Finding Points of Engagement to Introduce Climate Change Adaptation into Water Management Planning: A Synthesis of NCAP Activities in Guatemala

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1. Introduction

The impression of Guatemala as viewed from space is that it, along with its neighbors in Central America, is relatively green and verdant. This view does not conjure up the immediate image of water as a constraining factor in livelihood generating activities pursued by the population. This perspective, however, does not reveal the extent to which Guatemala is dependent on a natural resource based economy, and in particular the agricultural and forest management activities in which a significant proportion of the population is engaged. The productivity of these activities and their potential to support, and even enhance, the livelihoods of a largely rural population are dependent on climate and the associated hydrological response. Although it is a relatively small country, with a surface area of 108,890km^2, the geography of Guatemala creates strong spatial variations in climate across the national territory, to which local resource based economic activities are attuned. Production systems and livelihood generating activities can vary across very small distances, many of which are exposed to climate related risks. In addition, many of these risks, such as flooding, are exacerbated by heavy exploitation of the land base. Thus, Guatemala is an appropriate venue for studying the threat to sustainable water management posed by climate change and possible adaptation options.

For this reason Guatemala was selected as one of 15 countries across the globe to participate in the Netherlands Climate Assistance Project (NCAP). This five year study sought to achieve several objectives, among them:

- The creation of capacity in the developing world to recognize the threat posed by climate change, and to evaluate adaptation options;
- The integration of climate change considerations into national economic development and poverty reduction planning, primarily through a focus on important livelihood generating activities; and
- The development of a community of professionals around the world who can share experiences on climate change adaptation.

Running through these objectives is a desire to document the important lessons learned in each of the 15 partner countries during the NCAP project so that that the knowledge and insights gained can be shared with others confronting the challenge of adapting to climate change. This paper attempts to synthesize a set of insights from the work that has been completed in Guatemala.
In this regard, the primary lessons learned pertain to assessing the appropriate points of engage-

ment for introducing climate change considerations into policy setting and decision making processes. These lessons emerged from the fact that the NCAP implementation team made very intentional attempts to bind their work to such processes throughout the life of the project, to varying degrees of success. The evolution of the level of interest in NCAP activities among participants in the policy and decision making processes as the study progressed, is potentially instructive to others seeking to introduce climate change considerations into national development and poverty reduction plans. Although the focus of NCAP activity in Guatemala was on the water sector, and as such much of the information presented here will be relevant to water resources, the paper attempts to construct a general structure for successful engagement with policy makers and decision leaders on the issue of climate change adaptation.

2. The Guatemala Context

Guatemala, home to 13,002,206 inhabitants, is the most populated of the Central American countries. With a per capita GDP of US$4,700 per year, it has an economy roughly one-half the size of that found in Argentina, Brazil, and Chile. Since the cessation of civil unrest in 1996, and the initiation of the current period of political stability, economic growth has been steady and in 2007 was estimated to be 5.7%. The composition of the economy by sector, estimated to be 13.2% from agriculture, 25.9% from industry, and 60.8% from services, suggests that natural resource based livelihood generation is only of marginal importance to the people of Guatemala. Several additional factors counter this perception.

Firstly, two large components of the industrial sector are sugar processing and furniture manufacture, both of which are strongly natural resource dependent. Secondly, two-fifths of national exports are agricultural products, with coffee, sugar and bananas representing the main products. Thirdly, in terms of labor allocation between economic sectors 50% of the labor force is involved in agriculture. This contributes to a fourth critical factor, that 56% of the population in Guatemala falls below the poverty line. Taken together these figures suggest that any national development and poverty reduction plan for Guatemala must focus on individuals involved in natural resource based livelihood generating activities. For these individuals, water, defined both by the timing and quantity of availability and by its quality, is a critical resource. It was this assessment that led the NCAP implementation team in Guatemala, the Programa Nacional de Cambio Climatico (PNCC), to focus its NCAP supported activities on the potential link between climate change and water resources, and the implication of this link for efforts to improve the standard of living for the poor.

a. Climatic and Hydrological Setting

Guatemala's geography has a determining effect on climate and hydrology in the various regions of the country. Two factors, the distance to the ocean and positions relative to prominent mountain ranges that create a Continental Divide, contribute in large measures to spatially varied climatic conditions (figure 1). Typically the coastal areas are wetter and cooler while interior zones located behind major mountain ranges, the highest of which in the southwest rise to over 3,000m, are hotter and drier. Guatemala is also located well within the typical path of tropical storms affecting the Caribbean Sea and the Eastern Pacific Ocean and can experience extreme precipitation events, which are typically strongest at the point of landfall and dissipate as they move inland. Annual patterns of precipitation in Guatemala are also influenced to a large degree by the pattern of the "El Nino" and "La Nina" ocean temperature oscillations in the eastern Pacific.

The geography of Guatemala also plays a strong role in the distribution of watershed and catchment areas within the country. The map in figure 1 shows the boundaries of the major national watershed areas within the limits of the national territory (some of the watershed areas are shared with neighboring countries). What is most striking is the difference in size and shape between the band of relatively narrow watershed areas that descend from the Continental Divide to the Pacific Ocean in the southwest and the larger watershed areas that traverse the more tropical plains to the north and east.

Figure 1: Relief Map of Guatemala

Other features in figure 1, particularly the concentration of cities and the density of the road network, reveal that most of Guatemala's population is found in the southern portion of the country. In this region, it can generally be stated that watershed areas draining towards the Pacific experience higher levels of precipitation, while those draining towards the Caribbean are drier. This suggests that in order to explore the link between climate change, water resources and livelihoods, due consideration would have to be taken of this hydrologic spatial variability.

b. National Climate Change Program

The PNCC is a program within the Environment Ministry of Guatemala, and was created in part to coincide with the preparation of the 1st National Communication under the United National Framework Convention on Climate Change (UNFCC). The PNCC is charged with assessing the risks of climate change in Guatemala and recommending steps the government can take to reduce the country's vulnerability to these risks. Soon after its creation, the PNCC played a central role in preparing Guatemala's 1st National Communication, which concluded that the country is vulnerable to both current climatic variability and anticipated climate change. The communication also identified what were perceived to be the most vulnerable sectors, which included: public health; forest resources; cereal production; and water resources.

This assessment supported a conclusion drawn by the PNCC, namely that hydrology and water management were integrated themes across these sectors. They impact public health in terms of reliable access to clean potable water. They impact forest management and cereal production through the provision of soil moisture to promote biomass production and are impacted by these sectors in terms of the role they play in watershed areas' hydrological processes. As such, following the publication of the 1st National Communication, the PNCC made an early decision to focus much of its energy and resources on better understanding the link between climate change and water resources.

As part of this effort, the PNCC participated in a previous project funded by the United Nations Development Program, *Fomento de las Capacidades para la Adaptación al Cambio Climático en Centro América, México y Cuba* (Building Capacity for Climate Change Adaptation in Central America, Mexico, and Cuba). Based on activity undertaken as part of that project, the PNCC produced a report entitled *Síntesis de Vulnerabilidad Futura, Propuesta de Medidas de Adaptación y Estrategia de Adaptación al Cambio Climatico* (Synthesis of Future Vulnerability, Proposal of Adaptation Measures, and Strategy for Climate Change Adaptation) which included a long list of potential water management adaptation strategies. These strategies were divided into five categories: flood prevention; flood management; flood rehabilitation; drought management; and drought rehabilitation. This list of possible adaptations served as a starting point for the activities pursued under the NCAP project.

3. Selection of River Basins

Specifically, the goal of the NCAP activities was to investigate whether consideration of the proposed adaptation strategies could be integrated into ongoing water management policy settings and decision making processes in Guatemala. While there is a loose national context for many of these processes, Guatemala's constitution states that the country's water resources belong to the people and there is little national water planning infrastructure. Guatemala's legislators have tried unsuccessfully three times to pass a comprehensive water law and the most recent attempt in 2005 reached impasse in Congress. As an intermediate solution, a newly formed water resources and basins' unit within the Environment Ministry was administratively charged with the difficult task of formulating Guatemala's national water policy as it is to be applied under water management policy setting and decision making. This unit, referred to as the Unidad de Recursos Hídricos y Cuencas (Basins' Unit) will need to coordinate with other water focused programs housed in other ministries in Guatemala in order to arrive at a coherent national strategy.

In the meantime, important water resource management planning in Guatemala is occurring at the local watershed area level. In fact, it is likely that the Basins' unit will ultimately opt for decentralized basin oriented water management institutions as a central component of the eventual water planning infrastructure. As such the PNCC felt that it was reasonable to focus its NCAP analysis on the watershed area level. Furthermore, in light of the hydrological variability across the Continental Divide, the PNCC decided to select one target watershed area draining towards the Pacific Ocean and one draining towards the Caribbean Sea. The Rio Naranjo (Pacific) and the Rio San Jose (Caribbean) were selected.

a. Rio Naranjo

The Rio Naranjo watershed area flows southwest from the Continental Divide in a region close to the border with Mexico. The change in elevation between the headwaters and the water at the mouth of the river is 3,322m which is distributed over the river length of 104km. The overall 3.4% grade makes this a fairly steep, high energy system, particularly in the headwater region. Torrential flooding during large storm events is a very real concern. During dry periods, however, water scarcity can be an issue as is water quality owing to a near complete lack of wastewater treatment infrastructure in the basin. With a total area of 1,255km^2, the watershed area covers 1.16% of the national land mass.

b. Rio San Jose and Rio Shutaque

The Rio San Jose watershed area (figure 3) is located in the southeastern portion of Guatemala at the low end of a series of mountain ranges that cover the southern portion of the country. The

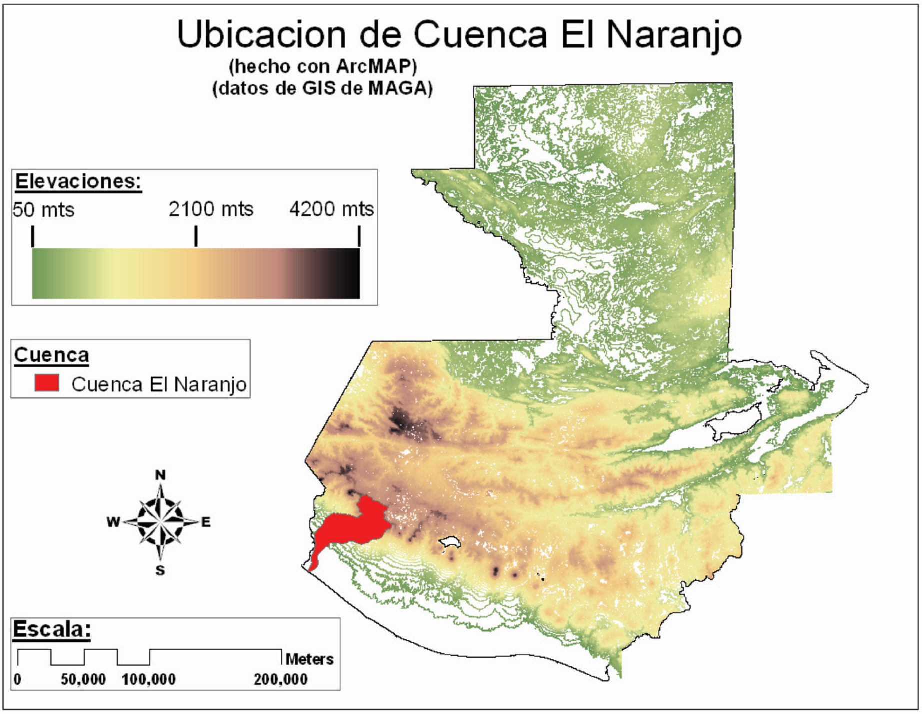


Figure 2: Location of the Rio Naranjo Watershed Area

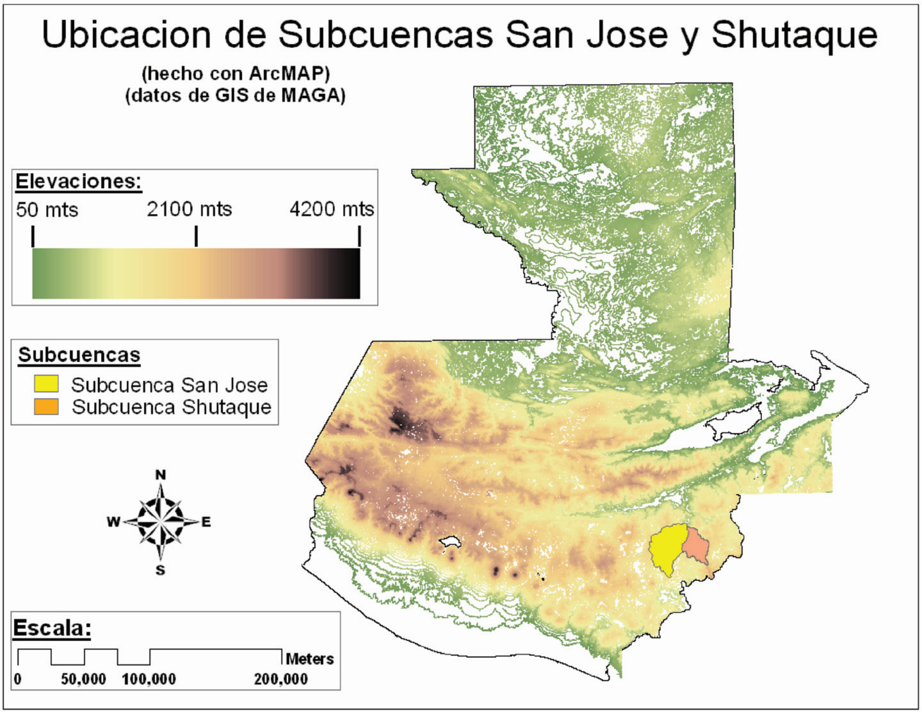


Figure 3: Rio San Jose (yellow) and Rio Shutaque (orange) Watershed Areas

headwater region of the watershed area, at an elevation of 1,820m above sea level is substantially lower that the Rio Naranjo, and the elevation at its mouth is 350m above sea level. After selecting the Rio San Jose as the second target watershed area, the PNCC decided to add the adjacent Rio Shutaque watershed area to the analysis as a water transfer towards the Rio San Jose watershed area is under consideration. Taken together, the Rio San Jose and Rio Shutaque watershed areas constitute 0.9% of the total Guatemalan land mass. Water scarcity is the main water management concern in these watershed areas.

4. Inventory of Water Management Planning Processes

In the absence of a clear national framework for water resource management and decision making into which climate change adaptation considerations could be introduced, the PNCC chose instead to analyze Guatemala's ongoing, somewhat ad hoc, water policy setting initiatives in order to determine where it would make the most sense to introduce a discussion about climate change adaptation. In preparation for this process, the long list of potential climate change adaptation strategies presented in the *Síntesis de Vulnerabilidad Futura, Propuesta de Medidas de Adaptación y Estrategia de Adaptación al Cambio Climatico* were collated according to their relevance to four general types of water management policy dialogues currently underway in Guatemala. These are:

1. Agricultural policy designed to promote agro-silvo-pastoral productivity;
2. Watershed area management policy to reduce flood risk and improve water quality;
3. System investment/operation policy to reduce flood risk and improve water quality;
4. Integrated Water Resources Management promotion for equitable water allocation.

Based on connections within the national government, the PNCC was aware that agents of the following organizations, working at both the national and local levels, were active in these policy dialogues. Guatemala's Agriculture Ministry (MAGA) oversees irrigation and researches farming and crop productivity with emphasis on soil conservation and crop productivity. Guatemala's National Forestry Institute (INAB) works to prevent deforestation through its *Programa de Incentivos Forestales*. Guatemala's National Disaster Planning Network (CONRED) is made up of various institutions that have an interest in preventing damage from storms, floods, forest fires, droughts and other natural disasters. As previously mentioned, the new basins' unit within the Environment Ministry is charged with water and wastewater planning and monitoring, and is an advocate of the IWRM.

Working through agents in these organizations, research was conducted in the Rio Naranjo and Rio San Jose/Rio Shutaque systems in order to identify an appropriate audience for the water management adaptation analysis that was planned for the NCAP project, which would follow the analytical process illustrated in figure 4. The basic structure of this framework is a four-step process:

- Step 1: Understand the implications of the general circulation models (GCM) of the global climate system for the climate in a particular region of the world.
- Step 2: Deploy appropriate techniques to downscale possible regional climatic predictions to climatic time series representative of possible future conditions in watershed areas of interest.
- Step 3: Evaluate how changes in the climate in these watershed areas will alter the local terrestrial components of the hydrological cycle, in particular streamflow, aquifer recharge and evaporative water demand, which are the types of flow that are typically managed.
- Step 4: Assess how water systems dependent on these flows will perform under anticipated patterns of change, and evaluate management options to ensure the long-term performance of the water system in the face of these changes.

Here it should be pointed out that the framework, which emerged from academic and applied research on how to implement a climate change adaptation analysis for the water sector, was pre

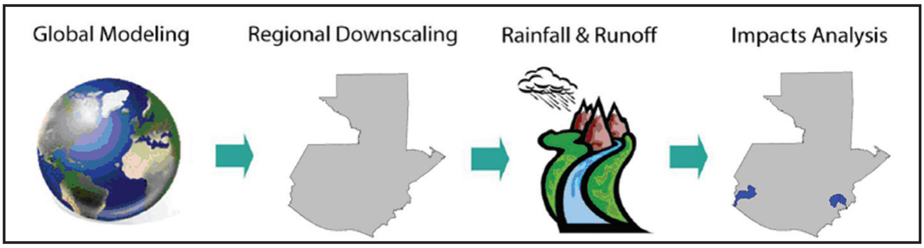


Figure 4: Proposed Water Sector Climate Change Adaptation Analytical Framework

sented to participants in the policy dialogues as an appropriate starting point. The selection of the target watershed areas was also presented as an appropriate place to start from.

In retrospect, it may have been better to engage the participants in the target dialogues for the development of the analytical framework, particularly in terms of creating a sense of ownership of the analysis and assuring its relevance to the particular process. A common reaction among stakeholders was that this approach was quite technical and that it may be difficult to implement in a data limited setting such as Guatemala. The other side to this argument is the fact that the framework represents the best accumulated knowledge on this subject. This dilemma has implications for the question of the appropriate point of engagement for the introduction of climate change information into a discussion on policy setting.

5. Possible Points of Engagement

Based on the experience of interacting with participants in policy setting processes in the target watershed areas from early on in the NCAP project, it became clear to the PNCC that there are at least three important points of engagement between the climate change adaptation community and water management planning and decision making.

a. Awareness Raising

The first point of engagement with an ongoing water resource policy setting process is simply to create awareness that the changing climate and associated changes to hydrological regimes could be an important factor to consider in arriving at a final policy or decision. This point of engagement typically provides several hurdles that can be a challenge to overcome. The first relates to lingering doubts among some stakeholders that climate change is really happening. The second is the perception that while it may be happening, it is too far off in the future to be of concern to the issues at hand. The third hurdle, which is perhaps the most difficult to overcome, is a belief on the part of one or several stakeholders that while climate change is happening, taking it into consideration is likely to reduce the justification for their preferred resolution of the decision making process in question.

b. Impact Assessment

The next possible point of engagement would be to actually try to understand the potential impacts of climate change on some key factors in the decision making process. These might include streamflow, water quality, evapotranspriation rates, aquifer recharge rates, reservoir storage, water supply reliability, indeed any number of water related factors. Obviously quantifying these impacts requires some analysis beyond simply inferring what higher temperatures or reduced rainfall may mean in terms of the future evolution of a particular factor. At this point of engagement, two hurdles are prominent. The first relates to a suspicion that any quantification of future impacts is too uncertain to be useful to the current decision making process. The second hurdle is more subtle and it relates to the fact that the water related factors analyzed in terms of their future evolution under conditions for climate change need to be considered relevant by those involved in the decision making process.

c. Defining Appropriate Adaptation Strategies

If relevant, potential impacts of climate change, properly characterized in terms of their uncertainty, are developed it becomes possible to begin an exploration of available adaptation strategies. This is the third possible point of engagement identified by the PNCC team. Activity at this level includes defining a series of strategies that could help overcome relevant, potentially negative impacts associated with climate change. Here again there are two primary hurdles that must be overcome as part of the effort to introduce climate change considerations. The first relates to the fact that participants often cling to their own preferred understanding of the process, as it is difficult to fully discount their strategy in the face of the uncertainty associated with climate change impacts analysis. The second hurdle is that climate change may require participants in a particular decision making process to imagine adaptation strategies that fall outside the range of strategies that have typically been considered. This is a difficult intellectual challenge.

6. Building Analytical Tools

In order to implement the analytical framework shown in figure 5, models of the Rio Naranjo and Rio San Jose/Rio Shutaque systems needed to be constructed. These models run using future climatic time series constructed based on output from the GCMs, they assess how hydrological processes in the target watershed areas will change under alternative future climatic conditions, and they simulate the performance of the installed water management system under this future hydrological regime. In order to construct the required models, the PNCC selected the Water Evaluation and Planning (WEAP) system developed by the Stockholm Environment Institute (SEI) as a modeling platform. The following section presents the platform and the process that was used to build, calibrate and run the WEAP applications developed for the target watershed areas.

a. The WEAP platform

The WEAP platform is a graphical software system in which a user assembles a series of model objects corresponding to the physical elements of a water system such as watershed areas, rivers, aquifers, reservoirs, diversion works and transmission links. These objects are characterized based on relevant available data. The WEAP user then defines a policy context, including the priority assigned to different water uses, the preferences between various supplies, and required flows in rivers and streams, within which the physical elements are arranged. This is done over a past time period so that the model can be calibrated to ensure that it provides a reasonable representation of the water system in question. The WEAP can then be used to construct “what if” scenarios about the future whereby critical system elements are varied. As an example, consider the following sequence of scenarios relevant to investigating water sector adaptation to climate change:

1. Current climate, watershed area conditions, infrastructure, and operating rules continue into the future in the face of increasing water demand.
2. In addition to increasing water demand, hotter and drier climatic conditions will change watershed area conditions, while infrastructure and operating rules continue.
3. In the face of these change, efforts are made to:
   a. Rehabilitate degraded watershed areas; and/or
   b. Change rules governing the operation of the current infrastructure, and/or
   c. Add new infrastructure.

Scenario 1 is classic water planning, scenario 2 is a climate change impact assessment, and scenario 3 is a climate change adaptation study. Work with the WEAP in Guatemala has moved through each of these steps.

b. Data Collection and Preparation

In spite of the perception that the availability of data is a limiting factor in the development of modeling tools such as the proposed WEAP applications, the PNCC succeeded in assembling all of the critical data through a process of outreach to the various institutions with relevant data in Guatemala. Given the current urgency around climate change in both the media and in political circles, a data request to work on climate change impact assessments and adaptation studies proved attractive. The PNCC was also assisted in the data collection effort, no doubt, by its well established connections with the government agencies working on some aspect of water management.

One of the critical data sets to acquire related to the recorded observations of streamflow within the target watershed areas. In the Rio Naranjo, data sets for six gauging stations were acquired, while information for five stations was available in the Rio San Jose/ Rio Shutaque system. Tables 1 and 2 summarize the period of record for these stations. Clearly, data from these stations is not continuous, and closer examination of the data conducted by the PNCC suggested that some of the records are of inadequate quality. Nonetheless standard hydrograph reconstruction techniques were used to develop streamflow time series for these stations which were deemed sufficient for the task at hand.

Table 1: Streamflow Records for the Rio Naranjo Watershed Area

CLAVE	NOMBRE	1970										1980										1990										2000			
		0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3
130601	COATEPEQUE	X	X	X	X	X	X	X	X	X		X	X	X																		X	X		
130701	CHUVA						X	X	X	X	X	X																							
171401	MELENDREZ	X	X	X	X																														
171403	MELENDREZ II				X	X	X	X	X	X	X	X	X	X	X																				
171402	PAJAPITA		X	X	X	X	X	X	X	X	X	X				X	X	X														X	X		
172301	CORRAL GRANDE	X	X	X	X	X	X	X	X	X		X	X		X	X																X	X	X	

Table 2: Streamflow Records for the Rio San Jose and Rio Shutaque Watershed Area

Clave	Estación	1960										1970										1980										1990										2000				
		0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4
	Vado Hondo																																										X	X	X	
40101	Petapilla																											X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	
40201	Camotán										X	X	X	X	X	X	X	X	X	X	X						X												X		X	X		X	X	
40202	Copán																									X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
100202	Volcán Ipala														X	X	X	X	X	X	X	X	X	X																						

Having acquired these streamflow records, locations of the gauges were used as a point for the definition of sub-watershed areas within each of the target watershed systems. Sub-watershed areas were necessary because it was the water from the point of outflow from a defined stream catchment that the WEAP rainfall runoff model needed to complete step 3. Without sub-watershed areas, the only place that these factors could be defined would be at the final point of discharge from the larger watershed area. Within each sub-watershed area, theWEAP applies a climate time-series appropriate for that particular portion of the larger watershed area.

The PNCC was able to secure from the Ministry of Agriculture, GIS data sets on land use and land cover in 2001 for the target watershed areas. These are shown in figure 5. Whilst the land use patterns in the Rio Naranjo system reflect a diverse agricultural economy with coffee, beans, palm oil, pasture, rice, vegetables and fruit all being produce, the Rio San Jose and Rio Shutaque system, outside the zones covered by forest, is dominated by forage pasture and to a lesser extent beans.

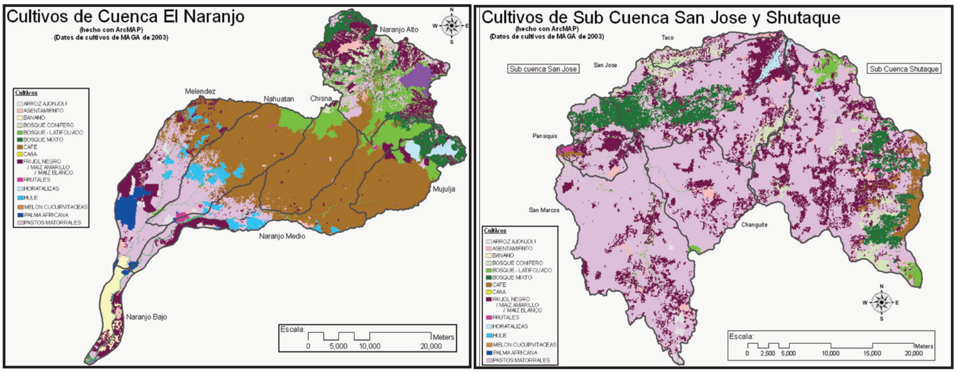


Figure 5: 2001 Land Use/Land Cover in Sub-Watershed Areas of the Rio Naranjo, Rio San Jose and Rio Shutaque Watershed Areas

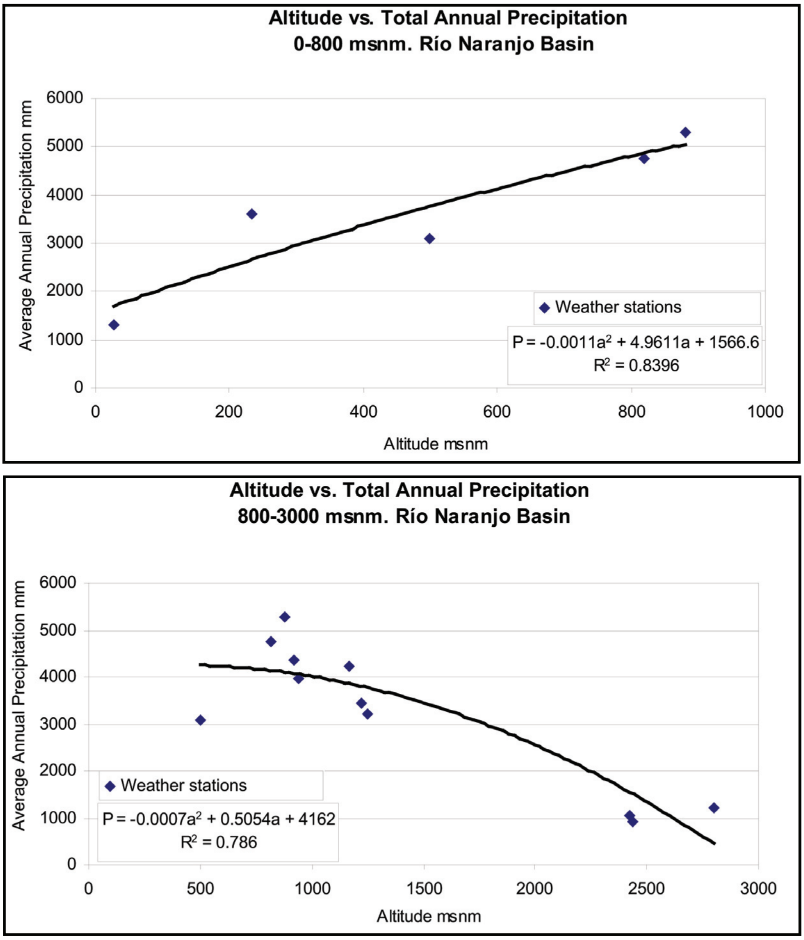
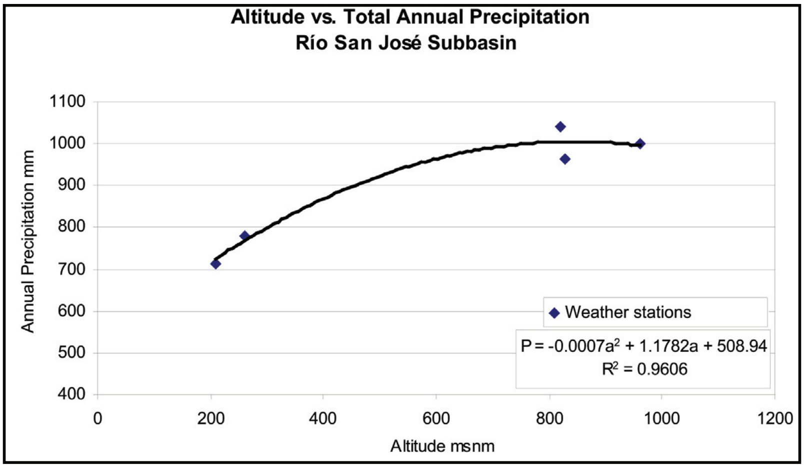


Figure 6: Relationship between Average Annual Precipitation and Elevation in the Rio Naranjo Watershed area

Coffee and fruit production are limited to the relatively high elevation margins of the watershed areas.

The differing nature of land use patterns in these two systems is largely explained by differences in climate, figures 6 and 7 present the relationship between elevation and average annual precipitation for the two watershed areas derived from monthly climate station data acquired from INSIVUMEH, the meteorological service of Guatemala. The first thing to observe from these figures is the maximum annual precipitation in the Rio Naranjo system, occurring at an elevation of approximately 1,000m above sea level (ASL), is close to 5,000mm/year. In the Rio San Jose system the maximum average annual precipitation level is closer to 1,000mm/year while in the Rio Shutaque system the figure rises to approximately 1,400mm/year. In all of the systems there seems to be a pattern whereby the average annual precipitation depth reaches its maximum value at an elevation of approximately 1,000m ASL, at which point it declines with increasing elevation.



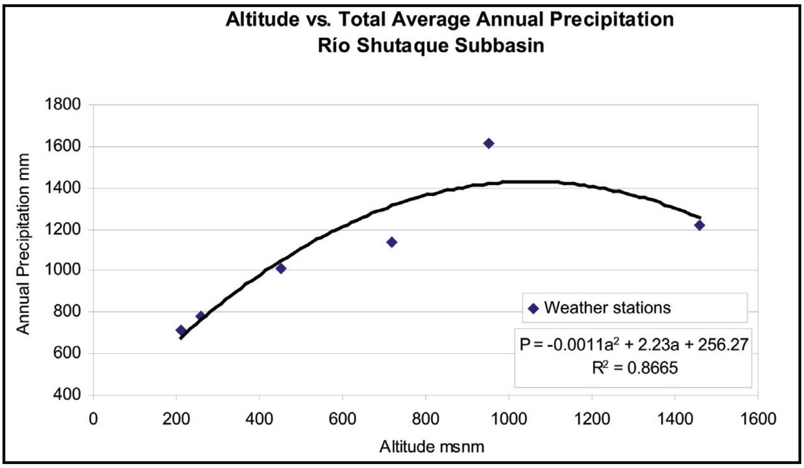


Figure 7: Relationship between Average Annual Precipitation and Elevation in the Rio San Jose and Rio Shutaque Watershed areas

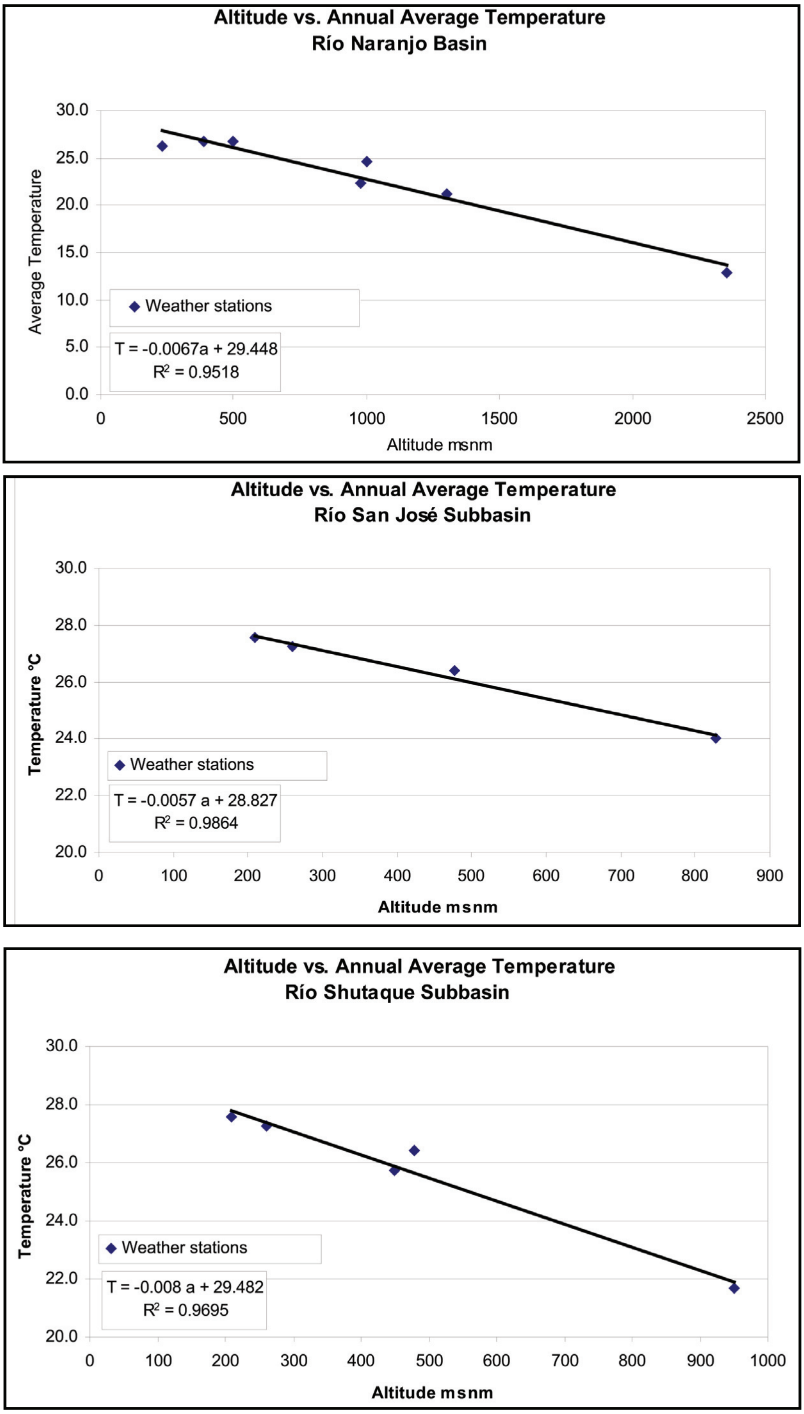


Figure 8: Relationship between Average Annual Temperature and Elevation in the Rio Naranjo, Rio San Jose and Rio Shutaque Watershed areas

In terms of air temperature, available time series of monthly values where processed in order to develop a relationship between the average annual temperature and elevation. Values for the two target systems, the Rio Naranjo and the Rio San Jose/Rio Shutaque, are shown in figure 8. Visual analysis of these graphs suggests that the target systems are not dramatically different in terms of their temperature profiles, the major difference being that as the Rio Naranjo system rises to higher elevations, it has areas with lower average temperatures than those observed in the Rio San Jose/Rio Shutaque system. It is in these cooler, high elevation zones that much of the diverse agricultural production in the Rio Naranjo system takes place.

In addition to data on land use and land cover, the PNCC team acquired data from the INE, the National Census Bureau, on the number of inhabitants living in each of the target systems. In 2001, a total of 335,883 inhabitants were living in the Rio Naranjo watershed area, whilst a total of 111,235 resided in the Rio San Jose/Rio Shutaque watershed area. The spatial distribution of these populations is shown in figure 9.

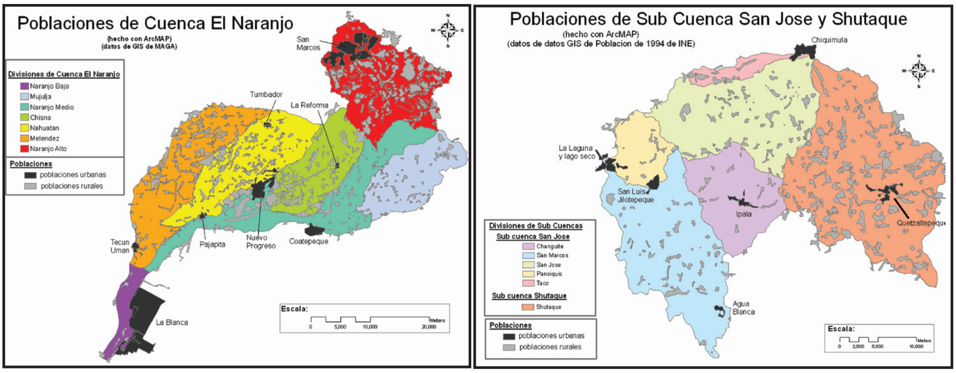


Figure 9: Spatial Patterns of Human Settlement in
the Rio Naranjo and Rio San Jose/Rio Shutaque Systems

This figure differentiates between those individuals living in towns and cities and those residing in rural communities. In the Rio Naranjo system, approximately 230,000 people, or 68% of the population, were living in rural communities. The largest urban center was San Marcos with a population of approximately 46,000 inhabitants. In the Rio San Jose/Rio Shutaque system the rural population in 2001 was 65,770, or 59% of the total, with the largest city Chiquimula supporting 27,040 inhabitants.

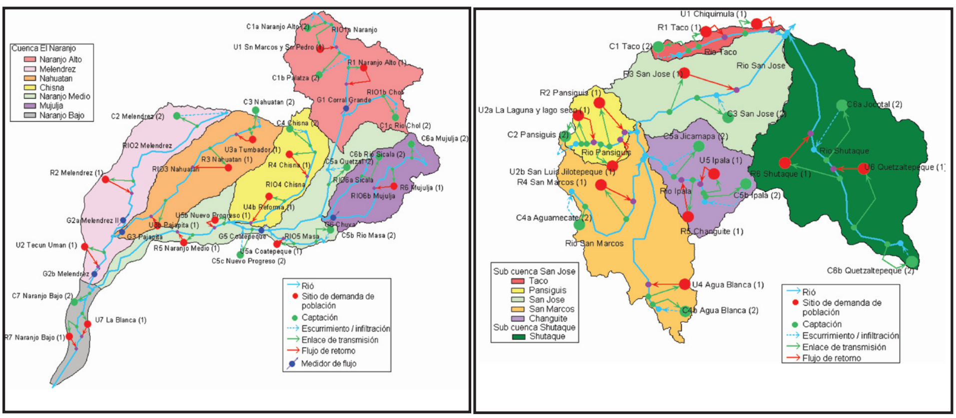


Figure 10: WEAP Application Schematics of the
Rio Naranjo and Rio San Jose/Rio Shutaque Systems.

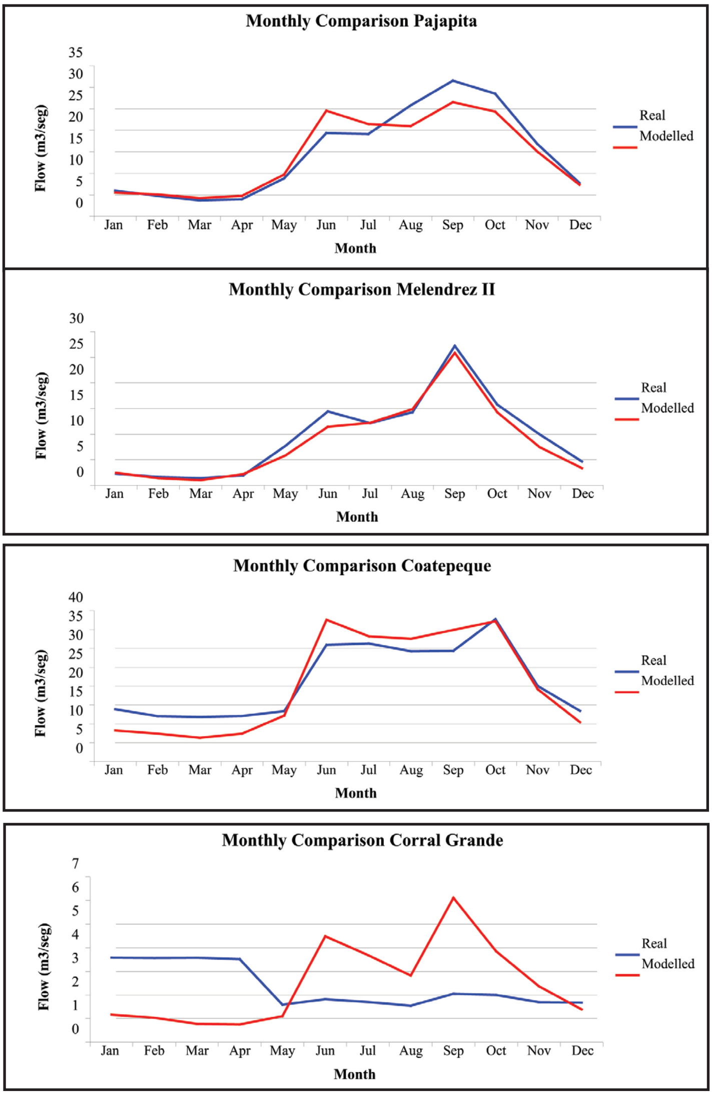


Figure 12: Streamflow Calibration for the Rio Naranjo System

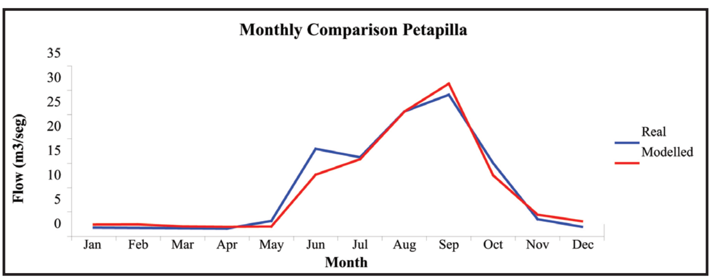


Figure 13: Streamflow Calibration for the Rio San Jose/Rio Shutaque System

c. Model Building

Having assembled and processed all of this data, the PNCC team turned its attention towards using it to build WEAP applications of the two target systems. These are shown in figure 10. A key feature of these applications is the various sub-watershed areas located upstream from the identified gauging stations. Within each sub-watershed area, two demand points (red dots) are identified; one is associated with the urban population in the sub-watershed area and the other associated with the rural population. Based on available data, urban inhabitants were assigned a slightly higher per capita water consumption rate. Green dots within each sub-watershed area contain information on the land use and land cover distribution within each sub-region and the climate time series that is applied for that particular zone. This information is used to simulate rainfall runoff processes. Other objects on the schematics represent the elements of the installed hydraulic infrastructure.

d. Model Calibration

Using these WEAP applications, run using climate time series constructed from the data presented in figures 6, 7 and 8, the models were calibrated so that the simulated streamflow values at the outflow point of each sub-watershed area reasonably matched recorded time series reconstructed from the record available at the gauges presented in tables 1 and 2. This was achieved by adjusting, within what were considered to be physically reasonable limits, a series of model parameters that control the simulation of rainfall-runoff processes in each zone:

- Root Zone Water Capacity
- Deep Water Capacity
- Deep Conductivity
- Surface Runoff Resistance
- Root Zone Conductivity
- Preferred Sub-Surface Flow Direction

Having settled on what was deemed to be an acceptable set of parameters, a final comparison between monthly simulated streamflow values and observed values was carried out. Figure 11 shows the comparison for points in the Rio Naranjo system and figure 12 shows the comparison for the Rio San Jose/Rio Shutaque system.

e. Climate Scenarios

The next step in the implementation of the analytical framework shown in figure 4 was the construction of downscaled climate time series for two target systems. There is still a great deal of scientific debate regarding the best methodology for transforming the information from the GCMs into something that can be used to carry out rainfall-runoff analysis at the watershed area scale. The PNCC chose to implement a "book-ending" approach whereby information from both pessimistic and optimistic GCMs was transformed for use in the Rio Naranjo and Rio San Jose/Rio Shutaque WEAP applications. The starting point for this analysis was to define the range of potential climatic conditions in 2050 in the two systems using output from the Hadley (Had) and Generalized Fluid Dynamics Laboratory (GFDL) models. Output from the GFDL model run under the B2 emissions scenario was used, while output for the A2, B2, and A1fi emissions scenarios was extracted from the Had model. The results for the Rio Naranjo watershed area are shown in figure 13, while those for the Rio San Jose/Rio Shutaque are shown in figure 14.

Notice that while all GCM/emission scenario combinations predict that temperatures will increase in Guatemala in 2050, the GFDL model suggests that precipitation will increase relative to historical conditions in 2050 while the Had model predicts drier conditions. The mid-century conditions shown

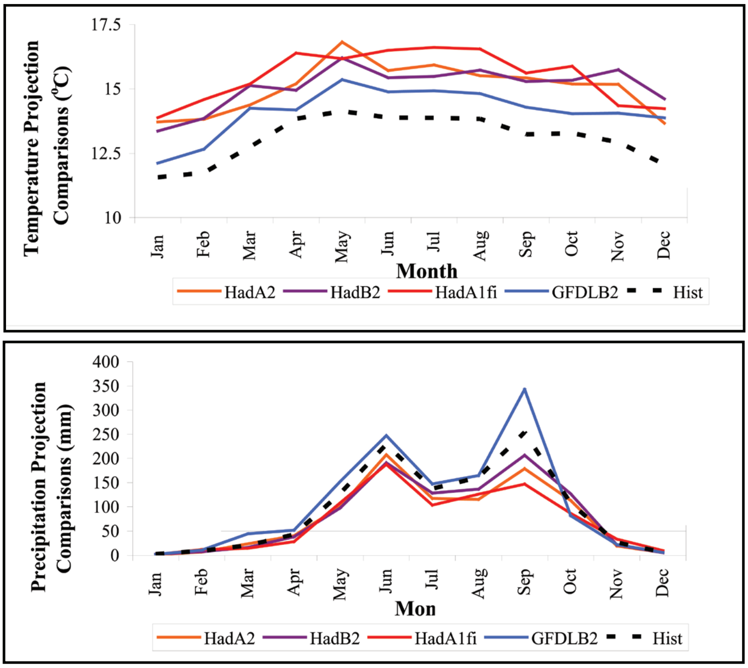


Figure 14: Estimated Mid-Century Changes in Monthly Temperature (top) and Precipitation (bottom) for the Rio San Jose and Rio Shutaque Watershed areas

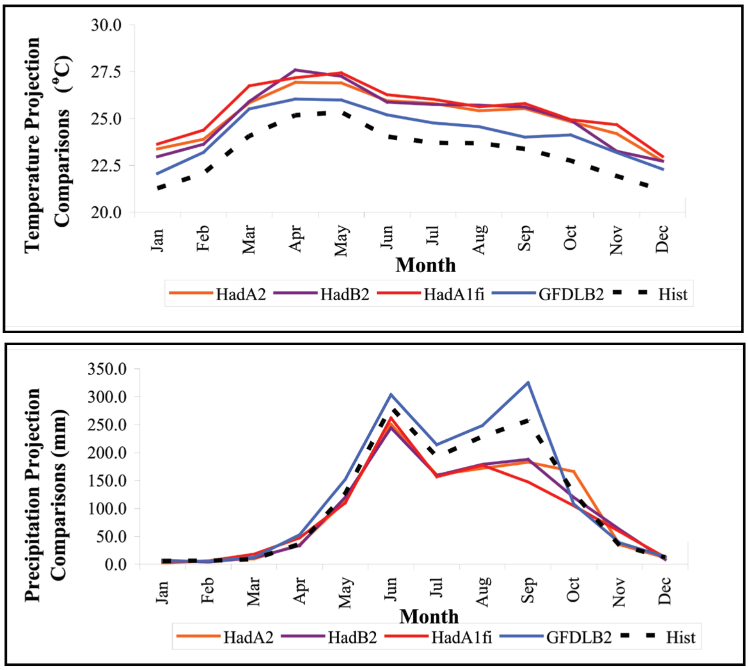


Figure 15: Simulated Mid-Century Streamflow Conditions in the Rio Naranjo below San Marcos under Different Climate Scenarios

in figures 13 and 14 were used to develop a set of factors that were used to challenge observed climatic time series so that they transitioned from currently observed conditions towards those predicted by the GCMs run under different emissions scenarios.

f. Assessing Impacts

Using these the climate time series derived from consideration of the GCM output downscaled in figures 13 and 14 to run the Rio Naranjo and Rio San Jose/Rio Shutaque WEAP applications, it was possible to assess what the impact would be on critical water factors. As an example, the simulated mid-century streamflow conditions under possible future climate conditions in the Rio

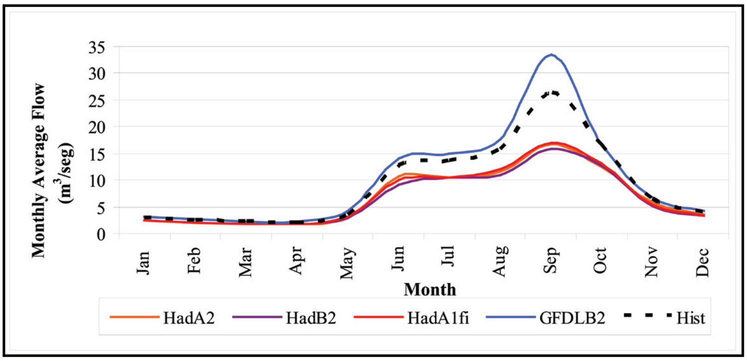


Figure 16: Simulated Mid-Century BOD Conditions in the Rio Naranjo below San Marcos under Different Climate Scenarios

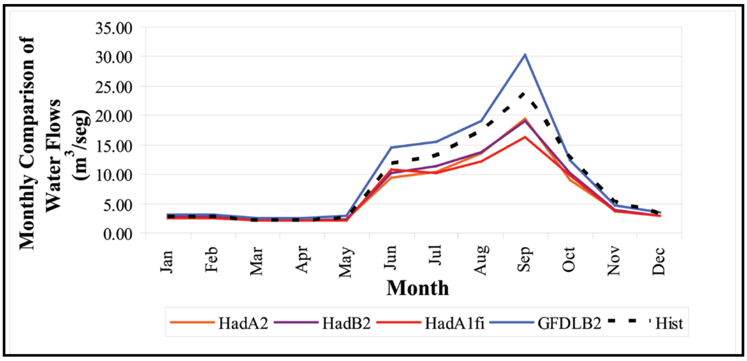


Figure 17: Simulated Mid-Century Streamflow Conditions at the confluence of the Rio San Jose and the Rio Shutaque under Different Climate Scenarios

Naranjo below San Marcos, of interest to stakeholders in a decision making process due to the proposed construction of an urban wastewater treatment plant, is shown in figure 15. The simulated Biological Oxygen Demand (BOD) at the same point for the same time period is shown in figure 16. It should be pointed out that these results were derived from a WEAP application that assumed that the population of the city of San Marcos would grow in the future at a rate which steadily declines from the current 2.4% per annum level to 0.2% per annum in 2050.

These figures provide some compelling potential insights for decision makers developing a wastewater treatment strategy for San Marcos. The first insight is that the worst case scenarios suggest a significant decrease in the flow in the Rio Naranjo relative to current conditions. This has implications in terms of the potential assimilative capacity of the Rio Naranjo as a water receiving body. Alternatively, the most optimistic scenario suggests that flows will increase. However, all scenarios agree that the increased population and the increased temperature will combine to create significantly higher BOD in the Rio Naranjo in the future relative to current conditions. This impact assessment information is of relevance to stakeholders in this decision making process

Figure 17 provides another example of potentially relevant impact analysis. This is the simulated mid-century streamflow at the mouth of the Rio San Jose/Rio Shutaque system compared with current conditions. Recall that one current decision making processes in Guatemala pertains to whether or not water should be transferred from the Rio Shutaque watershed area to meet high water demand in the Rio San Jose watershed area. This decision certainly relies in part upon an assessment of the total aggregate water supply. It may be useful for decision makers to know that some climate projections suggest that the total yield of these watershed areas will be reduced in the coming decades.

7. Mapping the Analytical Tool for the Points of Engagement

Returning to the main theme of this paper, namely finding appropriate points of engagement with actual policy setting and decision making processes for the introduction of climate change adaptation considerations, some concrete examples derived from the experience of the PNCC team over the course of the NCAP project are appropriate. One conclusion that can be drawn from this experience is that not all policy and decision processes can be informed by climate change considerations. For example, one process encountered during the NCAP process involved creating a real-time water allocation dispute resolution policy in the Rio Naranjo. The focus here is on creating a structure which can be called upon to resolve the conflict related to the current actual availability, or more correctly scarcity, of water. The status of the hydrological regime decades from now under an uncertain climate change future is not particularly relevant in this context.

Even in processes where climate change would seem to be more relevant, such as the setting of water quality standards and the design of a wastewater treatment infrastructure, this inference is not always evident to those involved in the negotiations. The strategy developed by the PNCC team at the awareness raising point of engagement was to attempt to develop what were called storyboards that cast the analytical framework presented in figure 4 in the details of the process in question.

The challenge at the awareness raising point of engagement was that the project team could not significantly move beyond general linkage and information flows, and owing to skepticism on the part of the participants about developing this information, there was little expectation that such a development was possible. The general response of those to whom the storyboards were presented can be summarized as: ‘We have heard of this sort of technical analysis in the past, particularly from experts coming from Ciudad Guatemala or abroad, and have yet to experience a time when it came to fruition. It is better to make our decisions based on our own current and local understanding of our system’. It is likely that this reaction is not unique to the watershed area managers and stakeholders of Guatemala.

As an alternative, the NPCC contemplated the potential benefits of developing a series of educational materials that were less technical in tone. Experience with this approach in Peru was considered exemplary. It was here that the posters shown in figure 18 were developed in an effort to raise the awareness about climate change in specific sectors. These posters suggest that a time is coming when the supply of staple foods, fish and fruit will be reduced because of climate change and ask the question, ‘What will happen then?’

The implicit assumption in these materials is that some analysis has been done to characterize the status of stable food, fish stocks and fruit production under some future climate regime. This is the sort of analysis summarized in a storyboard, analysis which was considered untenable by many of the participants in the policy setting processes. Some work needs to be done to characterize the impacts of climate change before effective educational materials can be developed. Viewed in these terms, it perhaps should not be surprising that the PNCC found relatively little understanding at the awareness raising point of engagement during its interactions with participants in ongoing water management dialogues.

Figure 18: Educational Materials to Raise the Awareness of Climate Change

The next potential point of engagement was the implementation of the impact analysis required to understand the implications of climate change on the water resources of the two target basins, in effect, to implement the analytical framework shown in figure 4. This became the major focus of the NCAP activity in Guatemala and while local water managers and stakeholders did provide some valuable insights into this effort, they adopted somewhat of a "wait and see" position towards the project. In fact most of the effort needed to gather the information required to implement the analytical framework was directed at the custodians of national databases in Ciudad Guatemala. This is unfortunate as it is likely to have resulted in a missed opportunity to build ownership of the analytical process among the participants in the policy dialogues. Recall also that one of the steps in the development of the analytical tool was calibration using historical climate data. This tool could be beneficial to decision makers whether or not they would chose to use it to investigate climate change impacts and adaptations.

In any case, it is at this point in the analytical process that some tension can arise between what can be referred to as the data camp and the modeling camp. The data camp would argue that there simply is not enough information available to implement the analytical framework shown in figure 4, and that in any case potential climate change impacts are still some years off. Better to use available time and resources to improve monitoring and data collection. On the other hand the modeling camp would argue that there is a lot of information available, albeit incomplete and poorly organized. Better to use available time and resources to organize it into imperfect modeling tools so that we can get a preliminary idea of potential climate change impacts and identify gaps in the available data. Figure 4 clearly emerges from the modeling camp.

One risk that must be recognized by the modeling camp is that the assessment of impacts that will emerge from implementation of the analytical framework will be uncertain. Finding ways to describe the sources of that uncertainty and to convey its implications to decision-makers and stakeholders is a critical component of impact assessment. Nonetheless, there are important reasons to engage with participants in policy setting processes during an impact assessment, not the least of which is to identify the impacts relevant to a particular decision. For example, a process targeting the establishment of water quality standards and the development of a wastewater treatment plan of action for the Rio Naranjo will be interested in potential changes in river water quality under climate change at specific places along the river. In fact it was interactions with the stakeholders involved in this process in San Marcos that lead to the definition of the decision factors shown in figures 15 and 16. Again, here the PNCC team was honest enough to recognize that for some decision making processes the impact analysis they would produce would not be informative.

The final point of engagement, namely defining appropriate adaptation strategies, certainly cannot be undertaken without the full participation of actors in a particular decision making process. Failure to develop comfort with the analytical tools and to allow the stakeholders to contribute to the definition and evaluation of appropriate adaptation strategies will condemn the analytical framework to the purely academic arena. Producing results showing that a wastewater treatment plant, sized based on information about historical climatic and hydrological conditions, should be expanded in order to accommodate climate change will likely prove impossible to digest for decision makers who have not been involved in reaching such a conclusion. Here it can be said that the PNCC has worked to promote the WEAP application that they developed with stakeholders in the Rio Naranjo system so that the participants in the water quality negotiations can propose and consider their own adaptation options.

8. Implications for the Use of Models

There is an old adage that states that 'All models are wrong, some are useful'. This seems relevant to this paper regarding the appropriate point of engagement in water management decision making process for those interested in climate change adaptation. It suggests that the builders of models need to be honest with the users of model about the assumptions that went into model construction and their implications for interpreting model results. By the same token, model builders should not be afraid to share the insights that are gained through the modeling process. In the case of Guatemala one critical insight was that in spite of the belief in some camps that sufficient data was available to implement the analytical framework shown in figure 4, the PNCC was able to assemble and process all of the data needed to build the WEAP applications which calibrated reasonably and which yielded pleasing results when run under a range of future climatic conditions. While by no means perfect, these models are at least based on factual predictions.

This leads to a second insight, how could one, without the use of a model arrive at any point of knowledge regarding potential climate change impacts on something like BOD in the Rio Naranjo below San Marcos. While it is certainly legitimate to question just how the information in figure 16 should be factored into the final decision regarding the proposed wastewater treatment plant at San Marcos, it would seem naïve to ignore the information completely. Much of the current research on climate change adaptation involves refining the exact approach that should be taken to integrate climate change consideration into planning, with major contributions emerging from the actuarial sciences and decision theory. As this approach is refined over time, the effort invested now in using models to develop information like that presented in this paper, and in building the level of understanding of and comfort in the analytical process within which these models fit, will be considered a very strong foundation for future efforts to plan for a future in which the climate stands to be very different than the one experienced today.

9. Recommendations and Conclusions

At the beginning of this paper, a statement was made that while the NCAP work in Guatemala focused on the water sector, an effort would be made to develop a general structure for successful engagement with policy makers and decision leaders on the issue of climate change adaptation. That effort will be made here.

At the awareness raising point of engagement, it seems to be of little value in terms of contributing to a policy setting or decision making processes to draw broad conclusions about the impacts of hypothetical climate change scenarios. Quite honestly the mass media is already filling this role.

Hardly a day goes by without some report on melting glaciers, more intense and frequent fires, shifting ecosystems and the link to climate change appearing in print or over the airwaves. Instead, decision makers need to have information on what these changes mean for the decision at hand. Here is it prudent to say nothing if the implications of the decision are of such a limited time horizon that they cannot possibly be affected by changes that will take decades to fully materialize.

There are decisions, however, where the time frame over which climate change will increase in severity are extremely relevant. These include decisions on investments in infrastructure which will be paid off and operated over a period of decades. Political and legal negotiations that are unlikely to be revisited for decades are another reasonable arena for climate change considerations. Property acquisition to meet a specific objective is another. A very relevant function of the climate change adaptation community is to develop preliminary sensitivity analysis of what are considered climate critical decisions in a particular sector. The goal of these analyses should be to show in a general manner what a difference a choice might make if plausible climate change considerations where realised. This should be the focus at the awareness building point of engagement.
At the level of impact assessment, a general recommendation is that the factors that will be assessed must emerge from an actual decision making process. It is of little benefit to describe how certain factors will change under future climate scenarios if they are of little relevance to the decision at hand. This would be a mandatory point of engagement and would have the added benefit that an effort could be made to improve the understanding of decision makers of the data that will have to be assembled and processed and the models that will need to be developed in order to carry out the assessment. In retrospect it is at this level that storyboards, laying out the general linkage and information flows could be most useful, not at the awareness raising point of engagement. The key is to create a sense of ownership, indeed to create a perceived need for the results of an impact assessment.

The completion of an impact assessment seems another logical point of engagement. Although the climate change adaptation community should to be prepared for two possible responses to the information generated. The first is the reaction that the decision at hand may not be that sensitive to climate change. There are times that this may indeed be the case, even under the worst potential climate change scenarios. If the awareness building point of engagement is properly implemented, climate change insensitive decisions should not have progressed to the level of impact assessment. The second potential reaction to an impact assessment might be uncertainty about how to actually use the information contained in the assessment. Here it would probably be useful to articulate future sensitivities in the language of risk and regret and the cost of climate proofing a particular decision.

This brings us to the final point of engagement, the definition of appropriate adaptation strategies. Adaptation costs money. The decisions are in effect insurance policies against the looming and potentially significant risk of climate change. This should be made clear to decision makers and rhetoric should be developed to help them grapple with the implications of this reality. Here also, the definition of adaptation strategies that will be analyzed should emerge from conversations with decision makers, if for no other reason than because they will have a good idea as to the costs of implementing various options. As experts in their field they will also be in a good position to imagine innovative strategies once they arrive at the point of internalizing the threat posed by climate change.

In conclusion, it seems clear that decision makers, and the analysts with whom they collaborate, are beginning to be able to define the process whereby climate change can be taken into consideration. As such the way forward is not entirely clear yet. This should not be surprising; decision makers have developed planning apparatus over the course of many decades that made the fundamental assumption that the climate experienced in the past will be representative of the climate that will be experienced in the future. Perhaps this report on climate change adaptation planning in the water sector in Guatemala will provide an help towards a new planning paradigm.