SUSTAINABILITY OF PERUVIAN WATER RESOURCES IN LIGHT OF CLIMATE CHANGE

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ABSTRACT:

Dire predictions of future water shortages tend to focus on areas of Africa and the Middle East, with scarce mention of the Americas. However, the prospect of adequate water resources to sustain existing and future demands for agricultural, industrial, and human needs is dependent upon demographics and climatic condition. Changes in either population or climate can upset the delicate balance of water resource supply. Peru faces an uncertain future for water supply due to a combination of both factors.

Precipitation in Peru is varied in space and time. The Pacific coastal regions receive precipitation only rarely, but have a high percentage of the population. To the east, the ranges of the Andes attract considerable precipitation during the normally wet summer months. Although tropical, the high altitudes result in accumulation of snow as glacial ice, sustaining runoff during the dry months of June through September. River flow has provided water to the arid coast, as well as fostered development of agriculture and hydroelectric power generation in mountainous areas and intermontaine basins.

Short-term and long-term climate variations are affecting Peruvian water resources today, and may jeopardize long-term sustainability of water supply. Although Peru has the greatest volume of glacial ice in the tropics, global warming has resulted in a 20-30% reduction of ice during the last three decades. Unusually strong ENSO events (El Nino) have altered precipitation patterns for extended periods, resulting in locally severe flooding and decreased annual precipitation in normally wet areas.

To assess the present precipitation and runoff conditions, and to evaluate future sustainability issues, two river basins have been studied. The Rio Santa in northwestern Peru drains portions of the Cordilleras Negra and Blanca, flowing through the Callejon de Huaylas to the Pacific. The Rio Vilcanota in southeastern Peru drains much of the area north of Lake Titicaca and is a major tributary of the Amazon. Both rivers drain areas of extensive alpine glaciers, and both rivers have major hydroelectric plants in their lower reaches. These similarities have resulted in good records of hydrologic conditions as well as long-term climate records from the glaciers. Efforts have been made in recent years to develop storage reservoirs high in the drainage basins in order to provide adequate flow for hydropower during prolonged dry periods.

If present trends continue, demand for water in both river basins will exceed supply in the near future. To ensure sustainability, additional storage capacity should be constructed within the basins. Increased development of ground water resources should also be encouraged to reduce impacts of short-term weather variation.

1 INTRODUCTION:

Fresh water supply in Peru is adequate to support the population today, but future sufficiency is questionable in light of local and global climate change. Population growth and demographic shifts may drive Peru to conditions of local and widespread water scarcity within the next two decades.

Compounding the population pressures facing Peru's water resource managers are near term declines in the renewable annual runoff, largely due to decreased accumulation, and accelerated melting of glacial ice throughout the cordilleras. This well-documented loss of glacial ice in Peru's mountains can only lead to an ultimate decline in total annual runoff, resulting in local seasonal deficiencies, and perhaps to widespread regional water shortages.

Population migration from nearly self-sufficient rural areas, to overcrowded and under-resources urban centers, results in an apparent decrease in the well-being and wealth of the migrants. For most of the migrant population, any real growth in income is lost in increased cost-of-living, with a subsequent decline in standard of living.

Sustaining water in the nations rivers during seasonally dry periods may require a program to increase storage capacity high in the basins with small to moderate size reservoirs. An increased reliance on ground water resources will also augment diminished surface water supplies.

2 GLOBAL WATER PROBLEMS:

Although Earth is a water-rich planet, the amount of fresh water available for man's use is a finite supply. The distribution of fresh water is widely varied, and adequate renewable water resources are not well matched to areas of rapid population growth and high water demand.

The adequacy of the finite water supply to support Earth's population will decrease as that population grows. Areas of marginal supply of renewable fresh water will be locally impacted. Global climate change, whether natural or anthropogenic may not alter the finite supply of renewable water, but shifts in regional or local climate may drastically affect supply. Widespread temporal change of climate, such as ENSO variations (El Nino-Southern Oscillation) will have pronounced regional impacts on the annual distribution of renewable water, with consequent flooding and periods of severe drought.

3 SITUATION OF PERU:

Peru is a nation of physical extremes, with highly varied topographic regions and very diverse ecological zones that result from these extremes of topography and precipitation. Located along the west coast of South America, from 3 degrees to 18 degrees south latitude, Peru's climate ranges from desert areas along the coast, to tropical rain forest of the Amazon basin in the eastern interior. Between these extremes lie a number of long narrow north trending cordilleras, which rise to elevations well above 5000 meters (Figure 1). Although located in tropical latitudes, Peru's mountains contain the largest volume of glaciers in any tropical region of the world. Melting of these ice masses results in significant fresh water flow in the nation's rivers, even during the extended dry season from April through October

Figure 1. Location map of Peru, and the major cordilleras and rivers. Locations of the two basins of study are highlighted (USGS PP 1386 I-4).

Today the population of Peru is more than 25 million, a large percentage of who are living along the western coast. These coastal cities are quite dry, relying on water flowing to the Pacific from the mountain regions; and on ground water well systems to provide fresh water resources.

Peru's population distribution is a relic of the Spanish occupation that began in 1530. Pre-Columbian population centers were more appropriately located in the mountainous regions of the interior, where water and agricultural resources were both more abundant. The pre-Inca Tiwanakan and Huari civilizations developed sophisticated and sustainable water and agricultural practices with canals and terraces, but may have been impacted by an extended period of drought around 1100 AD that resulted in a significant decline in their population and power. The earlier Chavin culture, which built major temples and structures along the northeast coast of Peru, disappeared about 2800 years ago, at a time when fossil records indicate that El Niño cycles became more frequent (Sandweiss, et al., 1996). The pressures of climate-induced change, may again impact the sustainability of civilization in modern Peru in the near future.

4 GLOBAL CLIMATE CHANGE TODAY:

At many times in earth history, global climate has fluctuated, resulting in prolonged periods of abnormally cold or warm temperatures. Since the beginning of the Pleistocene epoch, the climate has been mainly cold, with extensive periods of glacial ice accumulation, both as massive sheets on the continents of the northern hemisphere, and in high altitude and high latitude regions of the continents worldwide. Modern man evolved during the latter part of these ice ages, and world population has grown rapidly in the benign climate that has existed since the retreat of the last big ice sheets nearly 12,000 years ago. During the last 200 years of man's history industrial and technological progress has fueled an exponential growth in exploitation of natural resources, with a consequent exponential increase in anthropogenic contribution to greenhouse gases such as CO_2. The increased amount of CO_2 in the atmosphere is blamed for a significant influence on the global temperatures as the sunlight is trapped in the greenhouse of our atmosphere (Figure 2)

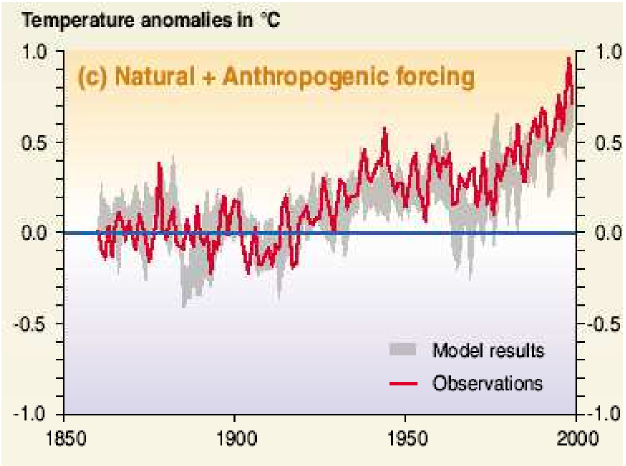


Figure 2. Global temperature deviation from the mean since 1850.
(Climate Change 2001, IPCC Plenary XVIII Working group, Wembley, UK September 2001)

One of the best records of atmospheric temperature through time is in the ice of glaciers, which have existed for thousands of years without melting. Glaciers will continue to accumulate snow, even when in advanced stages of recession. The fractionation of isotopes of O_2 of this annual water is preserved in the snow layers that become glacial ice. Ice core records have been obtained from ice caps throughout the world, and in combination with diverse records of carbon isotopic fractionation, indicate that temperature and CO_2 concentration in the atmosphere have been increasing rapidly since the beginning of the industrial revolution, particularly during the last 30-50 years (figure 3)

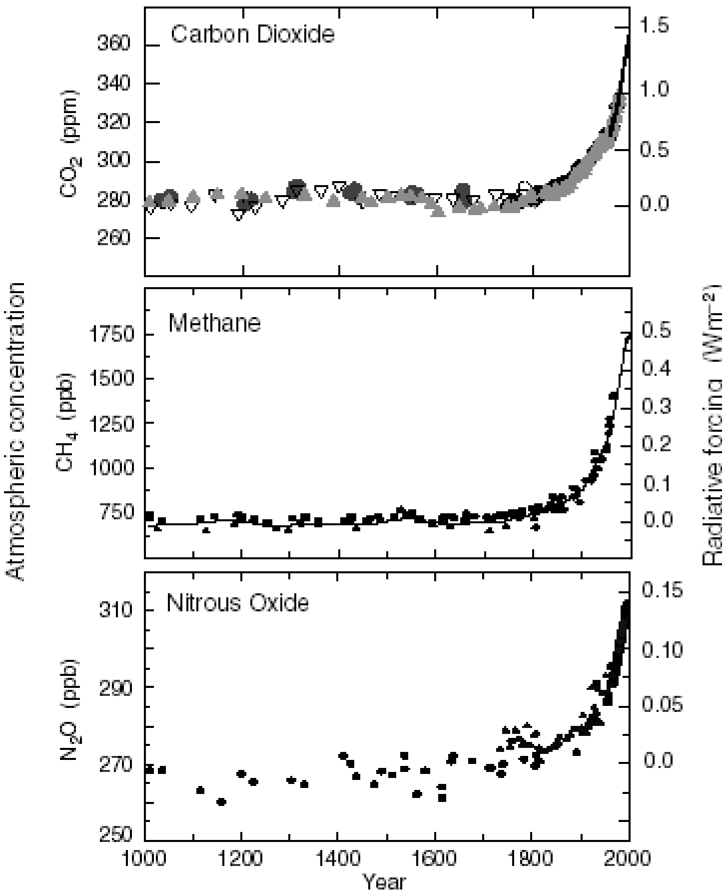


Figure 3. Atmospheric concentration of greenhouse gases since the year 1000 AD. (Climate Change 2001, IPCC Plenary XVIII Working group, Wembley, UK September 2001)

Tropical glaciers and ice sheets are sensitive to temperature change. Retreat of glacial fronts, and diminished ice masses has been well documented from tropical mountains in Africa and South America. The volcanoes of West Africa, such as Kilimanjaro, popular symbols of the environmental resources of the region, are changing at such an alarming rate that experts estimate that the "snows" of Kilimanjaro will cease to exist within the next century, and that ice masses on this and other tropical African mountains will completely disappear by 2100.

Throughout the tropics and sub tropic mountains of South America glaciers are retreating. Estimates of loss of ice mass in Peru's cordilleras range from 15-30% in the last 30 years (CONAM, 2002). This is readily documented through comparative aerial photo interpretation of the smaller glaciers, but more significant for sustainable water resources is the decrease of mass of ice caps such as Huascaran in the Cordillera Blanca, and Quelccaya in the Cordillera Vilcanota (Thompson, et al., 1985).

Much of the shrinkage of Peru's glaciers and ice caps can be attributed to global temperature increase, but the problems are exacerbated by decreased local precipitation in their accumulation zones resulting from El Niño weather patterns. The ENSO (El Niño -Southern Oscillation) phenomenon is increasingly blamed for deviations in weather patterns worldwide, but nowhere are the effects felt so profoundly as in Peru, the home of El Niño.

El Niño is a periodic warming of the Pacific Ocean surface water temperatures and resulting oceanic currents. The phenomenon was first named in Peru, during the 1800's, for its effects on coastal fisheries. Today it is recognized as a phenomenon of the open ocean and efforts to predict its cycles and global influence are widespread. The frequency of ENSO, and the severity of its effects, both in Peru and worldwide, are believed to be increasing as a result of warming of the Earth.

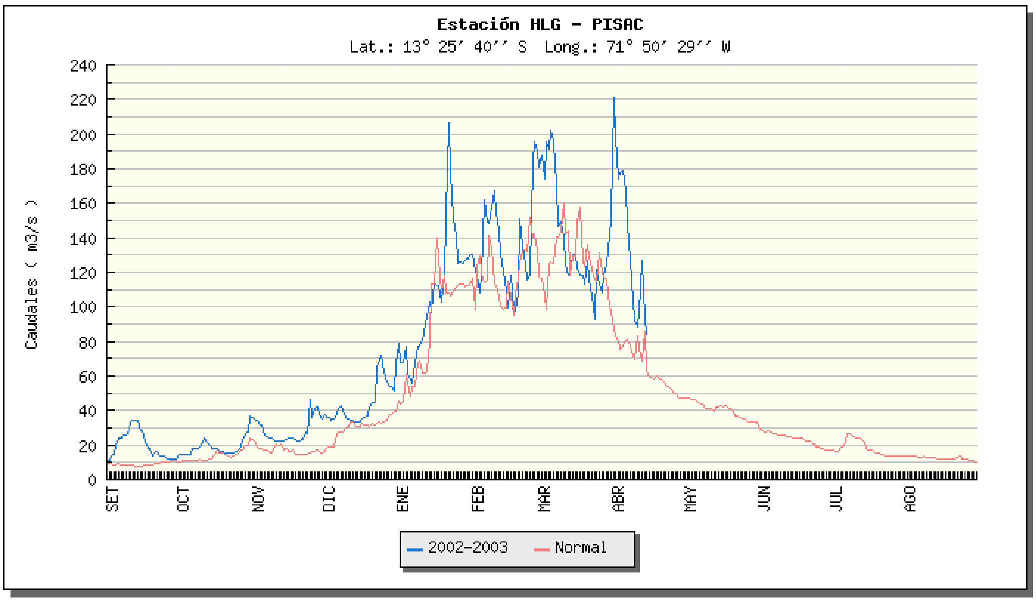
Peru has experienced several severe El Niño periods during the last 20 years. Severe flooding in normally dry regions of the country has marked these periods, along with decreased precipitation in normally wet regions of the mountains. The resultant decrease in snow and ice accumulation has compounded the problem of wastage of the glacial ice attributable to global warming. If severe El Niño events become the norm, then decreased precipitation in the mountains may be expected and accelerated shrinkage of the ice masses will continue.

5 HYDROLOGY OF THE RIO SANTA AND RIO VILCANOTA BASINS:

Two unrelated river basins are being studied to assess the local hydrologic response to altered precipitation patterns and decreased runoff potential from the glaciated uplands. This project, was begun in 2001 and focuses on the Rio Santa, which drains a portion of the Cordilleras Negra and Blanca in northwest central Peru; and the Rio Vilcanota/Urubamba, which drains much of the altiplano north of Lake Titicaca (figure 1).

Rio Santa drains the highest mountains of Peru (Cordillera Blanca) and the eastern slopes of the Cordillera Negra, flowing north through the Callejon de Huaylas to empty into the Pacific about 400 kilometers north of Lima. The Cordillera Blanca has a substantial portion of the glaciers of Peru, and runoff from this range has sustained flow during the dry season, allowing the production of hydroelectricity at the Huallanca. Additionally a significant new irrigation project is being developed to divert water from the river for agricultural use in three northern river basins in the Department of La Libertad, near Trujillo.

Rio Vilcanota (known as Rio Urubamba downstream) drains the other major glaciated range of Peru, arising in the uplands of the Cordillera Vilcanota, and is augmented downstream by runoff from the glaciated Cordilleras Urubamba and Vilcabamba. The basin of the Rio Vilcanota supports a significant population dependent upon the river for fresh water and hydropower. A major hydroelectric plant is located downstream at Machu Picchu and many communities along the river, including Cusco, draw drinking water from the river system and its tributaries. Although the seasonal discharge of the river varies greatly, dry season flow has been sustained in large part by runoff from the substantial ice masses high in the basin (figure 4).



6 CONCLUSIONS

During the 2003 field season both basins will be studied in detail to develop an understanding of the inputs and withdrawals, as well as the detailed hydrology of the rivers. The long-term records collected by SENHAMI (the Peruvian Meteorological Organization) for each region and basin will be analyzed to assess current hydrologic

balance, and to predict future hydrologic stresses. Each basin presently has only limited storage capacity in the upper parts of the drainage. The power companies producing hydroelectricity in the respective basins built these reservoirs for the express purpose of maintaining adequate flow in the rivers for generation during the dry seasons.

Opportunities for additional off-stream storage, particularly in tributary valleys, as well as the potential for ground water withdrawals will be evaluated. Although increased melting of the glaciers will maintain significant short-term dry season flow, the prospect of decreased ice mass and unsustainable dry season contributions to the nations rivers presents a prospect of future fresh water shortages. If the population is to continue to develop its natural resources in a sustainable fashion, planning must be done now to offset future water crises. If present trends continue, demand for water in both river basins will exceed supply in the near future. To ensure sustainability, additional storage capacity should be constructed within the basins. Increased development of ground water resources should also be encouraged to reduce impacts of short-term weather variation.

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