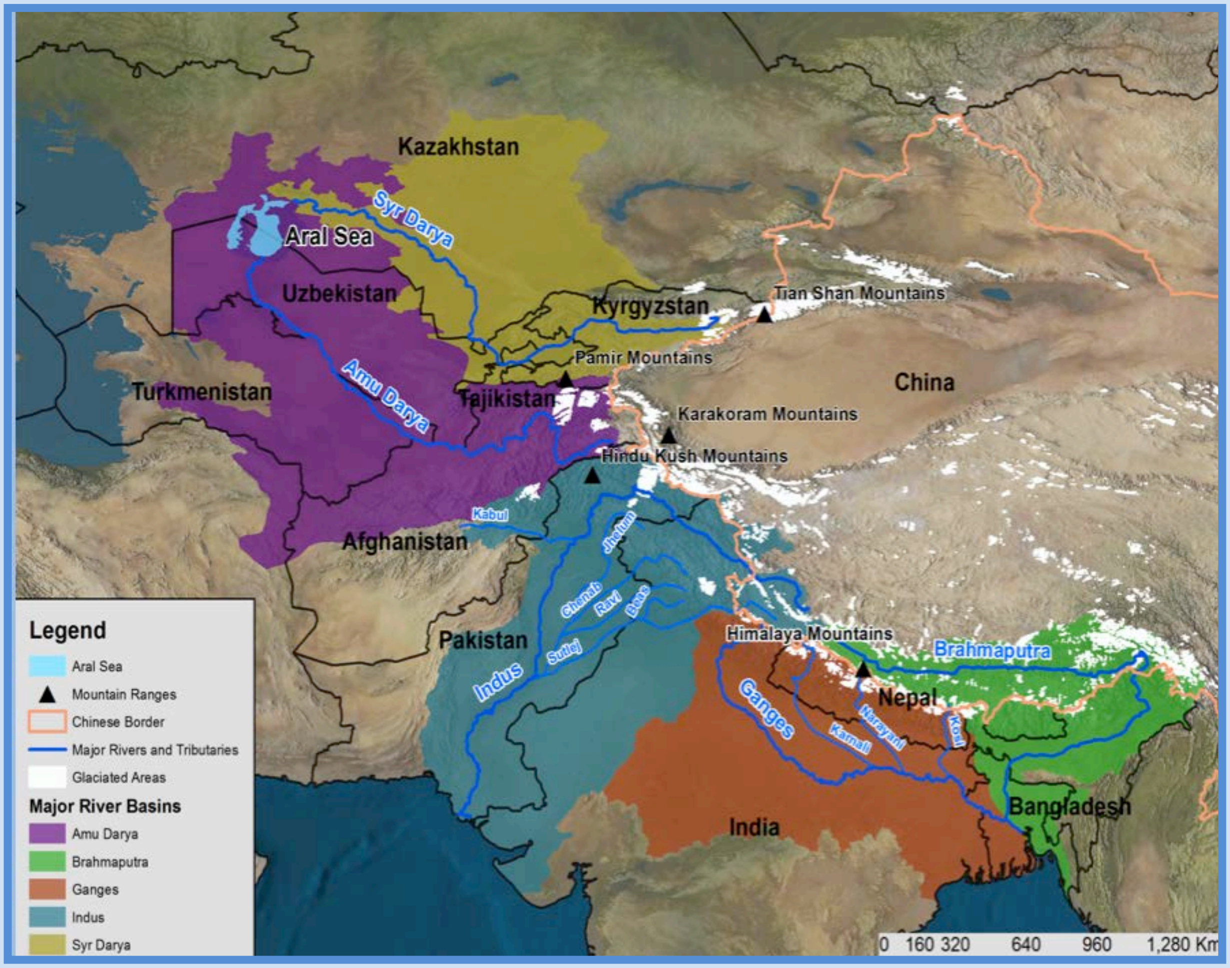
Adapting to Water Stress and Changing Hydrology in Glacier-Dependent Countries in Asia

A Tool for Program Planners and Designers



Glacier and Snowpack Dependent River Basins in High Asia

USAID FROM THE AMERICAN PEOPLE

Coastal Resources Center
University of Rhode Island

PATH Foundation Philippines, Inc.

CONSERVATION INTERNATIONAL

This document can be found at http://www.crc.uri.edu/

For more information contact:
Coastal Resources Center
University of Rhode Island
Narragansett Bay Campus
South Ferry Road
Narragansett, Rhode Island 02882, USA
Tel: (401) 874-6224
Fax: (401) 874-6920
Email: balanced@crc.uri.edu

June 2013. Coastal Resources Center, University of Rhode Island.

Citation

Leona D'Agnes, 2013. Adapting to Water Stress and Changing Hydrology in Glacier-dependent Countries in Asia: A Tool for Program Planners and Designers. Coastal Resources Center, University of Rhode Island.

Disclaimer:

"This document is made possible by the generous support of the American people through the United States Agency for International Development (USAID). The contents are the responsibility of the Coastal Resources Center at the University of Rhode Island as part of the Building Actors and Leaders for Advancing Community Excellence in Development (BALANCED) Project and do not necessarily reflect the views of the United States Government. This document is funded under Cooperative Agreement No. (GPO-A-00-08-00002-00)."

TABLE OF CONTENTS

ACRONYMS

ADB	Asian Development Bank
BALANCED	Building Actors and Leaders for Community Excellence in Development
BS	Black Soot
CAR	Central Asian Republics
CAKE	Climate Adaptation and Knowledge Exchange
CAREC	Central Asian Regional Environmental Centre
CMSE	Civilian Military Support Element
CSISA	Cereal Systems Initiative for South Asia
CDC	Centers for Disease Control
CCDS	Climate Change and Development Strategy
CSO	Civil Society Organization
DOD/PACOM	Department of Defense, Pacific Command
FAO	Food and Agriculture Organization of the United Nations
FETP	Field Epidemiology Training Program
FFP	Family Farming Project
FRC	Foreign Relations Committee
FTF	Feed the Future
GCC	Global Climate Change
GDO	General Development Officer
GAPS	Government Annual Program Statement
DPRR	Disaster Preparedness and Risk Reduction
GHI	Global Hunger Index
GMVR	Glacier Melt Vulnerability and Resiliency
GHG	Greenhouse Gases
GLOF	Glacier Lake Outburst Flood
GM	Glacier Melt
ICIMOD	International Center for Integrated Mountain Development
IFAS	International Fund for Saving the Aral Sea
IPCC	International Panel on Climate Change
IR	Intermediate Result
NAPA	National Adaptation Programmes of Action
NASA	National Aeronautics and Space Agency
NGO	Nongovernmental Organization
NRM	Natural Resources Management
OHE	Office of Health and Education
PHE	Population, Health and Environment
PRM	Bureau of Population, Refugees and Migration
RESET	Regional Energy Security, Efficiency and Trade Program
SERVIR	Regional Visualization and Monitoring System
SO	Strategic Objective
SFV	Stream Flow Variability
UN	United Nations
USAID	United States Agency for International Development

USDA	United States Department of Agriculture
USFS	United States Forest Service
USG	United States Government
USGS	United States Geological Survey
WHO	World Health Organization
WWDR	World Water Development Report
YLP	Young Leaders Program

GLOSSARY

Selected Glacial Terminology as Defined by U.S. Geological Survey[1]

Ablation: refers to all processes by which snow, ice, or water in any form are lost from a glacier — the loss of snow or ice by evaporation and melting.

Albedo: the percentage of incoming radiation that is reflected off a surface. An albedo of one indicates that 100 percent of the radiation is reflected. Fresh snow has a high albedo (0.7 to 0.9), indicating that 70 to 90 percent of the radiation received is reflected; glacier ice has a lower albedo of 0.2 to 0.4.

Glacial advance: the net movement of glacier terminus down-valley. Advance occurs when the rate of glacier flow down-valley is greater than its rate of ablation. Advances are characterized by a convex-shaped terminus.

Glacial retreat: the net movement of the glacier terminus up-valley. Retreat results when the glacier is ablating at a rate faster than its movement down-valley. Retreating termini are usually concave in shape.

Glacier: a body of ice showing evidence of movement as reported by the presence of ice flow line, crevasses, and recent geologic evidence. Glaciers exist where, over a period of years, snow remains after summer's end.

Glacier outburst flood: a sudden release of melt-water from a glacier or glacier-dammed lake sometimes resulting in a catastrophic flood, formed by melting of a channel or by sub-glacial volcanic activity.

Jokulhlaup: Icelandic term for glacial outburst floods. Jokulhlaup's are sudden outbursts of water released by a glacier. The water may be released from glacier cavities, sub-glacial lakes, and from glacier-dammed lakes in side valleys[1].

Mass balance: the net gain or loss of snow and ice through a given year — usually expressed in terms of water gain or loss.

Moraine: rock debris deposited by a glacier.

Terminus: the down-valley end of a glacier; may be referred to as the glacier snout.

[1] Molnia, B. U.S. Geological Survey. Glossary of Glacial Terminology. Open-File Report 2004–1216 http://pubs.usgs.gov/of/2004/1216/

SECTION 1: BACKGROUND

The Greater Himalaya Region

The Greater Himalaya region is a complex of high mountain ranges that ring the southern and western sides of the Tibetan Plateau, forming the headwaters of the large rivers flowing into Southeast, South, and Central Asia as well as parts of China. Also called "High Asia," the region spans the Himalaya, Hindu Kush, Karakoram, Pamir, and Tien Shan mountain ranges,[2] which have the largest areas covered by glaciers and permafrost outside the Polar Region.[3] The region's glacier and snowpack-dependent river basins (see cover photo) provide important ecosystem services for the highly populated Himalayan floodplains. While residents of High Asia have a long history of resilience to climate variability, some countries are already experiencing disruptive impacts to hydrology systems that are beyond their historical experience and consistent with the predicted consequences of climate change. These include the retreat of low-altitude glaciers in eastern Himalaya that people rely on for fresh water;[4] glacier wasting in low-elevation ranges of the Tien Shan and Pamir mountains where summers are dry and snow, and glacial melt-water is essential for water availability;[5] accelerated glacial melt and rising incidence of landslides, floods and glacial lake outburst floods (GLOFs) in Nepal,[6] Tajikistan,[7] Kyrgyzstan and Kazakhstan;[8] and extreme weather events that alter seasonal patterns of ice and snowpack melt, such as the 2012 cold wave that delayed glacial melt in the high mountains of Northern Pakistan resulting in dramatic reductions in stream flow in the Indus river.[9]

Overview of USAID Activity Related To Glacial Melt

In 2010, USAID commissioned a review of the scientific information on glaciers in the Greater Himalaya region. Review findings were described by Malone[4] in a report entitled *Changing Glaciers and Hydrology in Asia: Addressing Vulnerabilities to Glacier Melt Impacts.* The review revealed a lack of data on current and historical rates of glacier melt and retreat requisite to forecast future impacts with certainty. This is impeding any action to adapt to current hydrological changes in the region, which constitutes vulnerability in its own right. The reviewers also highlighted several existing issues that make Asia's populations inherently vulnerable to *any* changes in their water systems — even before considering the likely impacts of glacial changes. These issues are linked to population, health, and ecosystem and pollution dynamics in the region. Investing in adaptation strategies that address these inherent

---

[2] Armstrong, R. (2010) "Melting Glaciers: Current Status and Future Concerns. USAID Asia Glacier Melt Project. Cooperative Institute for Research in Environmental Sciences. University of Colorado, Boulder

[3] ICIMOD (2009) Water Storage: A strategy for climate change adaptation in the Himalayas. Sustainable Mountain Development No. 56, ICIMOD, Winter 2009

[4] Malone, E. L. (2010). Changing Glaciers and Hydrology in Asia: Addressing Vulnerabilities to Glacier Melt Impacts. With inputs from R.L. Armstrong, L. D'Agnes, J. Ayers, J. Gavin, S. Harding, K. McNamara, B. Melchior, F. Rosenzweig, and G. Taylor. CDM International Inc. for USAID.

[5] Sorg et al (2012) Climate Change Impacts on Glaciers and Runoff in Tien Shan (Central Asia). Nature Climate Change. 29 July 2012.

[6] ICIMOD (2011). Glacial Lakes and Glacial Lake Outburst Floods in Nepal.

[7] Diebold, A. Editor (2012) From the Glaciers to the Aral Sea: Water Unites. Trescher Verlag GmbH. Berlin Germany URL www.waterunites-ca.org. .

[8] Thurman, M. (2011) Natural Disaster Risk in Central Asia: A Synthesis. UNDP Bureau for Crisis Prevention and Recovery

[9] Saleem Shaikh and Sughra Tunio (2012) Low Indus River Flows Threaten Crops. ALERTNEW 9 July 2012 [WWW] http://www.trust.org/alertnet/news/low-indus-river-flows-threaten-crops/

vulnerabilities will yield net social benefits across several sectors — regardless how the glaciers respond to climate forcing ("no regrets" approach). Moreover, this approach will contribute to overall development in the region.[4]

A second USAID activity examined the health, food security, water, energy, and biodiversity and conflict dimensions of glacial melt in High Asia and explored opportunities for building synergies among multiple USAID programming areas to reduce glacial melt vulnerabilities at regional and country-specific levels.[10] Follow-on work undertaken by the USAID-financed BALANCED (Building Actors and Leaders for Advancing Community Excellence in Development) Project[11] resulted in the drafting of this Tool to guide adaptation planning based on all the knowledge, science, and experience collected and gained through the development of the above two reports, and as well as other sources of data and information. The draft Tool was vetted among key staff at USAID Offices in Tajikistan, Kyrgyzstan, and Kazakhstan who worked collaboratively with BALANCED to refine the Tool so as to more directly address existing water vulnerabilities in tandem with challenges posed by current glacial changes. The ensuing document constitutes the final version of the Tool entitled "Adapting to Water Stress and Changing Hydrology in Glacier-dependent Countries in Asia: A Tool for Program Planners and Designers."

Purpose of the Tool and Key Audiences

This Tool was designed with two main purposes in mind, namely to:

1. Increase understanding among decision-makers in glacier-dependent countries of the existing factors that make populations more vulnerable to *any* changes in their water systems and, as such, inherently vulnerable to the impacts of changing glaciers and hydrology in High Asia (Sections 2-6);

2. Provide program planners/designers in glacial-dependent countries with a practical Tool to guide the design of "no regrets" approaches to adaptation that address both existing vulnerabilities and those superimposed by current glacial changes in a manner that will yield net social benefits to multiple sectors under all future scenarios of glacial melt and climate change (Sections 7-8).

Key audiences and Intended Users of the Tool include:

- USAID and host government decision-makers and program/project planners and designers in glacier-dependent countries in Asia;

- Regional entities working in related fields such as the International Center for Integrated Mountain Development (ICIMOD), the Executive Committee of the International Fund for Saving the Aral Sea-IFAS (trans-boundary water dialogue), the Central Asian

---

[10] Schweithelm J. (2011) Glacier Melt Vulnerabilities in Asia: Exploring USAID Programming Opportunities. Draft Report submitted to URI/CRC for the BALANCED Project and USAID (GPO-A-00-08-0002-00)
[11]BALANCED is USAID's global population-health-environment (PHE) program (2008-2013) implemented by the University of Rhode Island (URI) and partners [http://balanced.crc.uri.edu/]

Regional Environmental Centre–CAREC (integrated water resources management in small trans-boundary watersheds), and others; and

- International, national and local nongovernmental organizations (NGOs) working in related fields such as climate change adaptation and mitigation, disaster preparedness and relief, and integrated population, health and environment (PHE).

Relevance to USAID's Climate Change and Development Strategy

USAID's Climate Change and Development Strategy (CCDS) affords priority to glacial-dependent countries and other nations that satisfy four adaptation criteria namely: (1) likelihood of significant physical changes, (2) dependency of population on climate-sensitive sectors, (3) percentage of population in high-risk areas, and (4) the ability of the country's economy to respond to climate change.[12] This Tool was specifically designed for application in Asia's glacial-dependent countries to facilitate cross-sectoral programming to simultaneously address existing vulnerabilities and new challenges posed by the region's changing glaciers and hydrology. As such, its use could enhance achievement specific CCDS objectives, namely:

SO1 Accelerate the transition to low emission development through investments in clean energy and sustainable landscapes *(such as through investments in appropriate technology to reduce black carbon emissions and glacial ablation, for example, improved cook stoves and fuel-efficient kilns);*

SO2 Increase resilience of people, places, and livelihoods through investments in adaptation (*such as by guiding investments in "no regrets" adaptation strategies that will yield net positive benefits under all future scenarios of glacial melt and climate change*);

SO3 Strengthen development outcomes by integrating climate change in Agency programming, learning, policy dialogues and operations *(such as by linking vulnerabilities of glacier melt on water supply with USG initiatives that work across compatible sectors, for example, Feed the Future Initiatives in Asia)*

The Tool's focus on reducing vulnerabilities of glacial melt on water supply is also relevant to USAID's new strategy on water programming in Asia — a strategy that supports community resilience through improvements in irrigation efficiency, watershed management, water productivity, and water sanitation and hygiene. Such integrated approaches to water security also help to diffuse tensions resulting from competition for dwindling resources among various water user groups and water-user sectors. Experts at the USAID Asia and Middle East Bureau[13] note that "water is fundamental" to some of the existing tensions in many conflict-affected communities in the region and could also contribute to future tensions."

[12] USAID (2012) Clean Resilient Growth. USAID Climate Change and Development Strategy/2012-2016
[13] Melnyk, M. (USAID Asia and Middle East Bureau) cited in "Strengthening Responses to Climate Variability in South Asia". Wilson Center, February 2013

Guidance for Readers

Individuals familiar with water supply and glacial melt (GM) issues in the Greater Himalaya Region may want to pass over the introduction to these topics in *Section 2,* and skip ahead to *Section 3: Vulnerabilities Perspectives,* which defines vulnerability and related concepts of resilience and adaptive capacity, and examines the "non-climatic" dimensions of vulnerabilities in the region. The next section, *Section 4*: *Social-Ecological Resilience,* explores existing issues that undermine the resiliency of Asia's populations and ecosystems rendering them more vulnerable to *any* change in water supply. The succeeding *Section 5: Measures to Cope with Existing Stress* highlights options for coping with water scarcity and current glacial changes, and measures to mitigate the drivers of glacial melt/retreat in High Asia. In sequence, *Section 6: Need for Integrative Systems Approach to Resiliency Building* builds on the case made in *Sections 2-5* that vulnerabilities arising from GM are entwined with other vulnerabilities, so programs that build resilience to GM must also address other social and ecosystem issues. An example is drawn from the Feed the Future (FTF) initiative in Nepal. This initiative takes an integrated approach that incorporates a strategy to directly address current GM issues that impact food security. Its framework also offers the potential to incorporate additional measures to redress other dimensions of GM vulnerabilities. *Section 6* also outlines a concept whereby USAID Missions can create a "virtual" multi-sectoral GM vulnerabilities activity by coordinating multiple (compatible) programming areas.

The ensuing *Section 7* outlines the *General Steps in Creating an Integrated Response that Works Across Sectors* based on the "no regrets" approach to GM adaptation. Lastly, an illustrative case for activating such a response is outlined in *Section 8: Operationalizing an Integrated and Multi-Sectoral Response to GM Vulnerabilities* with a focus on integrating activities to address GM impacts with other development needs in high-altitude communities that are on the frontlines of GLOFs and retreating glaciers affecting their local water supplies.

SECTION 2: INTRODUCTION

Water Issues in Asia

Unconstrained water use at the global level has grown to "more than twice the rate of population increase in the 20th century, to the point where reliable water services can no longer be delivered in many regions," according to the Food and Agriculture Organization (FAO) of the United Nations.[14] By 2025, much of Asia is expected to be under water stress, with demand exceeding available supply, not even accounting for the impact of receding glaciers.[15] Hydrologists typically assess scarcity by looking at the population-water equation. One method of measuring water scarcity is based on the amount of renewable internal freshwater resources (internal river flows and groundwater from rainfall) per capita. If less than 1,700 m^3 per year per capita is available, people experience water stress. Less than 1,000 m^3 per capita is classified as chronic water scarcity and less than 500 m^3 as absolute water scarcity.

Using data from FAO's global information system on water and agriculture (AQUASAT) and its own population estimates, the World Bank calculated the renewable water resources for 214 countries.[16] Data for countries in the Greater Himalaya Region are presented in Table 1 (for 2007 and 2011). The statistics indicate that people in Turkmenistan and Pakistan are experiencing *absolute* water scarcity while populations in Bangladesh and Uzbekistan are plagued by chronic water scarcity and people residing in India and Afghanistan are water stressed. China is considered vulnerable, as its water availability was less than 2,500 m^3 per person in 2011.

TABLE 1: Renewable internal fresh water resources per capita (m^3)

Country	**2007**	**2011**
Afghanistan	1,491	1,335
Bangladesh	729	698
Bhutan	113,276	105,653
China	2,134	2,093
India	1,232	1,165
Kazakhstan	4,156	3,886
Kyrgyz Republic	9,287	8,885
Nepal	6,985	6,501
Pakistan	334	311
Tajikistan	9,609	9,096
Turkmenistan	289	275
Uzbekistan	608	557

Source: The World Bank: Databank Indicator ER.H20.INTR.PC

[14] FAO (2012). Coping with water scarcity: An action framework for agriculture and food security. Water Report 38. Food and Agriculture Organization , Rome.
[15] Bernstein, S. (2002) Freshwater and human population: a global perspective. In K.Krehnak (ed.), *Human Population and Freshwater Resources: US Cases and International Perspectives*, New Haven: Yale University
[16] http://data.worldbank.org/indicator/ER.H2O.INTR.PC/countries?display=default

In Bhutan, Tajikistan, Kyrgyzstan, and Nepal water availability exceeds the global average (6,116 m^3). However, because the metric (renewable water per capita) is calculated as an average, it accounts for neither uneven water distribution within a country, nor seasonal shortages, nor the quality of water.

Drivers of Water Insecurity in Asia

The rapid growth of human populations and economies in South and Central Asia is a principal driver of water stress in the region (Figure 1) and high population momentum guarantees that demand for water will intensify for decades to come. This is particularly true in countries with a large youth bulge, such as the water-stressed nations of Afghanistan and Pakistan. Nepal, which seemingly has plenty of water, will see its consumption double within the next 30 years along with its population[17] at a time when receding glaciers are likely to cause significant change in water availability. Other drivers of water insecurity include agriculture policies that promote water-intensive crops and require unsustainable irrigation. Local government policies continue to pursue cotton production in Central Asia, particularly in Uzbekistan, adding further stress to populations and ecosystems already beset with chronic water scarcity. A report to the U.S. Committee on Foreign Relations notes: "The demise of the Aral Sea in Central Asia remains one of the most iconic global images of mismanaged agriculture policies and highlights the interconnectivity between such policies and water scarcity."[18]

Irrigation has been a boon to crop production in the region; however, wasteful consumption of irrigation water has induced not only water scarcity, but ecosystem degradation via processes of salination, waterlogging, and water erosion. A recent United Nations (UN) report[19] states "The limits to sustainable water abstraction have already been surpassed in many regions of Asia. For example, there is little or no additional stream flow or groundwater for further development in the Indus River in Pakistan and India and the Amu and Syr Darya in Central Asia — all important food-producing areas. The stress is reflected in ecosystem health, where all of these basins suffer from extreme pollution, river desiccation, competition for supplies and other ecosystem degradation."

Other stresses on water resources in the region include deforestation, over-cultivation, and overgrazing. Destruction of forests, particularly in Central Asia and Afghanistan, undermines water security via mechanisms that lead to decreasing regional rainfall through the loss of cloud-forming evapotranspiration from the forest. Deforestation also causes land degradation and erosion triggering mudslides, landslides, and flooding. Over-cultivation and overgrazing compromise water resources by reducing fertile topsoil and vegetation cover.

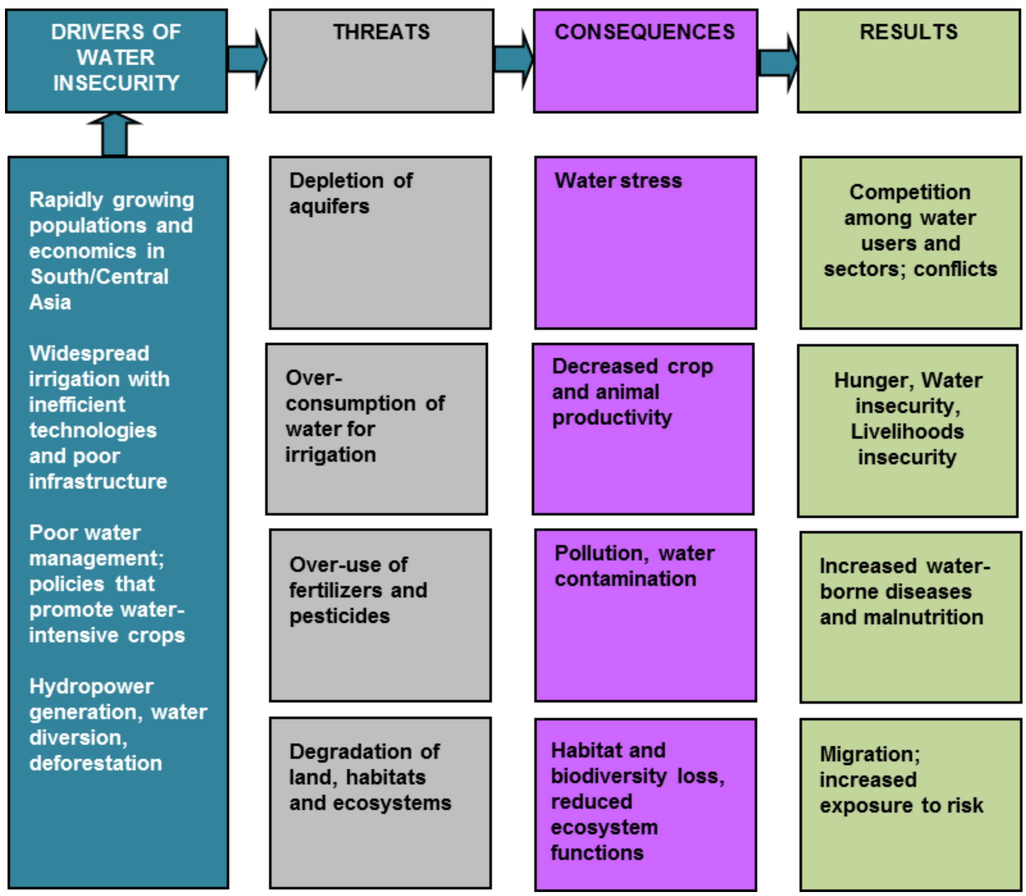
Hydropower development is yet another accentuating factor in High Asia (Figure 1). Dams, irrigation diversions, and other infrastructure are altering hydrological regimes and influencing the quantity, quality, and timing of downriver flows and river ecology. Moreover, hydropower development is adversely affecting relations between upstream and downstream riparians. The Tajik government, for example, is planning a new reservoir and power station on a tributary of the Amu Darya (located in Tajikistan) that will alter the flow regime used for downstream

[17] Government of Nepal Ministry of Health and Population: Nepal Population Report 2011
[18] Committee on Foreign Relations United States Senate Staff Report 112-10 (2011). Avoiding Water Wars: Water Scarcity and Central Asia's Growing Importance For Stability In Afghanistan and Pakistan.
[19] United Nations (2012) World Water Development Report 4 Volume 1: Managing Water under Uncertainty and Risk

irrigated agriculture in Uzbekistan. Tensions flared in 2012 when Uzbekistan's president, Islam Karimov, warned that the Rogun Dam project could lead to "not just serious confrontation, but even wars."[20] Experts agree, however, that "concerns about potential water wars flaring in the decades ahead must not overshadow the requirement to address critical needs of deprived populations living without adequate water supplies today."[21]

Climate change is poised to bring additional risks to water security with warmer temperatures that threaten the cyclical changes to glaciers that provide essential water to the river basins in western Himalaya. Climate-influenced shifts in monsoon dynamics and seasonal rainfalls, which are vital to agrarian populations and livelihoods in South Asia, also can be anticipated.

Figure 1. Drivers and Likely Consequences of Water Insecurity in Asia



[20] Economist, September 29, 2012. Water Wars in Central Asia. Print edition/Asia of the Economist.
[21] Stimson Center Water Conference Report (2010) Fresh Water Futures: Imagining Responses to Demand Growth, Climate Change, and the Politics of Water Resource Management by 2040

Hotspots with Overlapping Water Challenges in High Asia

The United Nation's 2012 World Water Development Report (WWDR) identified hotspots for multiple challenges to water security in Asia-Pacific.[19] The hotspots are countries, areas or ecosystems with overlapping challenges such as increasing water scarcity, high water utilization, poor water quality, and other water-related vulnerabilities. Data for countries in High Asia are excerpted below in Table 2. India and Uzbekistan face challenges in five categories followed by Pakistan and China with four overlapping risk factors. The Central Asian Republics and Nepal have poor water quality and low water endowment compounded by one or more additional vulnerabilities. Although not shown in Table 2, increasing water scarcity (Factor 1) also threatens Turkmenistan and Kazakhstan while Factor 5 (flood-prone country) also characterizes Kazakhstan, Tajikistan, and Kyrgyzstan, according to experts at USAID/CAR.[22] Addressing these existing water challenges is paramount to building resiliency to GM impacts.

Table 2: Water Hotspots in High Asia with Overlapping Challenges

	1	2	3	4	5	6	7	8	9	10	Total
India	x				x		x	x		x	5
Uzbekistan	x	x		x			x	x			5
China					x	x		x		x	4
Pakistan	x	x	x					x			4
Afghanistan	x								x	x	3
Kazakhstan				x			x	x			3
Nepal				x				x		x	3
Kyrgyzstan				x			x				2
Tajikistan				x			x				2
Turkmenistan				x			x				2
Bhutan				x							1

Legend

1 Increasing water scarcity threat
2 High water utilization
3 Deteriorating water quality
4 Poor water quality and low water endowment
5 Flood-prone countries
6 Cyclone-prone countries
7 Drought-prone countries
8 Elevated ecosystem/climate change risk
9 Poor access to drinking water
10 Poor access to sanitation

Data excerpted from WWDR[23] Figure 7.3 p 195.

The Role of Glaciers in Mountain Hydrology

Glaciers are the "water towers of the world" storing water in one place over several decades.[23] This glacier storage acts like a large-volume water tank on the mountain side with new water coming in the top throughout much of the year (retained in the form of ice) and some of the older water running out the bottom during the melt season.[4] The complex hydrologic system in High Asia, of which glaciers are a part, includes monsoons and other rainfall, as well as snow and

[22] Personal communication with Ms. Nina Kavetskaya, Mission Environmental Officer, Strategy and Program Office (SPO) USAID Central Asian Republics
[23] WWDR (2012) referenced from Viviroli et.al. *Mountain Research and Development*, Vol. 23, No. 1:.32–40.

seasonal ice. The proportional contribution of glacier melt-water to the flow of rivers draining the high mountains in Asia is generally lowest in the monsoon-affected eastern end of the Himalayan Range, increasing westward in the semi-arid and arid areas of western India, Pakistan, Afghanistan, and Central Asia.[4] Glacial and snow melt are extremely important in the Indus River Basin,[24] which provides the key water resource that drives the economies of Pakistan and Kashmir (India), and in the Yarkland River system,[25] which is the principal dry-season water source for populations living in extreme western China.

The Hindu Kush-Himalayan Mountains are the major source of stored water in the region. Water is retained in the form of ice and snow in the high mountains, as well as being stored in natural lakes, wetlands, and groundwater aquifers, and behind constructed dams.[6] Changes in glaciers and melt-water production, thus, have direct implications for the region's human populations, ecosystems, and hydropower potential. Accelerated snow melt and glacial run-off can produce glacier lakes and cause existing ones to outburst and flood downstream areas, threatening humans, infrastructure, and livelihoods. A prolonged glacier retreat could both increase the volume of water in the rivers as well as the levels of sediment that they carry, which could choke water supply and disrupt agriculture. As glaciers disappear, they release less water back into the rivers and streams; this process can lead to drought and disrupt riparian ecosystems and hydropower generation. Melting glaciers can also play a positive role in renewing water sources during times of drought. During the European drought of 2003, glacial runoff into Europe's Danube River was at a 100-year high. Viewed in this light, the National Research Council notes that "The melting of glaciers may serve as a sort of ecological buffer that will add water to blighted rivers and streams at the times when they are most needed."[26]

Changes in Hydroclimatic Dynamics in High Asia

USAID's review of scientific information about glaciers in the Greater Himalaya region concluded that scientific data on current and historical rates of glacier melt/retreat are *insufficient* to predict future retreat rates or impacts on downstream river flow volumes with certainty. Available information showing that seasonal and spatial patterns of rain and snowfall are changing as a result of climate change exacerbate uncertainties over the extent to which changes in glacial melt rates are changing downstream river flows[4]. However, because glacial melt is part of the water system, it is likely that impacts relative to climate forcing will be experienced across the region through changes in water quantity and quality. These impacts may be too much water (floods), too little water (droughts/ increased aridity), or water at different times (more early in the growing season/less late in the growing season). In areas where glacial melt is a larger portion of river flow, (e.g., the Indus River Basin) this link will be stronger. In those areas where glacial melt is a smaller proportion of river flow (e.g., the Ganges River Basin), small changes in water quality and timing will have larger impacts on denser populations living downstream — as will *any* change in their water systems.[4]

Along with glacial melt changes, increased temperatures will reduce snow cover throughout the winter, but especially in spring. Monsoon patterns will likely change as well and may turn out to be more important than changes in glacier wastage at lower, downstream elevations.[26] In

[24] For example, The Indus Irrigation Scheme in Pakistan gets about 50% of its runoff from snowmelt and glacial melt
[25] The Yarkland is a headstream of the Tarim River in the Uygur Autonomous Region of Xinjiang
[26] National Research Council (2012) Himalayan Glaciers: Climate Change, Water Resources, and Water Security. Washington, DC: The National Academies Press

monsoonal Himalaya, the seasonal peak in melt-water coincides with the monsoon peak.[6] Flooding is the graver problem in countries such as Nepal and Pakistan, which lack the capacity to store much or any of the melt waters at that time. In 2010, for example, a shift in the distribution of monsoon rainfall led Pakistan to experience massive flooding that inundated one-fifth of the country's land area.[27]

Changes in glacial melt amounts and patterns, along with other changes in high-altitude hydrology, are likely to affect agricultural production across the Greater Himalaya region. The Western regions of the Himalayan arc are more dependent on glacial-fed irrigation compared to the Eastern region; therefore glacial melt impacts will be more pronounced in the West. However, the Western regions show slower rates of glacial retreat, less formation of pro-glacier lakes associated with flood hazard, and quasi-constant glacier mass balance. This contrasts with the Eastern region, where lower elevation glaciers (below 5 kilometers) are retreating at increasing rates[2,28,29].Moreover, people in the western regions of the Himalayan arc tend to have greater wealth, infrastructure, and resources compared to those in the East. These and other non-environmental factors all influence peoples' ability to cope with external stresses, including GM.

Drivers of Glacial Melt in the Himalaya Region

Although glacier melting is predominantly due to global temperature rise, the deposition of pollutant particles like black carbon can enhance this effect. Black carbon is the soot and ash produced by diesel exhausts, thermal power plants, brick kiln smokestacks, forest fires, and inefficient wood-burning cook stoves. Black carbon deposits on glaciers cause them to absorb more sunlight, thus accelerating glacial and snow melt. Anthropogenic sources of black carbon, although distributed globally, are most concentrated in the tropics, where solar irradiance is highest. In the Himalayan region, scientists believe that solar heating from black carbon at high elevations "may be just as important as carbon dioxide in the melting of snow packs and glaciers."[30] The majority of soot emissions in South Asia are due to biofuel cooking. Lack of alternative energy options coupled with above-average rates of population growth and poverty amplify consumption of biomass fuels and emissions of black carbon. In Central Asia, salt deposits transported from the evaporated Aral Sea by dust storms cause glacial ablation in a manner similar to black carbon.[7]

Figure 2 below depicts the key drivers of glacial melt/retreat in High Asia, their threats and their likely impacts, and the principal issues and sectors to be addressed. The multi-dimensional aspect of the threats suggests the need for an integrative systems approach to adaptation with coordinated efforts in disaster preparedness and management, food security, water demand management, health (including reproductive health) and human capital development.

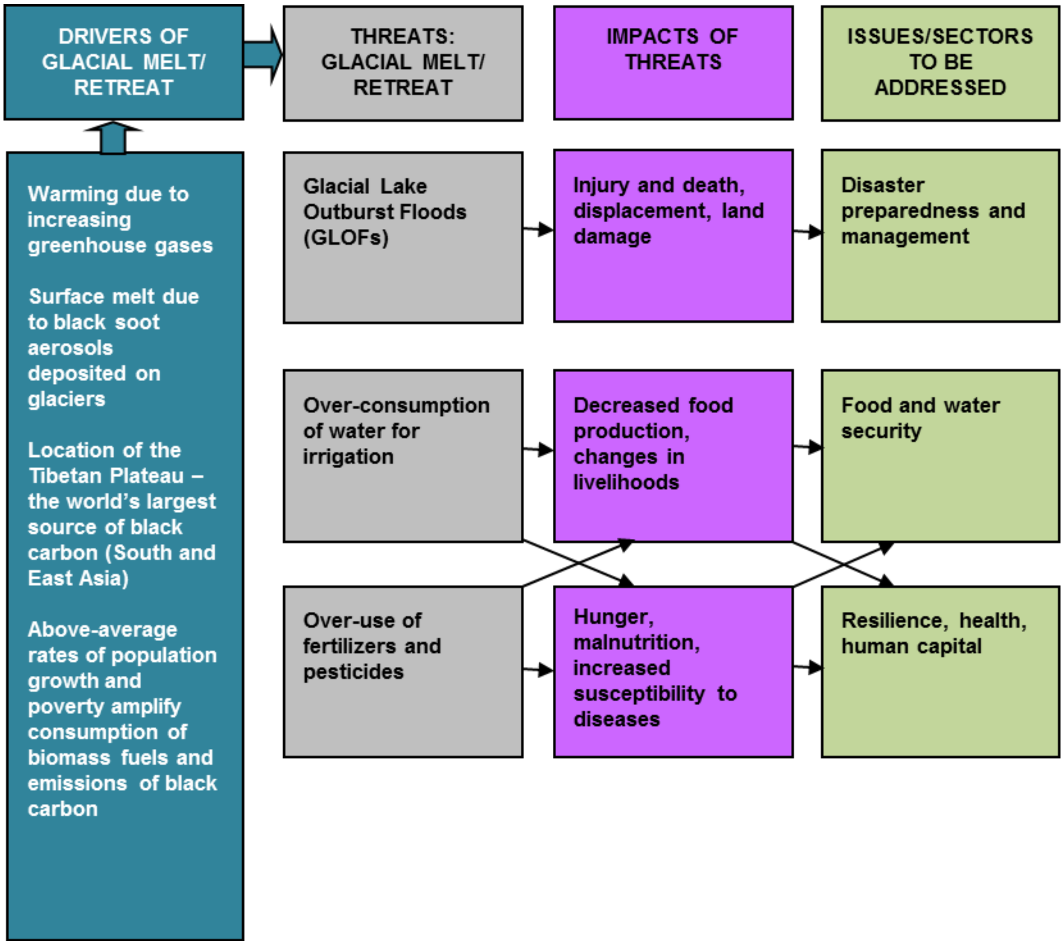
[27] National Research Council (2012) Climate and Social Stress: Implications for Security Analysis. Washington, DC: The National Academies Press

[28] Jacob, T., J. Wahr, W. T. Pfeffer, and S. Swenson (2012), Recent contributions of glaciers and ice caps to sea level rise, Nature, 482, 514–518, doi:10.1038/nature10847.

[29] Yao, T *et.al.* (2012) Different glacier status with atmospheric circulations in Tibetan Plateau and surroundings. *Nature Climate Change* doi:10.1038/nclimate1580.

[30] Ramanathan, V. and G. Carmichael (2008). Global and regional climate change due to black carbon. Nature Geoscience Vol 1. January 2008 [www.nature.come/naturegeoscience]

Figure 2: Drivers of Glacial Melt in High Asia and Likely Impacts



Source: Malone, E (2010) Framework for Considering GM Interventions (Power Point Presentation)

SECTION 3: VULNERABILITY PERSPECTIVES

Definitions of Vulnerability and Associated Terms

Vulnerability and its associated terms — resilience and adaptive capacity — have different meanings for different researchers, decision-makers, and practitioners. Vulnerability assessment and resilience analysis have roots in at least three disparate research communities: hazards/disasters, climate change impacts, and sustainability. In a 2009 review of current research on vulnerability and resilience in the face of climate changes,[31] Malone explains that definitions of vulnerability in the hazards literature tend to focus on characteristics that will help people plan for, cope with, resist and recover from the damages of natural hazards. In the climate-change oriented literature, vulnerability inheres mostly or completely in the characteristics of climate change impacts, whereas in sustainability analysis it inheres mostly in societal characteristics as reflected in the following definition:

- For poor people, vulnerability is both a condition and a determinant of poverty, and refers to the (in)ability of people to avoid, cope with or recover from the harmful impacts of factors that disrupt their lives and that are beyond their immediate control. This includes the impacts of shocks (sudden changes such as natural hazards, war or collapsing market prices) and trends (for example, gradual environmental degradation, oppressive political systems or deteriorating terms of trade). [International Institute for Sustainable Development 2003]

The resilience-oriented research community, which is contributing to both the literature on sustainable development and on climate change, uses definitions that convey the integration of the physical and social aspects of vulnerability and the dynamism of systems that need to respond to changes:

- Vulnerability refers to the propensity of social and ecological systems to suffer harm from exposure to external stresses and shocks [Stockholm Resilience Centre 2007]

- Resilience refers to the capacity of a social-ecological system both to withstand perturbations from, for instance, climate or economic shocks and to rebuild and renew itself afterwards [Stockholm Resilience Centre 2007]

Malone notes that vulnerability is a "deficit concept," whereas resilience is "a positive concept that places emphasis on society while also integrating environmental characteristics." It includes both an element of recovery and an element of change that can be equated with adaptive capacity. Brooks and Adger[32] offer a definition of adaptive capacity that resonates with this perspective of resilience:

- "In practical terms, adaptive capacity is the ability to design and implement effective adaptation strategies, or to react to evolving hazards and stresses so as to reduce the

[31] Malone E (2009) Vulnerability and Resilience in the Face of Climate Change: Current Research and Needs for Population Information. Battelle Pacific Northwest. Washington 99352
[32] Brooks, Nick and W. Neil Adger (2005) Assessing and enhancing adaptive capacity. In Adaptation Policy Framework for Climate Change: Developing Strategies, Policies and Measures, Ian Burton, Elizabeth Malone and Saleemul Huq (lead authors). Cambridge University Press, Cambridge.

likelihood of the occurrence and/or the magnitude of harmful outcomes resulting from climate-related hazards. The adaptation process requires the capacity to learn from previous experiences to cope with current climate, and to apply these lessons to cope with future climate, including surprises."

Susceptibility to changing glaciers and hydrologic regimes is closely tied to climate change vulnerability and adaptation capacity. The World Bank's assessment of these factors in 28 Eastern European and Central Asian countries[33] ranked Tajikistan highest in vulnerability, with Kyrgyzstan, Uzbekistan, and Turkistan 3rd, 6th, and 8th. These countries also ranked lowest in adaptive capacity.

Non-Climatic Dimensions of Vulnerability in Asia's Populations

Several existing, non-climatic factors make Asian's populations more vulnerable to *any* changes in their water systems. These include widespread poverty, hunger, high fertility, poor health status, low literacy, gender inequality, and existing water-related hazards. Table 3 provides a snapshot of conditions prevailing in nine countries where USAID Missions work in Asia. The data indicate that countries in the catchment areas of the Indus River Basin (India, Pakistan and Afghanistan) are water stressed and beset with widespread poverty with more than 50% of their

Table 3: Socio-Economic/Water-related Statistics, Selected Asian Countries

COUNTRY	WATER INSECURITY ($<1{,}700$ m^3 per year per capita)	POVERTY LEVEL[34]	FERTILITY[35] (births per woman) ASIA=2.5 (excluding China)	IMR[36] (deaths per 1000 births) WORLD RATE=49	HUNGER GHI INDEX 2009[37]
Nepal		**Severe**	2.6	46	**SERIOUS (19.8)**
India	Water stress	Moderate	2.5	47	**ALARMING (23.9)**
Pakistan	**Absolute water scarcity**	Moderate	**3.6**	**68**	**ALARMING (21.0)**
Afghanistan	Water stress	n/a	**6.2**	**129**	**SEVERE**[38]
Kazakhstan	Water stress		2.6	17	<5
Kyrgyzstan			2.7	25	<5
Tajikistan		Moderate	**3.3**	**53**	**SERIOUS (18.5)**
Turkmenistan	**Absolute water scarcity**		2.4	49	6.3
Uzbekistan	**Chronic water scarcity**	Moderate	2.6	46	7.5

populations living below the US $2 per day poverty line. These same countries have very serious hunger and health issues — as reflected in their elevated Global Hunger Index (GHI) scores[39] and above-average rates of infant mortality for which high fertility is a determinant in Pakistan

[33] World Bank (2009) Adapting to Climate Change in Europe and Central Asia.

[34] Severe = more than 50% of population below $1.25 a day poverty line; Moderate= more than 50% of population below $2.00 a day poverty line. Source: ILO http://kilm.ilo.org/manuscript/kilm18.asp

[35] Population Reference Bureau (PRB) 2012 World Population Data Sheet

[36] Infant Mortality Rate (IMR) Source: PRB 2012 World Population Data Sheet

[37] Global Hunger Index 2009. Scores from 10.0 to 19.9 = Severe Hunger Level; from 20.0 to 29.9 = Alarming Hunger Level

[38] Serious level of hunger but too little data to calculate GHI rate

[39] GHI is a multidimensional statistical tool used to describe the state of countries' hunger that was developed by the International Food Policy Research Institute (IFPRI).

and Afghanistan. In Kazakhstan, Uzbekistan and Turkmenistan, there is uneven water distribution across country territories; therefore water stress is an inherent feature of all three countries. Existing water-related hazards in mountainous parts of these countries include GLOFs, landslides and mudflows (not only of a glacial nature). The middle and low reaches of the same areas experience droughts and floods.

Current water vulnerabilities in Asia are estimated to increase under the pressure of global environmental change, which will superimpose additional burden on these societies. In South Asia — where a boom in groundwater-based irrigation in the 1980s and 1990s led to a major increase in agricultural production that is now constrained by aquifer depletion — declining agricultural productivity is expected. The "major worry" states FAO, is that "agricultural production will decline in highly populated areas at a time when demand is rising, and the issue of food security is coming to the fore in all regions.[40]" Even in the short term (by 2020), many Asian countries are likely to experience decreasing agriculture production (Table 4), particularly those least resilient to climate change.

Table 4. Projected change in population and agriculture production in selected countries in Asia: 30 year and 90 year projections[41]

Country	Population Change		Agriculture Production Change	
	1990-2020	1990-2080	1990-2020	1990-2080
Pakistan*	83.6%	150.7%	-4.6%	-10.0%
Afghanistan*	223.4%	692.2%	-3.6%	-11.7%
Nepal	84.3%	150.8%	-4.0%	-2.2%
Bhutan	48.4%	56.5%	-0.2%	2.5%
India	58.7%	91.2%	-3.4%	-3.3%
Bangladesh*	58.9%	67.8%	-3.1%	-0.8%
China	21.2%	-8.5%	-2.4%	2.5%

Countries least resistant to climate change

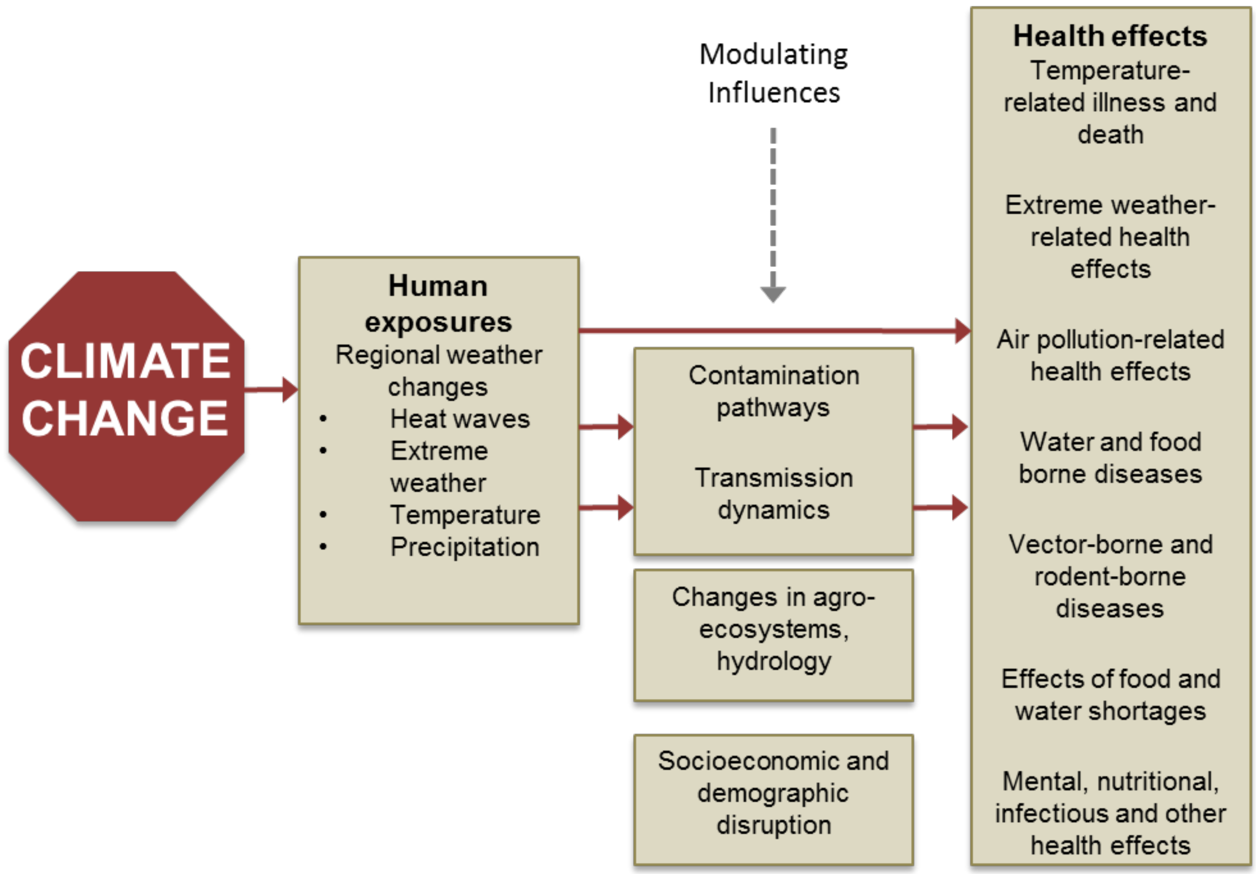
Changing Environments and Disease Patterns

Climate change and human health are linked in six ways: changing patterns of disease and mortality, extreme events, food, water, shelter, and population. Of these, glacier melt/retreat links indirectly with patterns of disease, food, water, and population. Although the direct effects of glacier melt/retreat on human health and natural systems have *not* been studied, two assumptions can be made: (1) human health and ecosystem impacts are likely to result from the

[40] FAO (2012) Coping with Water Scarcity: An Action Framework for Agriculture and Food Security: Water Reports 38. Rome
[41] Source of Data: Population Action International: Interactive Mapping – Population and Climate Change

changes in hydrologic systems, of which glaciers are a component; and (2) existing vulnerabilities in health status, ecosystem functions, population growth, and pollution make communities more vulnerable to any changes in their water systems.[4] The World Health Organization[42] has mapped the pathways by which climate change affects human health (see Figure 3 below). Exposure is a key variable and hydrology changes are one of the influences that modulate health effects.

Figure 3: Pathways by Which Climate Change Affects Human Health[42]



Source: WHO (2003) Climate Change and Human Health: Risks and Responses. Summary Report., Figure 3.1; p11

Changes in ecosystems, hydrology and other environmental changes can affect the occurrence of various diseases in humans (Table 5). A case in point is the diversion of water via dams and irrigation canals, which can increase breeding sites for mosquitos and increase the incidence and prevalence of malaria and other vector-borne diseases in humans. Changes in hydrological cycles in Tajikistan, for example, are projected to increase the number of potential malariagenic and choleragenic ponds in upstream rivers that flow through Khatlon Province,[43] the country's most densely populated and poorest province. Malaria is also influenced by deforestation and agricultural intensification via different transmission pathways as explained in Table 5. In 2000, an estimated 2.4% of diarrhea cases *worldwide* and 6.0% of malaria in some middle income countries was attributed to climate change.[42]

[42] World Health Organization (2003) Climate Change and Human Health: Risks and Responses. Summary Report.
[43] The Vakhsh and Kafirnigan rivers according to the Regional Environmental Center for Central Asia (CAREC). GAP Analysis in the area of climate change and energy efficiency in Central Asia: Defining opportunities for CAREC. 2009 Almaty. CAREC.

If one or more of the examples of diseases listed in Table 5 is prevalent in the targeted area, program planners/designers should examine available information to ascertain possible ecological-based factors and/or climate change-related links and incorporate appropriate eco-health management strategies into the project design, including information-education-communication interventions to increase community awareness of the factors affecting transmission as well as the links between them. Equipped with knowledge about these links, local communities can better manage ecosystems to improve the health of both humans and ecosystems, while at the same time starting to think through adaptation strategies for climate-induced changes including glacial melt.

Table 5: Examples of environmental changes on infectious diseases in humans

ENVIRONMENTAL CHANGES	EXAMPLE DISEASES	PATHWAY OF EFFECT
Dams, canals, irrigation	Schistosomiasis	▲ Snail host habitat, human contact
	Malaria	▲ Breeding sites for mosquitoes
	Helminthiasies	▲ Larval contact due to moist soil
	River blindness	▼ Blackfly breeding, ▼ disease
Agricultural intensification	Malaria	Crop insecticides and ▲ vector resistance
	Venezuelan hemorrhagic fever	▲ rodent abundance, contact
Urbanization, urban crowding	Cholera	▼ sanitation, hygiene, ▲ water contamination
	Dengue	Water-collecting trash, ▲ *Aedes aegypti* mosquito breeding sites
	Cutaneous leishmaniasis	▲ proximity, sandfly vectors
Deforestation and new habitation	Malaria	▲ Breeding sites and vectors, immigration of susceptible people
	Oropouche	▲ contact, breeding of vectors
	Visceral leishmaniasis	▲ contact with sandfly vectors
Reforestation	Lyme disease	▲ tick hosts, outdoor exposure
Ocean warming	Red tide	▲ Toxic algal blooms
Elevated precipitation	Rift valley fever	▲Pools for mosquito breeding
	Hantavirus pulmonary syndrome	▲Rodent food, habitat, abundance
		▲ increase ▼ reduction

Source: WHO (2003) Climate Change and Human Health: Risks and Responses. Summary Report. . Table 6.1 p17

SECTION 4: SOCIAL-ECOLOGICAL RESILIENCE

The social impacts of changing glaciers and hydrology in High Asia will be a function of the social-ecological resilience of the affected societies and ecosystems. Malone identified four main issues that are undermining social-ecological resilience in High Asia.[4] These inherent vulnerabilities, which are non-climatic, locally generated, and strongly linked to livelihoods, encompass population/demographic issues, human health concerns, ecosystems issues, and pollution. Two current glacial issues are superimposing additional challenges on the region's population and ecosystems. These include the growing danger GLOFs, which have already caused injury and death, displacement, and land damage in some localities. A second issue is the projected near-term retreat and disappearance of some glaciers that provide fresh water for nearby communities, particularly in the eastern Himalayas where glaciers are an important source of freshwater for high mountain communities. The following segments of this chapter provide further details about the inherent vulnerabilities (Table 6) and those superimposed by current glacial changes (Table 7).

Inherent Vulnerabilities that Undermine Social-Ecological Resilience

Table 6 examines dimensions of the four non-climatic factors that undermine adaptive capacity in High Asia and the *inter-relationships* amongst them. Statistics are cited for some countries in the region to illustrate the significance of an issue or the magnitude of an inherent vulnerability, but the Table is not meant to be all-inclusive in terms of incidence or root causes. Rather, the intent is to provide insights into the dynamics and sub-factors underlying each issue. Program planners/designers may wish to use the Table as checklist to guide site-specific analysis and investment decision-making.

Table 6: Inherent Vulnerabilities Undermining Resilience in High Asia

Issue	*Threat/Consequences for Humans and the Natural Environment*
Population Issues	**Large and Rapidly Growing Populations:** Population size and growth have significant impacts on the state of the environment, aggravating vulnerability and adaptation needs. South Asia is home to well over one fifth of the world's population, making it both the most populous and the most densely populated geographical region in the world. Population growth is a result of both natural increase and migration. Within the Greater Himalaya region, the highest rates of natural increase are found in Afghanistan (2.8%) and Tajikistan (2.3%) far surpassing the global average rate (1.2%) and the rate for less developed countries (1.4%). Numerous studies confirm that population growth exacerbates the challenge of providing adequate fresh water to sustain human life[44]. Reducing local overpopulation can decrease vulnerability to water scarcity and other environmental stresses; over the long-term, "it relieves climate change and other pressures on the global environment[45]".

[44] Bernstein, S. (2002) Freshwater and human population: a global perspective. In K.Krehnak (ed.), *Human Population and Freshwater Resources: US Cases and International Perspectives*, New Haven: Yale University

[45] Campbell (2009) Taking the heat out of population and climate change debate. WHO, Geneva, Switzerland http://who.int/bulletin/volumes/87/11/09-072652/en/index.html#R8

Issue	Threat/Consequences for Humans and the Natural Environment
	Population Density: High density population zones are characterized by overexploitation of lands and severely altered vegetal cover. Erosion and landslide processes are advanced and the risk of infectious disease transmission increases with overcrowding. *Loss of biodiversity occurs where human population density exceeds 200 persons per square kilometer*. It follows that fertility decline can contribute to the protection of biodiversity[46 47]. Population density in S. Asia averages 342 persons per square kilometer[48] which exceeds the threshold for biodiversity loss. Countries in High Asia generally have relatively low population density but in Tajikistan, where arable land is severely limited and densely populated by people and livestock, biodiversity loss is a concern[49].
	Population momentum ("youth bulge"): Population momentum is the tendency for population growth to continue beyond the time that replacement level fertility has been achieved because of a relatively high proportion of people in the childbearing ages which, in turn, is due to past high fertility. The rate of momentum is reflected in the proportion of the population under age 15 ("youth bulge"). *Countries in High Asia with large youth bulges include Afghanistan, Pakistan, Tajikistan and Nepal*. Lack of economic opportunities spurs significant rates of labor migration among youth in these countries. Youth also are susceptible to enticements by violent extremists [50]. Today's young people will be most affected by the consequences of shrinking glaciers over the next 30 years - and most likely to engage in future conflicts over water resources. Investment in programs that build youth leadership and skills in water resource management and conflict prevention and others that slow population momentum (e.g., voluntary family planning, adolescent reproductive health, female literacy and education) can help to mitigate these threats and reduce the absolute numbers of persons exposed to GM impacts in the future.
	Migratory Change: Climate change places an additional burden upon communities already facing migratory changes caused by rapid population growth, economic erosion, ecologic disaster or armed conflict. By 2050, the United Nations predicts there could be 200 million persons displaced by drought and other climate-related shocks ("climate refugees"). External migration carries with it a host of risks, including both trafficking of humans and greater risk of exposure to infectious diseases including TB and HIV because of crowded and inadequate living conditions and their involvement with infected sexual partners[51]. High poverty and unemployment rates are push factors for migrants from Nepal and Central Asia. An estimated one million Tajik citizens are migrant workers and one-third of Kyrgyzstan's workforce is employed abroad[52].

[46] Luck. G.W. (2007) A review of the relationship between human population density and biodiversity. Biological Reviews 84: 604-645
[47] Chu, C.Y. Cyrus (2008) Biodiversity decline and population externalities. Journal of Population Economics 21: 173-181
[48] World Bank Indicators (2012) South Asia - Density & urbanization
[49]USG (2012) Feed the Future Strategy for the Republic of Tajikistan
[50] Helgerson, J.L. (2002) The National Security Implications of Global Demographic Change.
[51] DevTech Systems Inc. (2010). USAID/CAR Gender Assessment.
[52] USAID Central Asia Development Strategy 2012-2015. Moving towards prosperity and stability along the New Silk Road.".

Issue	Threat/Consequences for Humans and the Natural Environment
Population Issues	**High Fertility:** High fertility poses health risks for children and their mothers, detracts from human capital investment, slows economic growth and exacerbates environment threats, according to the World Bank[53]. In many countries, high fertility (and the resulting population growth) is a direct and proximate cause of current and looming shortages in fresh water[54]. High fertility means not only a large number of births over women's reproductive careers, but also typically a high incidence of pregnancy at young ages, of unintended and unwanted pregnancies, and of closely-spaced pregnancies, all of which affect household and individual welfare and adaptive capacity. In South Central Asia (SCA) total fertility averages 2.6 births per woman (vs. 2.4 globally) but is much higher in Afghanistan (6.2), Pakistan (3.6) and Tajikistan (3.3). The latter three countries also present the highest infant mortality rates among the 14 countries in SCA[55]. Geo-referenced data from High Asia[4] *indicate high and above average levels of fertility are common in areas that will be most affected by glacier retreat.*
	Early Marriage and Child Bearing: The early onset of childbearing shortens the length of a generation which affects the rate of growth of a population because the more rapidly a generation replaces itself, the more rapidly it will add new members to the population. Widespread poverty and low education attainment are linked dynamically to the problem of early marriage and childbearing in the region[56]. The postponement of childbearing can contribute substantially to a country's fertility decline and help slow the rate of population growth and concomitant pressure on natural resources[57].
	Unmet Need for Family Planning (FP) and Reproductive Health (RH) Services: 222 million women, worldwide, want to avoid pregnancy but are not using a contraceptive method. 7 in 10 women in SCA have unmet FP needs; low contraceptive use is a direct determinant of child mortality in countries such as Tajikistan[50]. Addressing unmet FP needs through universal access to RH would avert 21 million unplanned births and 1.2 million infant/maternal deaths[58]. It would dramatically improve the chances of reducing world hunger and severe poverty and would also contribute to lower GHG emissions and slower rates of plant and animal extinction. Unmet need is greatest among women who face financial, geographic, educational or social barriers to FP/RH services. Investment in FP/RH saves lives,[59] reduces the burden on natural resources and the environment[60], and helps individuals and societies build climate resiliency. *FP is*

[53] Casterline, J. (2010) Determinants and Consequences of High Fertility: A Synopsis of the Evidence. (2010). Case study in "Addressing the Neglected MDGs: World Bank Review of Population and High Fertility. World Bank Economic and Sector Work (ESW). World Bank, Wash. DC. http://www.worldbank.org/hnppublications.

[54] Bryant et.al. (2009) Climate change and family planning: Least developed countries define the agenda. *Bull World Health Organization* 2009;87: 852-857 doi: 102471/BLT08.062562

[55]SCA includes Afghanistan, Bangladesh, Bhutan, India, Iran, Kazakhstan, Kyrgyzstan, Maldives, Nepal, Sri Lanka, Pakistan, Tajikistan, Turkmenistan and Uzbekistan.

[56] Eurasianet. Tajikistan: Poverty encourages early marriage. http://www.eurasianet.org/node/65075

[57] Timæus, I. M. and Moultrie, T. A. (2008), On Postponement and Birth Intervals. Population and Development Review, 34: 483–510.

[58]Darroch JE, Sedgh G and Ball H (2011) Contraceptive Technologies: Responding to Women's Needs, Guttmacher Institute

[59] Mazur, L. (2012) Building resilience to for a changing world: Reproductive health is key. [www.newsecuritybeat.org/2012/04/in-building-resilience-for-a-changing-world-reproductive-health-is-key/.]

[60] USAID (2012) Facts for Family Planning. Cooperative Agreement with FHI 360 GPO-A-00-07-0004-00

Issue	Threat/Consequences for Humans and the Natural Environment
	five times less expensive than conventional green technologies for reducing atmospheric carbon dioxide that leads to climate change[61].
Human Health Issues	**Lack of Access to Safe Drinking Water:** An estimated 635 million Asians lack access to safe drinking water[62]. The main health effects are diarrheal and other diseases caused by biological or chemical contaminants[63]. Diarrhea is the second leading cause of death among children under five worldwide; nearly 88% of diarrhea-associated deaths are attributable to unsafe water, inadequate sanitation[64], and insufficient hygiene[65]. In Tajikistan, 40%-60% of the population lacks access to safe drinking water[50] and there is a high incidence of waterborne diseases in many communities, especially when the only supply of water is from irrigation ditches. In Nepal, safe drinking water is very limited and many rural families draw water from polluted surface sources. Glacial changes are posed to create additional disease burden on populations whose resilience is already compromised by unsafe water and poor sanitation. Reduced river flow associated with glacial retreat, for example, could lead to declining water quality as the dilution of contaminants is reduced, less oxygen is dissolved in water, and microbiological activity increases. These effects could lead to major health problems for vulnerable people, *especially during drought.*
	High Infectious Disease Burden: The disease burden comprises the total amount of disease or premature death within a population. Countries in SCA have high levels of burden of disease - predominantly due to infectious diseases and maternal, perinatal and nutritional conditions[66]. Such conditions are associated with pervasive poverty and health and gender inequities. *Climate change is likely to increase the infectious disease burden – particularly for vector-borne tropical diseases that have historically been absent from the Himalayas.* Sakar[67] reports that vector-borne (and, often, reservoir-dependent) diseases have already emerged as problems in the region, including dengue and malaria. "Vectors are moving beyond their historic ranges to higher elevations; water quality is deteriorating, and the available supply is diminishing. Himalayan populations, with no prior history of exposure to these pathogens, are likely to be more vulnerable than their tropical counterparts."
	High infant and child mortality: Globally, the infant mortality rate (IMR) averaged 49 deaths per 1000 births in 2012. Four countries in SCA report above-average IMR namely Afghanistan (129), Pakistan (68), Bangladesh (59) and Tajikistan (53). Diarrhea and malaria rank among the leading causes of infant/child mortality; *both are sensitive to weather and climate.* The very

[61] Wire, T. Fewer (2009) Emitters, Lower Emissions, Less Cost. London: London School of Economics.
[62] Millennium Development Goals in Asia and the Pacific. http://www.mdgasiapacific.org/node/139
[63] The Lancet (2009) Managing the health effects of climate change. Vol 373 May 16, 2009
[64] 1.86 billion people in Asia lack access to sanitation facilities
[65] CDC Diarrhea: Common Illness, Global Killer. http://www.cdc.gov/healthywater/pdf/global/programs/Globaldiarrhea_ASIA_508c.pdf
[66] WHO. (2008) Global Burden of Disease Report – 2004 Update. World Health Organization, Geneva
[67] Sakar, S. (2010). Climate change and disease risk in the Himalayas. Editorial. Himalayan Journal of Science Vol 6 Issue 8

Issue	Threat/Consequences for Humans and the Natural Environment
	young (and the old) are especially sensitive to environmental insults. Scientists at MIT [68] who examined the impacts of weather fluctuations on infant health status anticipate higher temperatures will lead to increased IMR which is consistent with the medical evidence that "infants' thermoregulatory systems are not fully developed." Investment in RH can reduce infant mortality by empowering women with the means to better space or limit childbearing which, in turn, would better enable them to avail of opportunities to manage their families' exposure to environmental insults. In some Asian countries, low female literacy correlates with high infant/child mortality. As such, educating females is central to improving child survival outcomes and building climate resiliency. Female education has had one of the highest returns on investment among all development initiatives[69].
	Under-nutrition Burden: The magnitude of Asia's under-nutrition burden is "staggering" with nearly 93 million stunted children in Southeast Asia and South Central Asia alone[70] . Geo-referenced data from High Asia indicate that *hunger, stunting and the prevalence of young and therefore vulnerable children are serious issues in the downstream areas of the Greater Himalaya region[4].* Under-nutrition stems from a series of interrelated factors rooted in poverty—including a lack of access to food, healthcare, safe water and sanitation services, and inadequate child feeding/caring practices. Gender dimensions also factor into persistent under-nutrition and poverty in Asia. The impacts of climate change on the drivers of under-nutrition are posed to exacerbate the problem. In Tajikistan repeated drought over the last decade, coupled with glacier retreat, have reduced crop yields and livestock ownership, resulting in reduced nutrition [10]. At COP15, the UN Standing Committee on Nutrition advocated for the promotion and protection of nutrition as part of adapting to climate change via collaborative actions that build across the biological, environmental, social and economic dimensions.
Human Health Issues	**Chronic Food Insecurity and Seasonal Hunger:** Food insecurity and seasonal hunger are fundamental challenges throughout the Greater Himalaya region and of particular concern in Nepal and Tajikistan where the USG is mounting an all-agency response under the President's Feed The Future (FTF) Initiative. An analysis by the Asian Development Bank[71] indicates that "growing pressure on ecosystems to produce food, as well as changing temperature and precipitation patterns, will have unpredictable and deleterious effects on existing food-producing resources in Asia". *And those who grow their own food are least likely to be resilient to change, lacking enough good land, inputs such as fertilizer and irrigation water, and access to markets.* ABD recommends five basic policy strategies to promote food security and reduce both poverty and hunger by: providing food-based safety nets and related social protection programs, enhancing the productivity of agriculture, promoting rural development, supporting agricultural research, and investing in human capital and basic infrastructure.

[68] Deschênes, O. and Greenstone, M. (2007) Climate Change, Mortality, and Adaptation: Evidence from Annual Fluctuations in Weather in the U.S. MIT Joint Program on the Science and Policy of Global Change
[69] Borges, P. 2007. *Women empowered: Inspiring change in the emerging world*. Rizzoli, New York. p 13.
[70] International Food Policy Research Institute. Nutrition and Gender in Asia: From Research to Action. http://www.ifpri.org/sites/default/files/NutritionGenderbro.pdf
[71] Asian Development Bank – ABD (2012). Food Security and Poverty in Asia and the Pacific: Key Challenges and Policy Issues. [http://www.adb.org/sites/default/files/pub/2012/food-security-poverty.pdf]

Issue	Threat/Consequences for Humans and the Natural Environment
	Air Pollution: In the developing world, indoor air pollution from fuels such as wood and dung is the leading cause of death for children under age five and the fourth leading cause of premature death for women. Exposure to indoor air pollution causes respiratory diseases as well as heart disease, stillbirth, cataracts and other visual problems, pre-term delivery, and low birth weight[72]. Globally, more than 1.6 million people die prematurely each year from breathing elevated levels of indoor smoke. .In India alone, these impacts have been estimated to cause 440,000-500,000 premature deaths per year in women and under-five children.[73]
Ecosystem Issues	**Degradation of Ecosystems in Himalaya:** The Himalayan ranges represent a highly complex and diversified system both in terms of biological and physical attributes. Major rivers of the region have their origin from these mountains and are the source of water for a large proportion of the human population within and outside the mountain region. The region's diverse ecosystems include watersheds, flood plains, forest, wetlands and rangelands whose natural processes support the lives and livelihoods of hundreds of millions of people. These processes include hydrological cycling, plant biomass production, soil retention, climate regulation, drought resistance, carbon sequestration and other ecosystem services[74]. The region's ecosystems and functions have been degraded and disrupted by human activities particularly deforestation, diversion of water, submersion of valleys by hydropower plants, pollution of fresh water sources, improper sewerage disposal, forest fires (both intentional and accidental) and other man-made disturbances[75].
	Changes in the Natural Water Balance in Aquatic Ecosystems: According to the International Center for Integrated Mountain Development (ICIMOD), the high altitude wetlands account for around 16% of the total area of the Hindu Kush-Himalayas Himalayas and play a key role in water storage and regulating water regimes[3]. "They maintain water quality, regulate water flow and support biodiversity while also mitigating the impacts of climate change by acting as carbon sinks. The Himalayan wetlands are under pressure from drainage for agriculture, tourism-related pollution and overgrazing". In Central Asia, widespread irrigation with inefficient technologies and poor infrastructure as well as diversion of water for hydro-electric schemes have changed the natural water balance in the regions' aquatic ecosystems and caused substantial land degradation, according to USAID's recent biodiversity assessment of the five Central Asian Republics[76]. "Many lakes and wetlands have been drained and unique riparian forests have been felled to increase the area under irrigation. The most conspicuous impact of diversion and inefficient use of water is the Aral Sea disaster". Experts in the region also believe that water use and diversion by China is threatening Lake Balkhash in Kazakhstan

[72] Smith, K. cited by E. Malone in Changing Glaciers and Hydrology in Asia: Addressing Vulnerabilities to Glacier Melt Impacts

[73] USAID/RDMA ([2]010). *Black Carbon Emissions in Asia: Sources, Impacts, and Abatement Opportunities*. USAID Regional Development Mission for Asia, Bangkok, Thailand.

[74] e.g., weathering and erosion, disturbance regimes and recovery processes (succession), decomposition, nutrient cycling and energy flows, herbivory, predation, pollination, and seed and animal dispersal.

[75] Climate Himalaya http://chimalaya.org/2010/08/118/conservation-of-himalayan-ecosystem-essential-environmentalists/

[76] USAID (2010) Central Asian Republics Biodiversity Assessment Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan. Submitted in accordance with Foreign Assistance Act Sections 118/119

Issue	Threat/Consequences for Humans and the Natural Environment
	Habitat and Biodiversity Loss: The Himalaya region is a recognized "biodiversity hotspot" that conforms with the criteria defined by Conservation International (CI) as being a region of exceptionally high biodiversity values that has already lost at least 70 percent of its original habitat[77]. Despite their apparent remoteness and inaccessibility, the Himalayas have not been spared human-induced biodiversity loss. Unlike some other hotspots in the world, the human-biodiversity interactions in the Himalaya region dwell not in human density but rather in human activity. "Greater access to the global market has increased the demand for natural resources and encouraged both immigration from outside and movement within the region," explains CI. Increased human activity has led to extensive clearing of forests and grasslands for cultivation. Widespread logging – some on steep slopes –has resulted in severe erosion, while overgrazing by domestic livestock (cattle and domesticated yak) has degraded lowlands and alpine ecosystems. Flora in fragile alpine meadows has been overharvested for traditional medicine. Fuel wood collection and extraction of non-timber forest product - both for domestic consumption and export, has reduced biodiversity. Other threats to biodiversity, says CI, include "poaching of endangered species, mining, the construction of roads and large dams, and pollution due to agrochemical usage". While there have been no scientific studies on possible correlations between biodiversity and glacial melt, the natural habitats in close proximity to shrinking glaciers are no doubt being altered by changes in water availability and micro-climate[10]. Lower elevation terrestrial and aquatic biodiversity are vulnerable to water stress related to changing rainfall and river flow patterns.
	Changes in Land Use Patterns: Pradeep and others[78] report that "rapid growth of population has brought about extensive land-use changes in the Himalayan region, mainly through the extension of cultivation and large-scale deforestation. The high rate of land use change has accelerated several environmental problems such as high runoff, flash flood, river-line flood and soil erosion during monsoon season and drought during the non-monsoon period." As forests and grasslands are converting into agricultural land and settlements, huge regions of biodiversity rich habitat, and vital wildlife corridors are being decimated. "This is most intense in the densely populated regions of Nepal and the Indian States of Sikkim and Assam," according to an analysis of habitat loss in Himalaya by the World Wide Fund (WWF).[79] In the Central Asian republic of Tajikistan, "habitat loss has been a significant historic threat to biodiversity," says USAID's biodiversity assessment noting that about 30% of the country has been converted to agricultural or urban ecosystems. Unsustainable agricultural practices have led to land degradation and conversion of natural ecosystems in Kyrgyzstan as well. Other major land degradation practices

[77] Conservation International. Threats and human impacts in the Himalaya hotspot. http://www.conservation.org/where/priority_areas/hotspots/asia-pacific/Himalaya/Pages/impacts.aspx

[78] Pradeep K. Rawat, Prakash C. Tiwari, Charu C. Pant, (2012) "Climate change accelerating land use dynamic and its environmental and socio-economic risks in the Himalayas: Mitigation through sustainable land use", International Journal of Climate Change Strategies and Management, Vol. 4 Is: 4, pp.452 - 471 - See more at: http://www.emeraldinsight.com/journals.htm?articleid=17063366&show=abstract#sthash.x9ln1PIz.dpuf

[79] WWF Habitat Loss in Himalaya. http://wwf.panda.org/what_we_do/where_we_work/eastern_himalaya/threats/habitat_loss/

Issue	Threat/Consequences for Humans and the Natural Environment
	encountered in Kyrgyzstan include salinization, under-flooding, chemical pollution, and deteriorating vegetation. Tiwari[80] advocates for sustainable land use policies in Himalaya that would provide hydrological benefits to both upstream and downstream users via the promotion of forests and agroforestry in combination with rehabilitation of degraded land in the mountain watersheds and pollution control to improve land husbandry.
	Deforestation: In Asia, the forests in the Himalayan region are considered to be among the most depleted. While human population growth is a contributing factor, much of the degradation is due to commercial harvesting and mismanagement by governments. Tajikistan has lost up to 50% of its forest cover since 1988 due to deforestation[81]. State agencies charged with management of natural resources and biodiversity conservation in Tajikistan lack technical and institutional capacity. Kyrgyzstan's unique forests are also threatened by a range of human and natural pressures, and grazing on forest lands has prevented natural regeneration of forest ecosystems[82]. The illegal felling of trees and unsustainable logging for fuelwood and timber resources also have reduced the "buffering" capacity of natural systems (i.e., riverside vegetation) causing alternation of river flow and increased risk of flash floods. In addition to human activities, a number of forest areas and biodiversity resources in the region are threatened by shifts in precipitation patterns and climate variability. Slowing deforestation and securing the sustainable management of forests in the region are urgent tasks for climate change policy, investment, and action.
Pollution Issues	**Air Pollution Caused by Black Carbon:** Black carbon emissions from widespread biomass burning in Asia pose a special type of threat, to glaciers and people. Released to the atmosphere, it is an air pollutant and contributes to regional climate change and respiratory disease burden in humans; deposited on glaciers, it accelerates melt rates[4]. Even at altitudes above 5,000 meters (16,400 feet), soot is widespread as "the Himalayan valleys act as chimneys, pumping pollutants from the Indian plains to the mountain peaks[82]." The South Asian Atmospheric Brown Cloud (ABC), which contains black carbon, has been singled out as a contributor to accelerated melt of the Hindu Kush-Himalayan-Tibetan glaciers. Burning of organic fuels for residential cooking/lighting/heating and in small scale industries (i.e. brick-making) is a major source of black soot in the Himalayas - as are naturally occurring forest fires and man-made fires for clearing cropland. Use of diesel fuel in transportation is another source of soot and air pollution. Removing 1 ton of fossil fuel black carbon can have the same effect as removing 1000 tons of CO_2 over a 50-year period[83]. Emissions can be significantly limited at relatively low cost by deploying clean energy options for residential/small industry use, creating and enforcing regulations that curtail open burning (for clearing cropland) and eliminating incentives that favor the use of diesel. Such effort can produce rapid

[80] Tiwari, PC (2000) Land-use changes in Himalaya and their impact on the plains ecosystem: need for sustainable land use. *Land Use Policy* Volume 17, Issue 2, April 2000, Pages 101–111

[81] USAID (2008) Global Climate Change in the Asia Pacific Region: An analysis and roadmap in 2008. USAID Regional Development Mission Asia (RDMA).

[82] The Economist (2012) Pollution in the Himalayas. November 18, 2010. Print Edition. http://www.economist.com/node/17519770

[83] Ramanathan, V. 2009 Black Carbon: PowerPoint presentation for COP 15 Meeting in Copenhagen. Partnership for Clean Indoor Air. Scripps Institute of Oceanography

Issue	Threat/Consequences for Humans and the Natural Environment
	results and deliver local environmental, health and economic benefits. Additionally, it would reduce albedo change and its impact on glacial retreat. By restoring more pristine high-reflectivity snow and ice surfaces, it could also help to stabilize and possibly reduces GHG amount[84].
	Air Pollution linked to Water Diversion: Water from the Amu Darya and the Syr Darya rivers has been diverted from the Aral Sea for more than 30 years, used instead to irrigate millions of hectares of land for cotton and rice production[7]. More than 60% of the water in the Aral Sea has been lost, and it has shrunk in size to less than half its original 65,000 sq. km. Large areas of the seabed are exposed. Its salt concentration increased from 10% to more than 23%, contributing to the devastation of a once thriving fishery. The local climate has reportedly shifted, with hotter, drier summers and colder, longer winters. As the water retreated, salty soil remained on the exposed seabed. Dust storms have blown up to 75,000 tons of this exposed soil annually, dispersing its salt particles and pesticide residues. This air pollution has caused widespread nutritional and respiratory ailments, and crop yields have been diminished by the added salinity, even in some of the same fields irrigated with the diverted water. Consequently, the entire region is one of the most severely damaged ecological zones in the world[82].
	Contamination of Natural Resources: Pollution and contamination are major direct threats to natural resources and biodiversity in the region and to human health. In Central Asia, pollution has led to the decline of individual species, exacerbated land degradation, and resulted in contamination of lakes and rivers. Major causes of pollution and contamination include excessive fertilizer and pesticide use for agriculture, spills from oil and gas development, and contamination from mine tailings. In Uzbekistan, incompatible agricultural practices and extensive monocultures have required high levels of agricultural inputs including fertilizers, pesticides, and herbicides. High concentrations of these inputs have resulted in legacy contamination, significant land degradation, and loss of biodiversity [82]. Natural resources in India are contaminated with pathogenic bacteria, pesticides, nitrate and industrial effluents. The main source of pathogenic bacteria is sewage. Pesticides and nitrate contamination are mostly due to the use of inorganic fertilizers and pesticide spray in agricultural sector[86].

[84] Xu et al. 2009. Black soot and the survival of the Tibetan glaciers. PNAS Vol 106. No.52 pp 22114-22118

Current and Near-Term Glacial Changes in High Asia

Table 7 examines the near-term issues resulting from current glacier changes in the Greater Himalaya region. The most visible near-term issue is the danger of GLOFs and debris flows for which communities and activities in the high mountains are most susceptible. Since the 1930s, more than 25 GLOFs have been recorded in Bhutan, Nepal, and Tibet, with especially destructive events in 1985, 1991, and 1994. There is also a history of outburst floods from Karakoram glaciers involving much larger impoundments by short-lived, unstable ice dams that blocked tributaries of the upper Indus and Yarkand Rivers, causing outburst floods of exceptional size and destructiveness. Although communities threatened by outburst floods are often small and remote, impacts can be extensive; GLOFs destroy villages, agricultural lands, roads, bridges, hydropower, and trekking trails, as well as human lives and property. The destruction may be so complete that people who survive must move and begin to rebuild their lives in other places. Low-lying glaciers are most at risk of forming glacier lakes that may be unstable; thus, "these lakes require monitoring and the nearby settlements require disaster preparedness," states Malone.[4]

A second issue is the projected near-term retreat and disappearance of some glaciers that provide fresh water for nearby communities. Environmental change is already beginning in the high-altitude regions where glaciers are plentiful. For example, Tajikistan is already experiencing the effects of climate change. Annual average temperatures have risen by 0.8 degrees Celsius since 1940, and are expected to rise further. In the Pamir mountains in eastern Tajikistan, the Fedchenko Glacier (the world's longest outside of the Polar regions) has been shrinking due to warming temperatures, as have two other large glaciers in the Pamirs (Medvejiy and RGS). The Tajik government has expressed concern that "continuing temperature increases could threaten the nation's water supply and increase the risk of natural disasters including floods and landslides."[85]

Table 7 examines these two glacial issues in detail citing evidence from various sources of ongoing changes in the region's glaciers and hydrology. As with the previous table, the information below in *not* meant to be all-inclusive in terms of the incidence or prevalence of the threats. Readers looking for country-specific glacial change information are referred to Schweithelm's 2011 report on *Glacier Melt Vulnerabilities in Asia.*[10]

[85] IRIN Humanitarian News and Analysis (2007). Tajikistan: Melting glaciers pose growing threats in the Pamirs. U.N. Office for the Coordination of Humanitarian Affairs. 25 June 2007.

Table 7: Current and Near-Term Glacial Changes in High Asia

Issue	*Threat/Consequences for Humans and the Natural Environment*
Current Glacial Changes	**Glacial Lake Outburst Floods (GLOFs):** GLOFs are one of the major natural hazards in the Himalaya region. The number and size of glacial lakes is believed to be increasing in many parts of Asia's high mountains, but the level of hazard associated with these lakes has not been systematically studied other than in Nepal. The inaccessibility of many GLOFs makes it difficult to assess potential danger, and this difficulty is only partially overcome by satellite imaging. Accelerated glacial melt has resulted in rapid increases in the volumes of glacier lakes in Pakistan, raising local vulnerability to GLOFs. In Bhutan, there are 2,400 glacier lakes, 24 of which have been identified as potentially catastrophic. In Central Asia, most sources of glacial lake outbursts are located in Kyrgyzstan, Tajikistan, and Kazakhstan. In Kyrgyzstan, alone, scientists estimate that more than 20 glacial lakes are in danger of outbursts. In Kazakhstan, GLOF hazards are greatest in the Ili-Alatau mountain range, where the number of glacial lakes grew from 41 in the 1980s to 61 in the 1990s[86]. Owing to the large volume of water released by GLOFs, they present a significant transboundary hazard. Uzbekistan is threatened with 271 potential GLOFs, most of which are located outside its borders. The predicting of GLOFs remains a challenge, owing to lack of data concerning glaciers and the process of GLOF formation, and the dearth of suitable modeling tools.
	Other Existing Hazards: Frequent mudslides, rock falls and seasonal flooding constitute existing hazards for pastoral settlements found within remote mountain valleys of High Asia. Tajikistan and Kyrgyzstan are experiencing a higher number of landslides, mudslides, and floods in the spring as a result of earlier than usual glacier and snowmelt combined with spring rains[87]. Within these communities, social groups that are most susceptible to these hazards include: female-headed households and the elderly, disabled and ethnic/caste groups who are predisposed due to their deprived access to resources such as social influence, transportation, literacy, livelihood skills and assets. Thurman[89] synthesized the full range of socioeconomic vulnerabilities to natural hazards in Central Asia (*see Attachment 1*). Inadequate investment in disaster preparedness and risk reduction are immediate needs that should be addressed no matter how the glaciers respond to climate forcing in the future.
Projected Near-term Glacial Changes	**Retreating and Disappearing Glaciers:** Glaciers all over the world have been shrinking since the last ice age, and they experience melting every year (along with additions from annual precipitation). The increasing temperatures of climate change are speeding up the shrinking process – a concern usually captured in the terms "glacial melt" and "glacier retreat." Glacial melt/retreat in High Asia is occurring mainly at lower elevations in the eastern Himalaya (Bhutan, northeastern India and southern, central and eastern Nepal), especially glaciers located on southfacing and/or relatively flat landscapes and covered with melt-enhancing debris or black carbon[4]. Communities living near and downstream of these glaciers are most vulnerable to the impacts. The Indus Basin is very vulnerable due to its aridity, high and growing demands on its waters by India and Pakistan, and rapid population growth in Pakistan. Glacier

[86] Thurman, M. (2011) Natural Disaster Risks in Central Asia: A Synthesis. UNDP/BCPR,11 April 2011
[87] R.A. Niyazov, 2002 cited by Thurman in above reference.

Issue	Threat/Consequences for Humans and the Natural Environment
	retreat is also evident in Central Asia. Up to 20% of Kyrgyzstan's glaciers, for example, disappeared between the mid-1970s and 2000[88]. The downstream Central Asian states are at risk since much of their irrigation water originates as snow and glacier melt in the high mountains feeding the Amu Darya and Syr Darya Rivers. Water could become a conflict trigger among the Central Asian states as well as between Pakistan and India[10, 53] .
	Inadequate Disaster Planning: Inadequate disaster planning for both too much water (floods, GLOFs) and too little water (droughts, delayed glacial melting) constitute immediate needs that should be addressed no matter how the glaciers respond to climate change ("no regrets" approach). Glacial melt/retreat, although occurring at increasing rates, is not likely to produce widespread disastrous impacts in the next decade or two – which means that societies have time to build their resilience to changes in the amount of water available and when it arrives during the year. However, existing vulnerabilities in human health status, population pressure, ecosystem degradation and pollution make societies and ecosystems vulnerable to *any* changes in water availability as glacier melt accelerates in the coming decades[4].

[88]Kyrgyzstan Institute of Water Problems and Hydro Energy at the National Academy of Sciences

SECTION 5: MEASURES TO COPE WITH EXISTING STRESS

Options to Cope with Water Scarcity

Given that Asia's populations and ecosystems already are water stressed (even before glacial changes are counted), it makes sense to first address existing water vulnerabilities and the inherent factors that make communities more vulnerable to any changes in their water systems, since such investment will yield net social benefits under all future scenarios of glacial melt/retreat and climate change. Of all economic sectors, agriculture is the sector in which water scarcity has the greatest relevance for glacier-dependent countries and for nations worldwide. "Currently, agriculture accounts for 70 percent of *global* freshwater withdrawals, and more than 90 percent of its consumptive use," states experts at the UN's FAO.[89]

The FAO has put forth a conceptual framework to address food security under conditions of water scarcity in agriculture that encompasses both supply-side and demand-side options and strategies for coping with water scarcity within and outside the water domain (*see Attachment 2*). Some options apply to all sectors while others are specific to the agricultural sector. For example, options within the water domain relevant to all sectors for managing supply include: increased storage, groundwater development, recycling and re-use, pollution control, and desalination. Measures specific to the agriculture sector include, among others, on-farm water conservation, improved water service delivery in irrigation, integrated plant production and protection, control of pollution from agriculture (including payment for environmental services). Coping options outside of the water domain focus on reducing demand for irrigated products and services, and reducing water use per capita.

Adaptation Measures to Cope with Current and Near-Term Glacial Changes

Measures to adapt to current and near-term glacial changes may necessitate policy-based adjustments as well as structural, managerial, and technical changes and other measures that encourage behavioral modifications at the level of the individual and the community. To be effective, adaptation measures should be *mainstreamed*, together with mitigation, into development planning at national and sub-national levels. Constraining policy gaps also need to be identified. For example, National Adaptation Programmes of Action (NAPAs) need to give more attention to certain sectors such as water, agriculture, population/reproductive health, disaster reduction and forestry, as well as to the most vulnerable groups namely children, women, disabled persons and other disadvantaged groups.[4] Consistent with the "no regrets" approach, adaptations that represent appropriate responses to *existing conditions* should be pursued first.

A number of adaptation options to cope with GLOF risks may already be in various stages for implementation within the context of country-specific development projects in Asia, e.g., siphoning (physical reduction in flooding risks of glacial lakes) and moving proposed hydropower plants to other locations. Some countries are pursuing management adjustments to cope with accelerated glacial melt by integrating water resource and disaster management and/or technical measures by restoring river channels and protecting waterside vegetation. Community-

[89] FAO (2012) Coping with water scarcity: An action framework for agriculture and food security. Water Report 38. Food and Agriculture Organization of the United Nations, Rome.

led adaptation that builds upon local knowledge, innovation and practices for coping with stream flow variability (SFV) is also important for coping with GM challenges in high mountainous areas. A more complete range of adaption options is presented in *Attachment 3: Measures to Adapt to Current and Near-Term Glacial Changes.* Again, the intent is *not* to be all-inclusive but rather to provide examples of adjustments that work at the policy, structural, managerial, technical, and community-levels to build resiliency to ongoing and imminent changes in hydrological systems and glaciers in the region.

Measures to Mitigate the Drivers of Glacial Melt/Retreat

As stated previously, measures to adapt to current and near-term glacial changes should be integrated into development planning *together* with measures to mitigate the drivers of glacial melt/retreat. Referring back to Figure 2, the three main drivers are: 1) warming due to increasing GHG emissions, 2) surface melt due to black soot aerosol deposition on glaciers, and 3) existing population, poverty, and energy dynamics that amplify consumption of biomass-fuels and emissions of black soot.

Rising consumption of high carbon-intensity fuels, particularly coal, is a major contributor to increasing GHG emissions in Asia together with agriculture, deforestation and land clearance. Research conducted by the National Aeronautics and Space Administration (NASA) indicate that black soot (BS) and dust contribute as much, *or more*, to atmospheric warming as do GHGs in the Himalayas.[90] Sixty-five percent of BS emissions derive from biomass burning (residential, small industry and forest fires), while use of diesel fuel in transportation accounts for the remaining 35%. Among other options to mitigate BS emissions is the creation and enforcement of regulations that curtail open burning for cropland clearing, and the deployment of clean energy options for residential and small industry use (solar lanterns, improved biomass-fueled stoves and kilns, biogas digesters).

For each driver, there are policy issues that need to be considered for sound investment decision-making and in order to prevent inadvertent effects. For example, the decision taken by some countries to promote diesel as a means to encourage fuel efficiency and reduce GHG emissions may have had the inadvertent effect of increasing black carbon emissions in the region.[91] These and other mitigation options are further discussed in *Attachment 4: Measures to Mitigate the Drivers of Glacial Melt/Retreat in Asia* together with the co-benefits they would yield for several sectors including environment, human health, agriculture, food security, and the economic and social sectors.

[90] NASA News (2009) The Dark Side of Carbon: Will Black Carbon Siphon Asia's Drinking Water Away? http://www.nasa.gov/topics/earth/features/carbon-pole-briefing.html
[91] Wallack & Ramanathan (2009) The Other Climate Changers. Foreign Affairs Sept/Oct 2009

SECTION 6: NEED FOR AN INTEGRATIVE SYSTEMS APPROACH TO RESILIENCY BUILDING

Multi-Sectoral Platforms for Integrative Systems Development

To be effective, GM adaptation must integrate multiple programming areas (e.g., water management, population/health, biodiversity conservation, disaster preparedness, and governance) to the extent possible. Food security programs often tackle agriculture, water, and nutrition issues in a cross-sectoral manner and, as such, represent a possible framework for integrating other measures to build GM resiliency. One example is the U.S. Government's FTF initiative in Nepal. A key underpinning of FTF's strategy is the recognition that Nepal is undergoing changes in precipitation event patterns, temperature regimes, and hydrology (due to glacial melt) linked to climate change. Moreover, it acknowledges that Nepal's growing youth bulge (41% of population under 15 years of age) will add even more pressure on the country's dwindling natural resource base for decades to come.[92]

FTF-Nepal is part of a larger USG commitment to build the resilience of vulnerable populations to the changing climate in Nepal. It works to revitalize inactive mechanisms of the Government of Nepal to coordinate food security activities. FTF inputs concentrate on agriculture and nutrition investments in geographically defined areas including inputs to improve irrigation such as small water storage and micro/drip irrigation, and support for cereal research and development as well as school feeding programs. Satellite tracking of hydrological parameters, *including glacial melting*, is a unique element of the strategy not found in typical food security programs. The chart below depicts the "Whole of Government" investment in FTF-Nepal and the principal USG agencies and programs currently engaged in this collaborative effort. The strategy also identifies a number of other USG agencies that could multiple FTF's impacts including the Department of Defense (DOD) (role in disaster preparedness) and the Peace Corp (role in community nutrition and hygiene education), both of which would also build GM resiliency. Even though the strategy recognizes that Nepal's youth bulge portents decades of increasing environmental scarcity, it fails to explicitly tackle this challenge with interventions that can slow population momentum and redress youth's unmet need for RH information and services. Unless such interventions are integrated into the model, FTF's *gains* most likely will not be sustainable beyond the near-term.

[92] Feed The Future Nepal: FY 2011-2015 Multi-Year Strategy. U.S. Government Document. May 26, 2011.

Feed The Future-Nepal: Principle USG Agencies and Collaborating Programs [92]

STATE: Engages the Government of Nepal on agricultural priorities **USAID & NASA: SERVIR** satellite tracks glacial melting, surface water for irrigation, and improves response to droughts, flooding **Collaborative Research Support Program (CRSP):** Integrated pest management: tomato grafting, micro-irrigation and pesticides; Horticulture: technology for postharvest drying, seed storage; SANREM: conservation agricultural production; Nutrition: impact of agricultural interventions on nutrition outcomes **USDA:** School feeding program; **CSISA:** Cereals research and development support.
Additional USG Agencies that could multiply impacts: **DOD/Pacific Command (PACOM):** Targeted investment in productive infrastructure (multi-use shelters for disasters, also used as collection centers during normal times) **Millennium Challenge Corporation Threshold**: Policy and government capacity to achieve "Compact" (cash awards with conditionality dispensed on merit): Technical assistance to write new laws; build government technical capacity etc. **Peace Corps**: Community training and development (Ag training; nutrition/ hygiene education and others)

Creating a "Virtual" GM Vulnerabilities Activity by Coordinating Multiple Programming Areas

Other USAID Missions in Asia have sector-specific programs/projects that will decrease GM vulnerabilities even though they were not designed for that purpose. USAID Missions could create a 'virtual' GM multi-sectoral vulnerabilities activity by slightly modifying one or more compatible projects and creating a coordinating mechanism to allow the projects to work to achieve synergies in specific locations — perhaps starting with two or three pilot villages or districts to explore how such cooperation could work.

GM-compatible programming includes projects designed to: improve water supply and sanitation; increase adoption of family planning and reproductive health practices; increase the availability and efficiency of water use in agriculture; make agriculture more resilient to water stress; improve food security; improve water resource management and governance at the basin level, including international cooperation and conflict avoidance; increase availability of improved cooking stoves and renewal energy options for home lighting; decrease GHG and black carbon emissions from forest fires, small industries and the transportation sector; improve energy security; improve the science of glaciology and hydrology; and improve the management of biodiversity resources to maintain ecosystem functions and services.

Programs that are coordinated to decrease GM vulnerabilities can yield co-benefit streams for several sectors that may include combinations of the following:

1. **Improved health outcomes** (from healthier ecosystems, reduced pollution, improved sanitation, more efficient water use)
2. **Reduced fertility and easing of population pressures** (by meeting family planning needs)
3. **Strengthened governance institutions** (through environmental, agricultural, and forestry management; development of national and local policies; establishment and empowerment of local resource user groups)

4. **Improved regional cooperation** (through scientific cooperation, shared monitoring and information programs; common educational outreach programs; community-based monitoring, strengthened cross-boundary institutions and treaties)
5. **Protection of biodiversity and maintenance of ecosystem services** (through improved water management and ecosystem management for health)
6. **Better water management** at all levels including basin-wide, within irrigation systems and farm fields and for municipal/household water supply
7. **More efficient, climate change-resilient food production** (irrigation systems, on-farm management, harvest of food and fodder from forests and rangeland, and homestead vegetable gardens)
8. **Creative, effective approaches to monitoring and managing climate-change-induced threat**s, starting with glacier lakes
9. **Effective disaster planning** for both too much water (floods, GLOFs) and too little water

EXAMPLE: Prototype of a "Virtual" Multi-Sectoral GMVR Activity

There are multiple USG-financed programs and activities *ongoing* in Tajikistan that support one or more objectives that directly or implicitly contribute to GMVR although not all work in the same geographic areas or with the same target groups (*see schematic below*). For example, USAID's portfolio of health projects is addressing the country's high infectious disease burden while the DOD/Pacific Command (PACOM) is supporting a national health campaign to eradicate intestinal parasites that underlie malnutrition. The CDC is transferring disaster preparedness and response know-how to Tajik public health units, while a number of initiatives of USAID's Office of Economic Development are redressing important land use, agriculture, irrigation, and legacy issues. USAID's Regional Energy Security, Efficiency and Trade (RESET) Project is establishing economic value of water-regulating services related to flood control and irrigation. Projects managed by the USAID Office of Governance and Democracy are advancing the role of youth, women, and CSOs in local development, governance and conflict prevention — all pertinent to GMVR. None of USG's current investments, however, explicitly address existing population (youth bulge), ecosystem (biodiversity loss) and pollution (black carbon) issues that undermine social-ecological resilience and that factor into current and near-term glacial changes.

.

Two or more of these programs could possibly be coordinated to create a “virtual” multi-sectoral activity with the goal of increased resilience of people, places, and livelihoods to the impacts of changing glaciers and hydrology (in addition to other goals that the same programs aim to achieve). Given that today’s generation of young adults in Tajikistan comprise the subpopulation that will be affected most by glacial retreat over the next three decades, the Youth Leadership Program (YLP) represents a logical choice for spearheading a multi-sectoral GM activity. Linkages could be forged with compatible sectoral programs, such as the Family Farming Project (FFP), and mechanisms of coordination established to enable YLP to leverage resources from FFP and vice-versa. YLP’s mandate could also be broadened to enable support for youth skills-building and leadership development in water resource management, biodiversity conservation, clean energy (improved cook stoves), and reproductive health responsibility.

A precedent has already been established for coordination of USG investments to achieve a common goal as evidenced by the 2012 FTF Strategy for the Republic of Tajikistan.[93] The Strategy is leveraging resources from all USG agencies operating in the country to improve food security and nutrition outcomes in the nation’s largest and poorest province (Khatlon). FTF links with three major USAID agriculture projects in Tajikistan that have a strong food security focus, and with USDA’s food emergency forecasting service. It also supports the Tajik Government’s commitment to change its system of water resources management from an administrative district approach to a basin level approach with an increased role for community-based water users associations. Moreover, coordination with programming by USAID’s Office of Health and Education is facilitating the delivery of nutrition and essential health care interventions to pregnant women and preschool children in Khatlon. DOD/PACOM is also coordinating the efforts of its Civil Military Support Element (CMSE), which works with Khatlon’s provincial government emergency service branch to prepare for upcoming spring glacial melt, which historically causes flooding that threatens crops and livelihoods. DOD is the sole USG agency with resources for infrastructure development which, perhaps, could be tapped for productive investments in infrastructure for disaster preparedness/management in other areas of the country prone to GLOFs and water-related hazards.

FTF-Tajikistan holds promise for generating important lessons and best practices for *coordination of multiple USG programming areas to achieve a common goal*. Distinctively missing from the Strategy are inputs to mitigate the province’s high rate of population momentum critical to safeguarding FTF’s gains in the medium and long term. As the Strategy rolls out in coming years, new USG investments in Khatlon could compensate for this shortcoming by strengthening female literacy and education and encouraging policy reforms to reduce barriers to youth’s access to sexual and reproductive health information and services.

[93] USG (2012) Feed the Future Strategy for the Republic of Tajikistan

SECTION 7: GENERAL STEPS IN CREATING AN INTEGRATED RESPONSE THAT WORKS ACROSS SECTORS

Below are general steps that an organization should review when creating a multi-sectoral response to GM vulnerabilities. As there is no one way to create such approaches, this is not meant to be a step-by-step plan. Rather, it examines the general steps an organization should review to determine if existing vulnerabilities and GM threats are being adequately addressed in ongoing (or planned) programs and to identify options to bridge the gaps with adaptation measures that will yield net positive benefits under all future scenarios of glacial melt and climate change.

1. Conduct a Situation Analysis

- Identify existing non-climatic factors (population, health, ecosystem, pollution) that undermine social-ecological resiliency in the hotspot targeted for GM adaptive-capacity building
- Ascertain current and near-term glacial change issues (GLOFS, glacial retreat) and the populations most vulnerable to their impacts
- Facilitate participatory assessments in selected hotspot(s) to identify disaster-prone areas and prioritize emergency preparedness and risk reduction measures along with key stakeholders

2. Identify Options

- Review literature to analyze past and current responses and understand successes and failures
- Identify options to cope with current and near-term glacial changes and examine their feasibility
- Consult local communities and stakeholders to identify existing coping measures and indigenous knowledge of the environment
- Identify existing institutional channels that have the networks and capacity at the local level to facilitate adaptation (institutional mapping)

RESOURCES

Steps 1 and 2 should be guided by socio-economic and ecological information specific to the area targeted for GM adaptive-capacity building. If such information is not available or up-to-date, consider building a community research activity into the project design. Such activity should support participatory research methods (PRM) that engage local stakeholders and communities in the assessment of vulnerabilities and disaster-prone areas and the identification of local adaptation strategies.

The PRM may need to be modified to enable illiterate and semi-literate members of the target community(s) to participate in the process. For example, Christmann and Ah-Hassan transformed Social Analysis Systems methods into drawings, symbols and conceptual diagrams that enabled illiterate and semi-literate residents of Zerafshan-mountain communities in Tajikistan to identify strategies to adapt to glacier loss. To learn more, click the following link:

http://www.ipmpcc.org/2012/01/28/harnessing-local-knowledge-and-potentials-for-climate-change-adaptation-a-pilot-research-in-mountain-villages-in-western-tajikistan/

3. Envision Linkages

- Review USG and other donor assistance to identify compatible programs that directly or implicitly address dimensions of GM vulnerabilities; identify the gaps, etc.
- Create a conceptual model of the synergies and programming areas to be coordinated
- Ground truth the conceptual model via a site assessment and in consultation with key stakeholders

4. Examine Policy Context

- If a suitable framework exists (i.e. climate change adaptation), work with government to see how to take advantage of it
- If not, explore other compatible development frameworks (poverty reduction, food security) that could be capitalized upon
- As important as project-based adaptation measures may be, it is crucial that they be supported by an overall policy framework that provides a truly enabling environment to facilitate faster GM adaptation

ONLINE TOOLS
The World Bank Climate Change Knowledge Portal (CCKP) is an online tool for access to comprehensive global, regional, and country data related to climate change and development. The CCKP contains environmental, disaster risk, and socio-economic datasets, as well as synthesis products, such as Climate Adaptation Country Profiles.

http://sdwebx.worldbank.org/climateportal/index.cfm?page=why_climate_change

The CCKP also provides intelligent links to other resources such as the **Climate Compatible Development Tools:** A guide for national planning
http://www.climateplanning.org/

CENTRAL ASIA RESOURCE
The Adaptation Partnership has reviewed current and planned adaptation action in Central Asia and synthesized lessons learned and good practices in a 2011 publication that also highlights needs and priorities, and identifies opportunities for cooperation and alignment of support to build resilience to the adverse effects of climate change.
http://www.adaptationpartnership.org/

Review of Current and Planned Adaptation Action: Central Asia: Kazakhstan, yrgyzstan, Tajikistan, Turkmenistan and Uzbekistan.

Contributing Authors

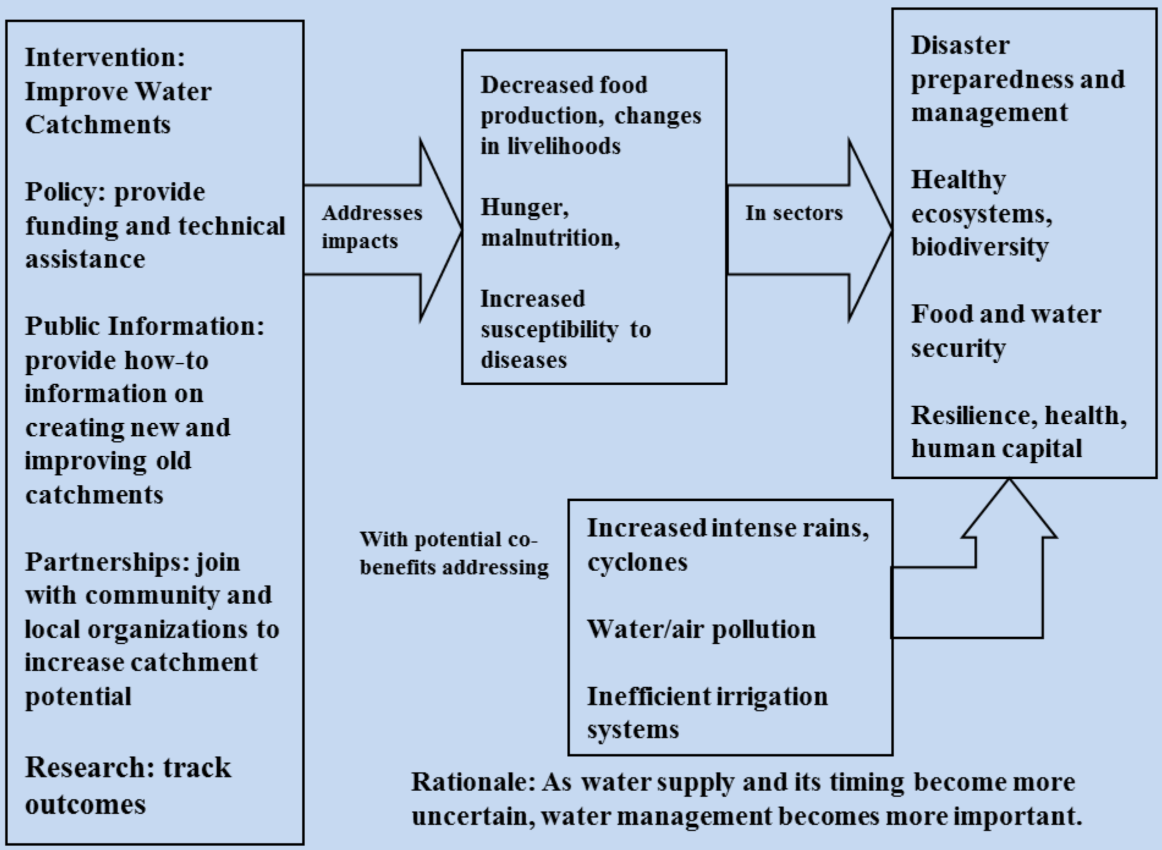
Livia Bizikova, Hilary Hove, Jo-Ellen Parry
International Institute for Sustainable Development November 2011

5. Make Strategic Decisions

- Engage stakeholders in the process of selecting co-benefit interventions and mechanisms of service delivery (both public and private) for outreaching to the intended target audience(s), including community-based service delivery
- Generate a list of the requirements; identify existing resources that could be leveraged and additional inputs needed

In selecting an intervention that has the potential for yielding co-benefits across several sectors, it is useful to map out the anticipated benefit stream as this can help to guide investment decision-making and the selection of appropriate indicator(s) to measure the yields and capture the impact. Following is an example of such a mapping exercise.

Example Cross-Sector, Co-Benefit Intervention



Rationale: As water supply and its timing become more uncertain, water management becomes more important.

6. Facilitate Coordination and Collaboration

- Determine mechanism(s) for coordination across relevant sectors and amongst compatible programs towards a common goal and converge actions, competencies and interventions linked in time and space to benefit the same target audience(s)
- Explain how the gap strategies complement and contribute to the compatible programs
- Facilitate partnership arrangement; define the roles and responsibilities of each partner/actor

Step 6 focuses on the level at which coordinated efforts are both appropriate for achieving the goal and that can be ensured.

This level is based on:

Delineation of relevant geographic boundaries for coordinated action

Identification of all key players operating within those boundaries

Agreement on a common goal, for example:

> *Increased resilience of people, places and livelihoods to the impacts of changing glaciers and hydrology*

Agreement by the above players to be part of a partnership working towards this common goal [in addition to any other goal(s) their organization or program aims to achieve.]

7. Implement Model

- Chose modality(s) for operationalizing the mechanisms of coordination and for implementing the gap strategy(s)
- Plan activities to test one or more implementation models
- Define the indicators for measuring success (gender sensitive and age-specific), the means of verification and how the information will be gathered and how often; refer back to your benefit stream map(s) to ensure that the selected metric(s) will capture the anticipated output(s) or outcome(s)

8. **Field Test**

- Pilot activities at a local level (village, ward) most conducive to cross-sectoral coordination and collaboration
- Monitor progress and facilitate adaptive management
- Document results and learning; feedback findings to collaborators and communities and, together, frame the lessons and best practices from the field trial
- Share experience with other practitioners via case studies and/or by contributing to online platforms that build a shared knowledge base for climate change adaptation and mitigation

9. **Scale-up**

- Scale-up the model's successful elements and best practices to the next level (i.e., to the district level, or landscape level)
- Link with other existing programs and institutions in the focal area to leverage resources to support the expansion effort and/or broaden the range of GMVR strategies
- Refine monitoring and evaluation indicators based on results from the field test; integrate the indicators into the enabling development framework, if feasible
- Facilitate adaptive management for scale-up; document challenges, approaches used to trouble-shooting the scale-up issue and learnings that emerged from both failed and successful attempts

LIVING KNOWLEDGE EXCHANGE

Climate Adaptation and Knowledge Exchange (CAKE) **http://www.cakex.org/about**
CAKE provides organizations, agencies, and individuals interested and/or engaged in climate change adaptation with a free, open access venue for interactive information exchange between professionals. Its goals are to:

Build an innovative community of practice around climate change adaptation;
- Facilitate the identification and development of best practices; and
- Connect practitioners to share knowledge and strategies.

CAKE includes Case Studies of on-the-ground adaptation efforts, a Virtual Library of useful resources to support adaptation action, a Directory of individuals and organizations rich with adaptation knowledge, a "Tools" section full of useful online resources for adaptation action, and a Community section with an expert advice column and more.

SECTION 8: OPERATIONALIZING AN INTEGRATED AND MULTI-SECTORAL RESPONSE TO GM VULNERABILITIES

Malone[4] outlined three program concepts that respond to the challenges posed by: 1) the lack of scientific knowledge about the rate of glacial melt and the impacts of the phenomenon, which is impeding adaptation; 2) vulnerabilities arising from current deficits in water, health, and population conditions and economic resources of glacier-dependent countries, and 3) black carbon and other aerosol emissions that accelerate glacial melt and compromise human health. For each response, she describes the sectors to be addressed, the main components of the program, and the anticipated outcomes and co-benefit streams. These illustrative programs also offer insights for operationalizing response mechanisms at national, subnational and local levels.

Under the second programming concept mentioned above, Malone provides an example of a cross sectoral approach that focuses on integrating activities to address glacial melt impacts with other development needs in high-altitude communities. High-altitude communities are chosen as a focus for two fundamental reasons. First, they are on the frontlines of GLOFs and retreating glaciers affecting their local water supplies. These changes are happening now. Secondly, these communities are at the headwaters of the major river systems of Asia. Maintaining headwater ecosystem health and the well-being of communities will benefit potentially millions of people downstream.

Illustrative Response Focused On High-Mountain Communities

Sectors Addressed:

Human health, including reproductive health; water-resource management; biodiversity and ecosystems conservation; agriculture; energy; health; and disaster preparedness/ management.

Program Investments and Operations:

1. At the national level, support development planning processes that promote community-based and integrated approaches to glacier disaster preparedness and risk reduction that are comprehensive and include family planning and sustainable management of water resources, among other coping and adaptation strategies. The effort should seek to mainstream integrated approaches into existing policies and action plans (e.g., NAPAs for the UNFCCC) rather than create new initiatives.

2. At the sub-national level, organize multi-sectoral working groups to facilitate coordination and collaboration among public health, environment, water/sanitation, and agriculture for implementation of integrated approaches to glacier disaster preparedness/risk reduction.

3. At the local level, deliver training programs for local actors (government and NGOs) on how to facilitate community disaster preparedness planning processes that are comprehensive and link to broader socio-economic assessment of downstream flood paths to determine potential risk to communities. Such inputs can be integrated with health, water management, forest restoration and other community-identified needs.

4. At the community level in low-altitude locations:

- Facilitate participatory assessments to identify disaster-prone areas and prioritize risk reduction needs and activities along with potential partners and stakeholders.
- Train communities in how to develop local disaster preparedness and risk reduction plans based on the findings of the participatory assessment.
- Help communities identify and access existing resources for disaster mitigation within the community and externally from local government, NGOs, and upward links to other government disaster preparedness plans and early warning systems.
- Support collective actions of communities to improve disaster-prone areas. This may include hazard mapping, slope stabilization of landslide-prone areas, use of vegetation to counter landslides and erosion, and protection of waterside vegetation ad forests that serve as watersheds.
- Provide technical assistance to organized grassroots groups (e.g., cooperatives, eco-clubs, mothers' groups) to establish a community resource center. The center will provide basic information about glacier risks/hazards and appropriate behavioral responses and coping strategies, materials on rescue and rehabilitation during disasters, and psychosocial support related to the psychological impact of a glacier melt disaster. The center will also be used to conduct informal education classes for mothers, adults and youth on family planning, water conservation, clean energy (improved cook stoves/biogas) and their co-benefits, agro-ecology topics, and more.
- Train local shopkeepers and vendors to distribute contraceptives and essential health products (e.g., water purification tablets, oral dehydration salts, first aid supplies) and link them with public or private supply chains (social marketing networks).
- Ensure that women and vulnerable groups have equal access to these opportunities.

5. At the community level in high-altitude locations prone to GLOFs, support the same activities as above but with the following additions:

- Strengthen the capacity of community-based organizations in emergency preparedness for GLOF damage control.
- Create a village-level warning system for floods, landslides or earthquakes.

6. Supported measures to improve Water Conservation and Ecosystem Health. Given the presence of these communities near the headwaters of major river systems, interventions in these areas are key to adaptation for the region as a whole.

Anticipated Outcomes/Co-Benefits

The anticipated outcomes and co-benefits that the response will yield are summarized below. The program's monitoring and evaluation frameworks will include process, output and outcome indicators (gender sensitive and age-specific) and other measures of success and impact.

- Integrated approaches to glacier disaster preparedness and risk reduction will be mainstreamed into national and local development plans with more attention paid to the population, health, and water sectors and the role of the community.
- Local leaders better able to facilitate planning processes for disaster preparedness among both upstream and downstream communities.
- Communities empowered with knowledge and skills to identify and improve disaster-prone areas and to mobilize existing resources and external sources of support to do so.
- In the event of a disaster, loss of life will be reduced and land and infrastructure may be better preserved as a result of functional early warning systems maintained by communities.
- As disaster planning is integrated with other concerns, improved practice for family planning and preventive health will improve families' and communities' ability to cope with glacial melt risks and hazards via smaller family size and improved health and economic status.
- Measures to conserve water and counter landslides, erosion and flooding will help to maintain and enhance the integrity of the environment which, in turn, helps to sustain the flow of ecosystem services to people.

ATTACHMENT 1: Key Socioeconomic Vulnerabilities[94]

Vulnerabilities	Earthquake	Landslides	Floods	Drought
Socioeconomic status (poverty, income disparities and social status)	X	X	X	X
Poor targeted social safety nets	X	X	X	X
Location in remote areas, especially mountains, and transportation access	X	X	X	X
Poor land use and/or land use planning	X	X	X	X
Haphazard urbanization and poor municipal planning	X	X	X	X
Inadequate operations and maintenance of infrastructure	X	X	X	X
Outdated building and safety codes and standards	X	X	X	X
Inadequate channel maintenance and bank reinforcement			X	
Destruction of slopes (mining and excavation)		X		
Off-farm employment and income diversification			X	X
Inefficient on-farm water use		X		X
Poor salinity management				X
Unsustainable agronomic practices			X	X
Low access to agricultural credit, inputs, and markets			X	X
Overgrazing		X	X	X
Desertification		X	X	X
Wind and soil erosion		X	X	X
Deforestation		X	X	X
Loss of wetlands			X	
Lack of buffers/illegal construction on riverbanks			X	
Unsafe storage of toxic substances			X	

[94] Thurman, M. (2011) Natural Disaster Risks in Central Asia: A Synthesis. UNDP/BCPR,11 April 2011

ATTACHMENT 2: Options to cope with water scarcity[95]

The column labeled "Measures" in the chart below refers to the response options available to decision-makers for developing strategies for coping with water scarcity within and outside the water domain. The column labeled "All Sectors" identifies response measures that apply to all relevant sectors. For example, options within the water domain relevant to all sectors for managing supply include: increased storage, groundwater development, recycling and re-use, pollution control, and desalination. Options within the agricultural water management domain are categorized in a separate column labeled "Agriculture."

		Measures		All sectors	Agriculture
Supply side options	Within the water domain	Reducing inter-annual variability of river flow		Increased storage (multi-purpose dams)	On-farm water conservation
		Enhancing groundwater supply capacity		Groundwater development, management and artificial recharge	Aquifer recharge enhancement in irrigation
		Water recycling and re-use		Closed loop re-use and recycling	Re-use of urban wastewater for crop production
		Pollution control		Point source pollution control (industry, cities)	Integrated plant production and protection, control of pollution from agriculture (including payment for environmental services)
		Importing water		Inter-basin transfer, desalination	
Demand-side options		Reducing water losses		Improved monitoring, leakage control circuits (industry)	Pressurized conveyance and application of water (drip), improved irrigation scheduling and moisture control, canal lining
		Increasing water productivity	Through better water control	Better water management mechanisms, enhanced predictability of supply, early warning	Improved water delivery service in irrigation (increased reliability and flexibility of water delivery through modernization of infrastructure and management), precision irrigation, deficit irrigation, drainage in irrigation

[95] FAO (2012) Coping with water scarcity: An action framework for agriculture and food security. Water Report 38. Food and Agriculture Organization of the United Nations, Rome.

		Measures		All sectors	Agriculture
Demand-side options	Within the water domain		Through improved production process	Dry cooling (power)	Yield gap reduction through improved agricultural practices (fertility management, pest control), improved genetic material
		Water re-allocation		Intersectoral transfer (through water markets or other water allocation mechanisms) Intrasectoral transfer (including restraining demand)	Shift to higher value crops in irrigation and/or limiting evapotranspiration by reducing areas under irrigation
		Reducing losses in the value chain		Waste control, improved processing and distribution	Reduction of post-harvest losses; storage, processing, distribution, final consumption
	Outside the water domain	Reducing demand for irrigated products and services		Import of manufactured products	Reduced yield gap in rainfed production (improved agricultural practices; fertility management; pest control; soil moisture management; mulching, weeding drainage, improved genetic material, seasonal forecast and crop insurance schemes).
					Import of food and other agricultural products (virtual water trade)
		Reducing water use per capita		Changes in consumption habits	Change in food consumption patterns – less water intensive diets

ATTACHMENT 3: Measures to Adapt to Current and Near-Term Glacial Changes in High Asia

GLACIAL CHANGES	ADAPTATION MEASURES (Adjustments and Changes)				
	Policy-based	**Structural**	**Managerial**	**Technical**	**Community and individual (Changes in behavior)**
Overall approach to adaptation	Identify opportunities to mainstream adaptation (together with mitigation) into development planning and identify the constraining policy gaps The most urgent need is to empower national and local government and local communities in affected areas to understand GM implications and take action		Identify adaptations that also represent appropriate responses to existing conditions; these should be pursued first i.e., improving the management of scarce natural resources; sound environmental guardianship, addressing unmet family planning and health needs of vulnerable populations	Analyse the local resource base and institutional context[96] and use the findings to inform intervention planning by suggesting feasible options for strengthening existing micro-level capacity by building on existing formal and informal norms of behaviour (institutions) and improved natural resource management	Community-led adaptation should build on local knowledge, innovation, and practices
GLOF	Mainstream adaptation into development planning	Better design specifications of bridges and roads	Integrated water resource and disaster management	Improve forecasting; invest in better weather prediction system	Creation of a village-level warning system for floods/ landslides
	Regional cooperation in trans-boundary disaster risk management should become political agenda	Enforcing design standards for buildings and infrastructure that take into account site-specific risks	Emergency preparedness for damage control	Establish new tools and indicators to rate vulnerability in relevant sectors e.g., forestry	Involve communities in assessment of vulnerabilities and design of solutions
		Construct reservoirs to collect glacial water (to adjust seasonal water levels and compensate for long-term loss of water as glacier shrinks		Monitoring of lakes; preparation of siphon materials	

[96] Use tools such as the Community-based Risk Screening Tool – Adaptation and Livelihoods (CRiSTAL)

GLACIAL CHANGES	ADAPTATION MEASURES (Adjustments and Changes)				
	Policy-based	**Structural**	**Managerial**	**Technical**	**Community and individual (Changes in behavior)**
Near-Term Glacial Melt/Retreat and Changes in stream flow variability (SFV) particularly increasing stream flow	Policy intervention to support integrative systems approach to water resource management and disaster preparedness and risk reduction		Integrated water resource and disaster management	Measures to maintain flood plains, protect waterside vegetation, restore river channels, and reduce water pollution	Water storage, based on local practices should be developed in the mountain region to deal with the problem of too much water during the monsoon
	Forest recovery through policy intervention (to reduce the negative impacts of flooding)		Improved land use management via reforestation and afforestation	Community-based forestry management	Participation of local communities in forest conservation/management and tree plantation
Secondary impacts of changes in stream flow variability (SFV)	Policy intervention to reduce the negative effects of SFV on food systems		Conduct research on the vulnerability of food systems and possible adaptation options i.e., how will increased stream flow affect crop yields and other factors such as trade, affordability of food	Use research findings to design solutions based on possible adaptation options, i.e., options to address loss of cropland due to flooding	Encourage farmers to store crop seeds for post-disaster recovery
	Policy intervention to reduce the negative effects on human health and wellbeing and build coping capacity		Design solutions based on ecosystem management interventions i.e., improved vector and habitat management	Incorporate measures to redress gender inequities and promote good governance and the roll of the community in ecosystem co-management	Community participation in improved systems for safely storing and treating water, vector control and, promotion of bed net use to prevent malaria
			Improved delivery of evidence-based health, family planning and nutrition interventions and behavior change communication. Priority should be allocated to the most vulnerable groups	Involve indigenous leaders and local institutions (both public and private) in the design and implementation of systems and mechanisms to outreach to affected areas/communities with essential services	Involve vulnerable communities and groups in service delivery, to the extent possible

ATTACHMENT 4: Mitigating Drivers of Glacial Melt

DRIVER OF GLACIAL MELT/RETREAT	MITIGATION MEASURE/ INTERVENTION	POLICY CONSIDERATION	EFFECT AND CO-BENEFIT STREAMS				
			ENVIRONMENT	HEALTH	ECONOMY/ PRODUCTIVITY	AG/FOOD SECURITY	SOCIAL
(1) Warming due to increasing greenhouse gases (CO2, methane) Main sources of GHG emissions in Asia: • Increasing population and rising consumption of energy and high carbon- intensity fuels, particularly coal[97] • Deforestation and land clearance • Agricultural practices[98] **Overall approach:** Mainstream mitigation (and adaptation) into development planning	**Interventions to reduce GHG emissions:** • Discourage subsidies for coal-powered plants • Promote the use of natural gas in power production in place of coal[99] • Encourage development of unconventional gas resources [100] • Forest recovery and conversion of croplands to grasslands, forest lands or natural ecosystems • Transfer know-how for improved agricultural practices that are	Policies to slow global warming need to be integrated with those to reduce air pollution in order to prevent inadvertent effects. Carbon intensity of energy itself has increased. Since 1999, carbon emissions per unit of energy have been raising due to the increasing share of coal in the energy portfolios of many countries (particularly non-OECD countries[101] Developing countries are energy intensive partly because of various	Natural gas-fired power stations emit about half as much carbon as the cleanest coal plants[102] Reforestation and afforestation increases carbon bio-sequestration Improved practices that protect soils used in agriculture can prevent the release of carbon sequestered in soils Subsidies for biogas can reduce consumption of firewood and charcoal thus maintaining forest	Reduction in air pollution and related health risks Reforestation can reduce breeding area for vectors of malaria/ encephalitis Use of biogas reduces indoor air pollution and related health risks Biogas digesters help to reduce animal feces and pathogens around the homestead thus reducing gastro-intestinal (GI) illnesses	Natural gas development can facilitate the transition to low carbon economies Reforestation/ afforestation can generate carbon credits for trade Use of biogas can reduce household expenditures on biomass fuels, fertilizers and medicine for treatment of respiratory and gastro-intestinal illnesses	Eco-agriculture can boost food output while reforestation can enhance water security Reforestation/ afforestation can reduce the risk of flooding and landslides and their adverse effects on land and agriculture production Effluent from biogas digester can be used as a substitute for synthetic fertilizer thus reducing methane emissions	Use of biogas in the homestead can reduce women's and children's burden i.e., time and energy spent collecting biomass fuels Reduces the risk of violence against women and children (while foraging for biomass fuels in remote locations)

[97] Ruhl notes that "Not only is more carbon being emitted as the economies of developing countries grow, but the energy consumed itself is dirtier."
[98] Main contributors include the production and use of fertilizers, methane gas production from wetlands (especially rice wetlands) and methane emissions from livestock.
[99] Natural gas could supplant coal as the fuel of choice in Asia if unconventional natural gas can be development. (Ruhl C. Foreign Affairs Mar/Apr 2010: 63-75)
[100] The International Energy Agency 's (IEA) estimate of unconventional natural-gas resources in the Asia –Pacific region total more than 250 trillion cubic meters
[101] Ruhl says this is because coal is more widely available than oil and gas and is abundant and relatively cheap. Foreign Affairs Mar/Apr 2010
[102] The Economist, March 13, 2010 "Briefing Natural Gas: An unconventional glut." pg 72-74

DRIVER OF GLACIAL MELT/RETREAT	MITIGATION MEASURE/ INTERVENTION	POLICY CONSIDERATION	EFFECT AND CO-BENEFIT STREAMS				
			ENVIRONMENT	HEALTH	ECONOMY/ PRODUCTIVITY	AG/FOOD SECURITY	SOCIAL
	more ecologically sustainable • Deploy technologies that capture and recycle methane gas emissions from livestock i.e., biogas digesters for farms and homesteads	inefficiencies, particularly the widespread subsidization of energy.	coverage and resilience				
(2) Surface melt due to black soot aerosols deposited on glaciers Black soot (BS) aerosols contribute as much (or more) to atmospheric warming in the Himalayas as greenhouse gases[103] Tibetan plateau is located near the world's largest source of black soot (S and E Asia) Main sources of BS emissions in Asia:	**Interventions to reduce BS emissions:** • Create/enforce regulations that curtail open burning (for clearing cropland) • Discourage incentives that favor the use of diesel • Deploy clean energy options for small	BS reduction efforts can produce rapid results and deliver local environmental and economic benefits (to areas where reductions were achieved) Black soot emissions can be significantly limited at relatively low cost with technologies that already exist[105]	Reduces albedo change and its impact on glacial retreat; stabilizes and possibly reduces GHG amount[106] Buys time to develop transformational technologies for zero CO_2 emission Clean energy options reduce	Reduces air pollution and related health issue: • low birth weight in infants • acute respiratory infection (ARI) in under-fives[107] • chronic obstructive pulmonary disease in adults (esp. women)	BS reduction promotes economic growth by reducing the adverse effects of air pollution on human productivity (lost days of labor and schooling due to illness) Reduces financial burden on public health system Generates income	Reduction efforts can offsets the downstream impacts of glacial melt on agricultural production and food security	Use of clean energy options can reduce burden on women and children (time and energy spent collecting biomass fuels and cleaning sooty pots) and violence against women and children (while

[103]NASA 2009. http://www.nasa.gov/topics/earth/features/carbon-pole-briefing.html

DRIVER OF GLACIAL MELT/RETREAT	MITIGATION MEASURE/ INTERVENTION	POLICY CONSIDERATION	EFFECT AND CO-BENEFIT STREAMS				
			ENVIRONMENT	HEALTH	ECONOMY/ PRODUCTIVITY	AG/FOOD SECURITY	SOCIAL
• Burning of biomass[104] for cooking, heating and small scale industry (65%) • Use of diesel fuel in transportation; vehicles with poorly maintained engines (35%)	industry/residential use i.e., solar stoves, driers and lanterns; improved biomass-fueled stoves and kilns; biogas digesters : • Subsidize diesel particulate filters and engine upgrades • Establish monitoring systems/quality control standards for clean energy options/diesel particulate filters	Reduction strategies can be built into existing regional anti-pollution agreements and bilateral discussions	consumption of wood/ charcoal thus maintaining forest ecosystems and carbon bio-sequestration	• heightened risk of mortality among people with pre-existing respiratory diseases	opportunities and local employment Increases energy efficiency of small industries/HHs Clean energy options provide a means to verify carbon offsets		foraging for biomass fuels)
	• Finance technology that tracks air quality (i.e., indoor air pollution monitors) • Sponsor inter-ministerial	Data generated via air quality monitoring can be used to inform policymakers Research and experience suggest	Data can be used to inform environmental activists and policy advocacy communication	Data to assess the impact of clean energy options on health outcomes	Data to assess the cost-benefit of clean-energy options		Data can be used to inform public education and motivate individuals to curb their emissions of

[105] Removing 1 ton of fossil fuel black carbon can have the same effect as removing 1000 tons of CO_2 over a 50-year period (Ramanathan, V. 2009. Black Carbon: PowerPoint presentation for COP 15 Meeting in Copenhagen. Partnership for Clean Indoor Air. Scripps Institute of Oceanography

[106] By restoring more pristine high-reflectivity snow and ice surfaces. Xu et al. 2009. Black soot and the survival of the Tibetan glaciers. PNAS Vol 106. No.52 pp 22114-22118

[107] In the developing world, indoor air pollution from fuels such as wood and dung is the leading cause of death for children under 5 and the fourth leading cause of premature death for women. (Colorado State University 2006) . More than 1.6 million people (mainly women and children) die prematurely each year from breathing elevated levels of indoor smoke.

[104] Through naturally occurring forest fires, man-made fires for clearing cropland, and the use of organic fuels for cooking, heating, and small-scale industry.

DRIVER OF GLACIAL MELT/RETREAT	MITIGATION MEASURE/ INTERVENTION	POLICY CONSIDERATION	EFFECT AND CO-BENEFIT STREAMS				
			ENVIRONMENT	HEALTH	ECONOMY/ PRODUCTIVITY	AG/FOOD SECURITY	SOCIAL
	working groups to (a) facilitate coordination among public health, agricultural, energy, environment and antipoverty programs and (b) identify opportunities that mitigate black soot and promote development	that development models that use multi-disciplinary approaches generate synergies not found in single-sector approaches resulting in higher impact and efficiency, and stronger community buy-in	Mechanisms identified to mainstream mitigation into NRM agendas	Mechanisms identified to mainstream mitigation into public health agendas	Mechanisms identified to mainstream mitigation into poverty reduction agendas and sustainable livelihood approaches	Mechanisms identified to mainstream mitigation into agriculture and food security agendas	BS Mechanisms identified to mainstream mitigation into local governance and social programs
	• Sponsor public campaigns to education people about the health benefits of clean air and how to reduce BS and GHC emissions	Behavior change will depend on information, incentives and emphasis on the health benefits that will improve quality of life by reducing the effects of air pollution.	Changes in land use, forestry and farming practices will operate on multiple fronts and contribute directly and indirectly to NRM and conservation objectives	Behavior change will operate on multiple fronts and contribute directly and indirectly to public health objectives	Behavior changes will operate on multiple fronts and contribute directly and indirectly to poverty alleviation and economic development	Improved farming practices contribute directly and indirectly to food security and eco-agriculture development	Behavior changes will operate on multiple fronts and contribute directly and indirectly to good governance

DRIVER OF GLACIAL MELT/RETREAT	MITIGATION MEASURE/ INTERVENTION	POLICY CONSIDERATION	EFFECT AND CO-BENEFIT STREAMS				
			ENVIRONMENT	HEALTH	ECONOMY/ PRODUCTIVITY	AG/FOOD SECURITY	SOCIAL
(3) Above-average rates of population growth, population momentum and total fertility in south Asia coupled with high incidence of poverty and the lack of clean energy technology amplify consumption of biomass-fuels and emissions of black soot	**<u>Interventions:</u>** • Policy reforms that support a climate-sustainable human population and remove barriers to the use of family planning Interventions to stabilize population and slow momentum such as voluntary family planning (FP); adolescent sexual and reproductive health (ASRH), female literacy and education	FP is a low-cost, safe, and acceptable intervention, with proven benefits that encompass health, education, and reduction of poverty and environmental degradation Population momentum can be slowed by delaying the age at first birth and via increased birth spacing.	The slower population growth that results from access to FP operates on multiple fronts—easing increases in water shortages; slowing loss of forests, fisheries and biodiversity; and helping to brake the rise of BS and GHG emissions	The use of voluntary FP directly decreases child mortality and improves maternal health ASRH prevents the negative health, social and economic impacts of teenage parenthood	Slowing the growth of a population can expedite progress towards poverty alleviation and development Investments in human development, esp. basic educ. and employment opportunities for women, play a major role in delaying age at first birth while a responsive and high quality FP program can make birth spacing effective	The slower population growth that results from access to FP contributes to the eradication of hunger	Improved access to sexual and reproductive health is essential for individual welfare FP increases primary schooling and women's education and empowerment FP builds climate resiliency