2000) Climate and freshwater resources in Northern Mexico: Sonora, a case study. Envir Monit Assess 61:167–185
Magaña V, Conde C (2003) Climate variability and climate change, and their impacts on the freshwater resources in the border region: a case study of Sonora, Mexico. In: H. Diaz, B. Morehouse (eds) Climate and water. Kluwer, Dordrecht, pp 373–392
Martínez JM, Largarda N, de la O. Romero M, Aguilar J (2003) Diseños y materiales de construcción de viviendas en zonas áridas: Adaptaciones ante el fenómeno de cambio climático: Caso de Hermosillo, Sonora. Background paper for Vulnerability and Adaptation Support for Mexico Project Report. Stratus Consulting, Boulder, CO
Méndez Pérez JM (2003) Un estudio de eventos hidrometeorológicos extremos en la república Mexicana, Masters Thesis, UNAM – CCA
Mendoza V, Villanueva E, Adem J (1997) Vulnerability of basins and watersheds in Mexico to global climate change. Climate Res 9:139–145
Meza A (2001) Benefician las lluvias captación de presas. El Imparcial 27 julio. www.elimparcial.com
Mirghani MMO, Sevenije HHG (1995) Incorporation of people's participation in planning and implementation of water resources projects. Phys Chem Earth 20(3–4):229–236
Moreno JL (2000) Apropiación y sobreexplotación del agua subterránea en la costa de Hermosillo 1945–2000, Doctoral Dissertation, CIESAS-Universidad de Guadalajara
Moreno JL (2003) Adaptación al cambio climático: Un programa de cultura del agua en Hermosillo, Sonora, Background paper for Vulnerability and Adaptation Support for Mexico, Project Summary Report, Stratus Consulting, Boulder, CO
Nash LL, Gleick PH (1993) The Colorado River Basin and climate change. Washington DC: U.S. Environmental Protection Agency. EPA-230-R-93-009
Natalini M, Klees D (eds) (2000) Reciclaje y reutilización de materiales residuales de construcción y demolición. Comunicaciones Científicas y Tecnológicas, Universidad Nacional del Nordeste, Chaco-Corrientes, Argentina
National Research Council (1999) New strategies for America's watersheds. National Academy Press, Washington, DC
OECD (2003) Environmentally sustainable buildings. Paris, OECD
Pandey DN et al (2003) Rainwater harvesting as an adaptation to climate change. Curr Sci 85(1):46–59
Pineda Pablos N (1998) Una introducción al sistema de agua potable y alcantarillado de la ciudad de Hermosillo. In: Pineda N (ed) Hermosillo y el Agua. El Colegio de Sonora/Centro de Investigación en Alimentación y Desarrollo, Hermosillo, Sonora, Mexico
Ponce A (2003) Concreto ligero celular. Centro de Tecnologia Cemento y Concreto. CEMEX, Mexico
Scheraga JD, Furlow J (2001) From assessment to policy: lessons learned from the U.S. National Assessment. Hum Ecol Risk Assess 7(5):1227–1246
van den Hove S (2000) Participatory approaches to environmental policy-making: the European Commission Climate Policy Process as a case study. Ecol Econ 33:457–472
U.S. EPA (2000) Protecting the environment of the U.S.-Mexico Border Area: a Briefing Paper for the Incoming U.S. Administration, U.S. EPA's Border Program, Washington, DC
Venter AK, Breen CM (1998) Partnership forum framework: participative framework for protected area outreach. Envir Manage 22(6):803–815
Welp M (2001) The use of decision-support tools in participatory river basin management. Phys Chem Earth 26(7–8):535–539
Wesemael B et al (1998) Collection and storage of runoff from hillslopes in a semi-arid environment: geomorphic and hydrologic aspects of the aljibe system in Almeria Province, Spain. J Arid Environ 40:1–14
Wigley, TML (2004) MAGICC/SCENGEN Technical Manual. National Center for Atmospheric Research: Boulder, CO. Available at: http://www.cgd.ucar.edu/cas/wigley/magicc/index.html
Willmott CJ, Rowe CM, Mintz Y (1985) Climatology of the terrestrial seasonal water cycle. J Climatol 5:589–606
Wolfe AK et al (2001) Public involvement on a regional scale. Envir Impact Assess 21(5):431–448