IEG

Independent Evaluation Group

Development Actions and the Rising Incidence of Disasters

Evaluation Brief 4

IEG WORLD BANK
INDEPENDENT EVALUATION GROUP

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Preface

This Evaluation Brief brings attention to World Bank investments at risk. It alerts task managers to increases in the number and severity of flood and windstorm disasters resulting from environmental degradation, population pressure in coastal areas and mega-cities, and the possible effects of climate change. In particular, the report analyzes the potential risks to investments in roads, ports, storm sewers, and embankments on the one hand, and highlights actions undertaken to preserve and restore wetlands and forests on the other. Finally the report develops a set of findings to be taken into account when preparing projects in countries likely to be affected by these types of disasters.

This report serves as a bridge between a 2006 evaluation of the World Bank's response to natural disasters and two upcoming IEG evaluations, one on the environment and the other on climate change.

This Brief was conducted under the leadership of Ronald S. Parker, and the report was written by Ronald Parker with contributions from Kristin Little and Silke Heuser. Anna Amato provided research support. It was edited by William Hurlbut and revised for publication by Caroline McEuen. In particular, IEG acknowledges the cooperation with the U.S. National Oceanic and Atmospheric Administration (NOAA) and Ruth Kelty's valuable contributions to the research process. We are also deeply indebted to Piet Buys, who was taken from us so suddenly through a fatal accident, and to his colleague, Siobhan Murray, who supported us both with GIS and a regional disaster hotspot analysis. We would also like to thank Marie Charles, who provided administrative support.

This report is based on a database of project information with all the available information on every Bank project that had disaster-related activities. This database has since been turned over to the Sustainable Development Network for continuous updates.

For an expanded version of this Brief, including appendixes of supplementary information, visit http://www.worldbank.org/ieg/naturaldisasters/.

CHAPTER 1

Development Actions and the Rising Incidence of Flood and Windstorm Disasters

This paper serves as a bridge between the IEG report *Hazards of Nature, Risks to Development* (2006) and two upcoming IEG evaluation reports, on the environment and on climate change. *Hazards of Nature* reviewed the Bank's work to prevent and respond to all natural disaster types over a 20-year period. Although the review of 528 project experiences revealed a number of trends, one unexpected insight was that Bank lending in response to tropical storms and floods was increasing at a rate even higher than the sharply rising pace for disasters generally. In response to a new and more accurate understanding of the risk levels that hobbled development gains in borrower countries, IEG opted to devote additional resources to further explore the threat presented by these hazards under the broader theme of natural disasters.

This Brief is partly based on visits to the field, including recent IEG project-level evaluations and several background papers. This material is supplemented by a comprehensive desk review and an interactive database summarizing the achievements and challenges faced by recent disaster-related projects and based on self- and independent evaluation.

Although this Brief focuses on flooding and windstorms—reflecting the seriousness of their rapid increases—certain disaster-related statistics are presented in accordance with UN definitions (see box 1.1). Accordingly, some of the analyses include other disaster types (but only when so noted). Data from the Center for Research on the Epidemiology of Disaster (from its EM-DAT database) includes all intersecting hazard types listed in the UNISDR definition of hydrometeorological disasters (see box 1.1). Vulnerability levels were determined using the findings of the *Natural Disaster Hotspots Study* (World Bank 2005).

How Serious Is the Increase in Disasters?

In the aggregate, the reported number of natural disasters worldwide has been rapidly increasing, from fewer than 100 in 1975 to more than 400 in 2005. A glance at the 100-year record highlights the dramatic nature of the recent upsurge (see figure 1.1).

The human cost of these disasters has been staggering. The number of people affected[1] by natural disasters each year nearly quadrupled from 1975–84 to 1996–2005 (see figure 1.2), and

Box 1.1: UNISDR Definitions

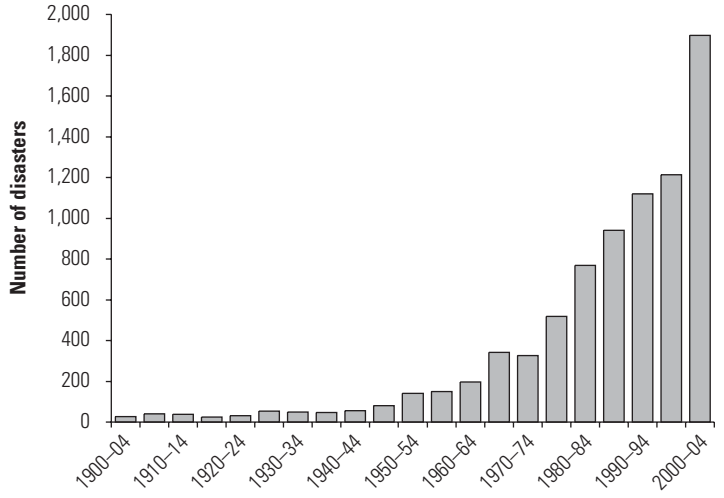
Disaster: A serious disruption of the functioning of a community or a society causing widespread human, material, economic, or environmental losses that exceed the ability of the affected community or society to cope using its own resources.

Hydrometeorological Disasters: Natural processes or phenomena of atmospheric, hydrological, or oceanographic nature, which may cause the loss of life or injury, property damage, social and economic disruption, or environmental degradation.

Hydrometeorological hazards include: floods, debris and mud floods; tropical cyclones, storm surges, thunder/hailstorms, rain and wind storms, blizzards and other severe storms; drought, desertification, wildland fires, temperature extremes, sand or dust storms; and permafrost and snow or ice avalanches. Hydrometeorological hazards can be single, sequential, or combined in their origin and effects.

Source: UN 2006.

Figure 1.1: Number of Natural Disasters in All Countries



Source: EM-DAT: The OFDA/CRED International Disaster Database, <www.em-dat.net > Université Catholique de Louvain, Brussels, Belgium.

the vast majority were in developing countries. In fact, 98 percent of the 211 million people killed or affected by natural disasters each year from 1991 to 2000[2] were from nations of low or medium human development (International Federation of Red Cross and Red Crescent Societies 2001).

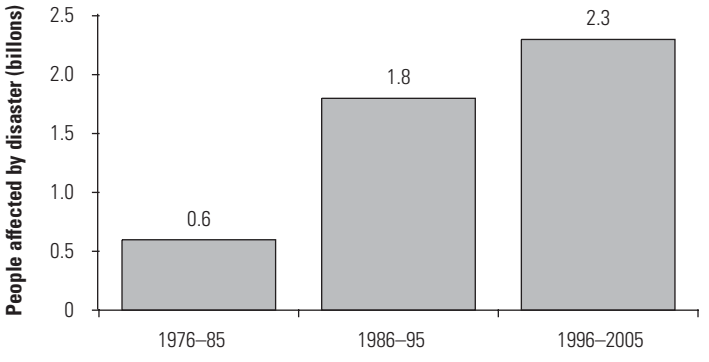
What Are the Major Causes?

In part, the rise is related to population. The long-term disaster trend remained relatively static until the 1940s, when the incidence of catastrophic events began to rise steadily. During the same period, the world's population grew from approximately 2.7 billion to about 6.5 billion.[3]

Another cause is urbanization. As the population grew, it began to shift from rural areas to cities.[4] In 1950, only one-third of the world's people lived in urban areas. With more than half of the world's population now living in cities, urban areas are the drivers of economic growth. In 1950, New York was the only *megacity*—defined as a metropolitan area having a population of over 10 million. In 2006, there were 25 such cities, including 19 in developing countries.

Environmental fragility caused by changes in population and land use over the past 50 years has greatly increased vulnerability, so that now even small-scale events produce large disasters. Population growth has meant increased strains on the environment and resultant environmental degradation. As people move from rural areas to more densely populated zones, "greenfield" sites become urbanized, disrupting watershed dynamics, and potentially aggravating flooding. And as people move to overcrowded cities and the cities themselves generate additional population growth, the areas available for occupation tend to be more dangerous than those occupied by the people that came earlier (Mellinger, Sachs, and Gallup 1999). Overcrowded and rapidly growing cities pose an increasing risk to many of the people living in them—but especially the poor.

Figure 1.2: Billions Affected by Natural Disasters



Source: EM-DAT: The OFDA/CRED International Disaster Database, <www.em-dat.net > Université Catholique de Louvain, Brussels, Belgium.

Coastal areas are being used more intensively and account for 53 percent of the world's GDP. About a quarter of the world's population lives within 100 kilometers of the coast, and many rural areas are vulnerable to tidal surges and swollen rivers bringing runoff from higher elevations. And the coasts are much more densely settled now than they were a few decades ago. Of the 25 megacities, 14 are on the coast and 7 are within a few hours' drive. This concentration of settlement along the coast is "setting us up for rapidly increasing human and economic losses from hurricane disasters, especially in this era of

heightened activity," according to the latest scientific thinking (Emanuel 2006).

Developing Countries Experience Disproportionate Economic Impacts

Living in dangerous zones, on marginal lands, and with precarious livelihoods, the developing world's poor are rarely insured against disaster-related damages. Global disaster databases[5] reflect the increase and highlight the likelihood of rising costs to national governments.

The economic costs of disasters are large. During 1996–2005, disasters caused over $667 billion in direct material loss worldwide. Economic losses due to natural disasters are 20 times greater (as a percentage of GDP) in developing than in developed countries.[6] This disproportionate effect has many explanations. Lack of development itself contributes to disaster impacts, because the quality of construction often is low and building codes, land registration processes, and other regulatory mechanisms are lacking, as well as because numerous other development priorities displace attention to the risks of natural events.

Developing countries are especially hard hit, not only because of direct damages, but also because of the indirect and secondary economic effects, such as disruptions in the flow of goods and services following disaster.[7] Another important economic impact, which is quite difficult to quantify, is the extent to which the possibility of another disaster striking the same area may be a disincentive to investors—referred to by some as a "fear factor." If businesses and investors are worried that a country is not prepared for the next disaster (because the underlying risks have not been reduced), the long-term impacts of investor uncertainty can equal or surpass the cost of the disaster itself (Dercon 2006). Even the stability of an economy may be affected, if investors worried about underlying conditions dramatically reduce capital inflows.

Considering both the economic implications of the loss of productive assets and the secondary and indirect costs that are not part of the totals presented, true disaster losses are even higher than those reported. Taken together, the accumulating burden of human and economic loss from disaster throws into tumult the development plans of the regions and countries affected by disasters.

Which Disasters Are the Fastest Growing Problem?

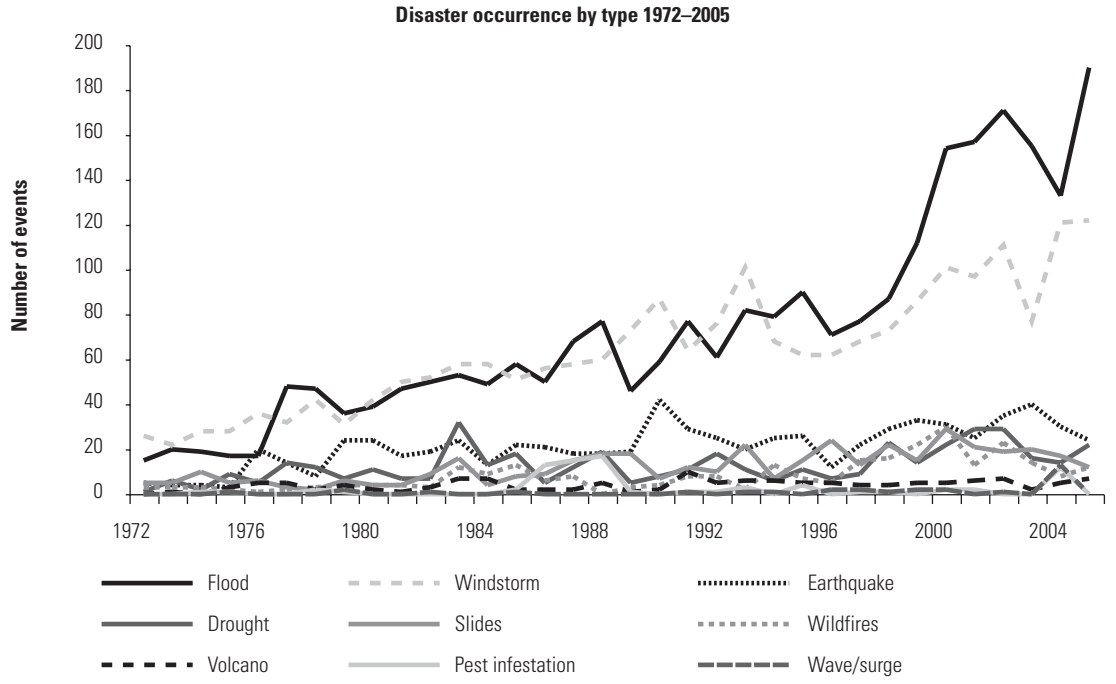
While natural disasters are increasing overall, as noted above, two types—flooding and wind storms— are increasing much more rapidly than the others (figure 1-3).

Their number is increasing dramatically, with an annual average increase of at least 5 percent. To some degree the two types of events go hand in hand. Tropical storms can cause flooding, and flooding is frequently triggered by unusually heavy rains—which are not always from "named" storms. And not only are tropical storm disasters up; extreme weather events (that is, unusually heavy rainfalls not caused by cyclones or hurricanes)[8] also are more frequent. Moreover, the *damage* caused by extreme weather events, flooding, and wind storms has also accelerated.

As a group, weather disasters—drought, extreme temperatures, floods, mudslides, wave/surges, and windstorms (commonly referred to as hydrometeorological events)—affect more people than all other disasters combined. During 1972–2006, more than 5,250 million people were affected by hydrometeorological disasters, compared with about 11.5 million for all other disasters combined (earthquakes, insect infestations, volcanoes, and wildfires).[9] Storms and floods alone account for about 67 percent of the above number of individuals impacted, or 3,500 million people.

The economic costs of these disasters are particularly high when compared with other devastating events, not only because of their frequency, but also because they often occur near the coast, where much of the population is concentrated (see figure 1.4). In addition, the rate of increase for the economic damages caused by floods, hurricanes, cyclones, and typhoons has been escalating. When a regression line is plotted to

Figure 1.3: Flood and Wind Storm Disasters Are Increasing in Frequency



Source: EM-DAT: The OFDA/CRED International Disaster Database <www.em-dat.net > Université Catholique de Louvain, Brussels, Belgium.

the annual amount of actual economic damage (current dollars), the percent increase of the line is 10 percent. In constant dollars the increase is 7.8 percent.

Development Actions

Investments in development generate activities that have a multiplicity of positive outputs and impacts. But unless natural hazards (in this Brief, the risks of floods and windstorms are emphasized) are expressly taken into account, development investments can inadvertently raise vulnerability, sometimes dramatically. Box 1.2 shows how a badly needed rural road also contributed to a rise in vulnerability.

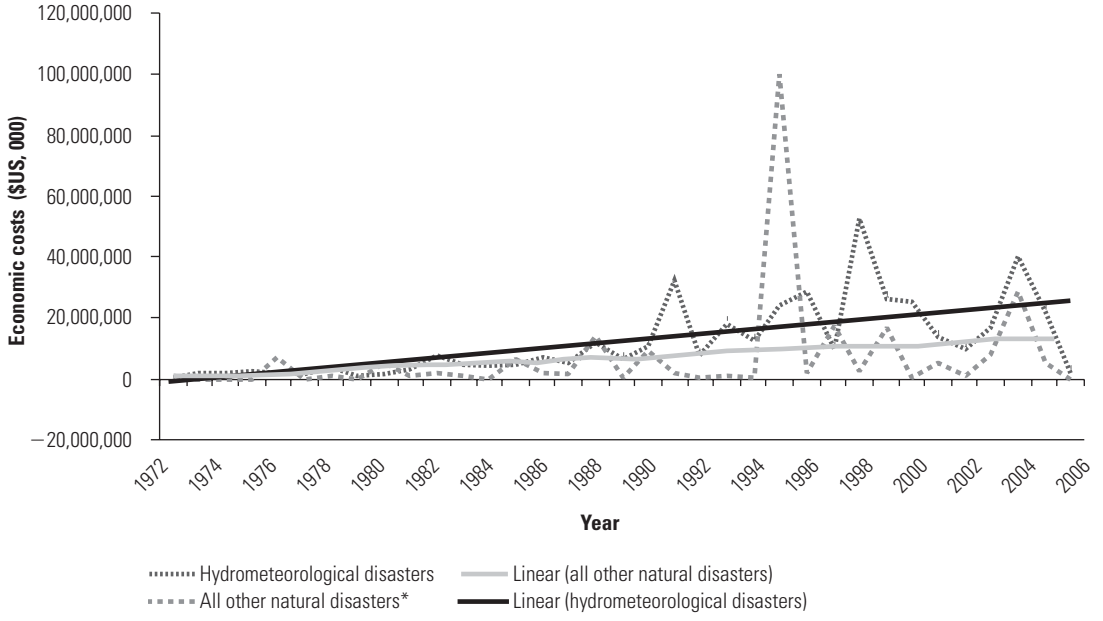
Projects financed by the Bank naturally tend to focus on zones where economic activity occurs and more people live. They therefore tend to be located along the coast—an area particularly vulnerable to flooding and storms. The Bank's intensive focus on the poor also means that Bank-financed infrastructure risks being increasingly located in fragile areas.

The Study

To determine the vulnerability of Bank-financed projects it was necessary to ascertain exactly where they are located. This Brief relies on a number of innovative evaluation techniques involving a mix of geospatial analysis, qualitative data analysis, and database analysis. For instance, it employed GIS/ArcInfo in its analysis. Latitude and longitude for all of the Bank-financed port projects implemented since 1983 were obtained where possible and activities were mapped using ArcInfo. The ports were located on a GIS map, and 100-kilometer-radius buffer zones were established for each of the 300 ports. The percentage of vulnerable land within this radius was then calculated by overlaying hazard maps. This study deliberately piloted methods for the two follow-on studies on climate and environment, especially the former. This sort of analysis will be further developed in those upcoming studies.

Qualitative data analysis (QDA) software (AtlasTi) enabled the team to analyze the entirety of

Figure 1.4: Economic Cost of Hydrometeorological Disasters Is Higher than That of All Other Disaster Types Combined



Source: EM-DAT: The OFDA/CRED International Disaster Database <www.em-dat.net> Université Catholique de Louvain, Brussels, Belgium.

Note: This database reports large- and medium-scale disasters, not local, small-scale ones. *This category includes earthquake, insect infestation, volcanoes, and wildfires. Hydrometeorological disasters include drought, extreme temperatures, floods, mudslides, wave/surges, and wind storms.

Box 1.2: A Chain of Events, Beginning with a Road

People have always been vulnerable to disaster, and no matter what is done to prevent disasters, they will still happen. However, vulnerability is affected by development activities. Such activities may have desirable outcomes, yet may also increase vulnerability to disasters.

Unpaved roads contribute disproportionately to basin-wide runoff and stream sediment. According to Ziegler and others (2004), who studied the impact of rural roads in Pang Khum Experimental Watershed (PKEW) in northern Thailand, many road sections are constant sources of sediment and runoff during most rain events. This happens because water begins flowing over land on compacted earthen surfaces after small depths of rainfall, and these flows go directly to nearby streams. Surface preparation processes performed when these roads are maintained renew the supply of easily transportable surface sediment. The authors note that erosion of the road surface is accelerated in locations where slopes are steep, overland flow distances are long, and/or vehicle usage is high. Furthermore, runoff typically exits from the road directly into the stream. Sediment delivery rate on the studied roads is more than an order of magnitude higher than that on adjacent fields. The research team concluded that unpaved roads appear to be of the same order of importance as agricultural lands in contributing sediment to the stream network, despite occupying a fraction of the total surface area in the basin.

Burning the forest to clear land for agriculture is a practice that has spread rapidly and has contributed to increasing runoff. The phenomenon has made its way into the rainforest through the road system, with close to 75 percent of the deforestation taking place within 50 kilometers of a paved road. Often these fires accidentally get out of control, destroying even more of the forest. As a result, nearly 60 million hectares have been cleared in the past two decades.

almost 6,000 project documents related to the Bank's disaster operations. Key words were flagged, and pertinent passages pulled for thorough analysis of discrete topics.

A portfolio review was conducted using Bank documentation and the database prepared for the 2006 natural disaster study (*Hazards of Nature,* 2006), which contains over 80 fields of information on 528 Bank-financed disaster responses. These responses were analyzed to identify which activities have been undertaken most often, along with project performance ratings, to determine where the Bank has been most successful as well as where it needs to improve practice. Where practicable, the database was updated to include recent developments.

The report team conducted an extensive review of the literature to capture a broad picture of the latest information in the field, including a thorough review of several scientific journals. The literature review focuses on weather events and their interactions with urban and rural environmental degradation. Key policy issues regarding urbanization, tools and indicators, current debates, and cutting-edge issues also were reviewed.

Notes

1. The Red Cross and Red Crescent Societies define "the affected" as "those who at least for a time either lost their homes, their crops, their animals, their livelihoods, or their health, because of the disaster."
2. This is seven times the number of people killed or affected by conflict.
3. Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, *World Population Prospects: The 2004 Revision* and *World Urbanization Prospects: The 2005 Revision,* http://esa.un.org/unup, 25 October 2006.
4. Cities have absorbed almost two-thirds of the planet's growing population since 1950.
5. Global databases that show an increase in the destructiveness of tropical storms are NatCat, maintained by Munich Reinsurance Company (Munich); Sigma, maintained by Swiss Reinsurance Company (Zürich); and EM-DAT, maintained by the Centre for Research on the Epidemiology of Disasters (CRED, Université Catholique de Louvain, Brussels).
6. Disaster Management Facility (DMF) Web site, The World Bank, http://www.worldbank.org/dmf/
7. The convention is that indirect losses should not be reflected in the economic cost figures, nor should the secondary effects of the event be taken into account (such as the impact on the overall economy in the years following).
8. Not graphed because the relative frequency of heavy rainfalls would alter the scale and hide the main point being made here.
9. EM-DAT: The OFDA/CRED International Disaster Database <www.em-dat.net >, Université Catholique de Louvain, Brussels, Belgium.

CHAPTER 2
Bank Lending for Flooding and Storms

Each Bank Region is affected differently by disasters. Table 2.1 shows that flooding disasters are increasing in all borrower Regions, but the rate of increase is considerably smaller in one of them. Europe and North America are included for comparison purposes. Tropical storm disasters are increasing in Africa, Latin America, and the Middle East and North Africa. Drought is increasing everywhere but in North America.

East Asia and the Pacific, Latin America and the Caribbean, and South Asia have the largest number of Bank-financed flood projects, and the East Asia and the Pacific Region has the highest percentage of its disaster lending related to flooding (see figure 2.1).

The Region hit hardest by tropical storms is Latin America and the Caribbean, which accounted for 51 percent of the 75 projects related to storms (see figure 2.2). Africa follows, with 23 percent of the Bank's tropical storm projects. As a percentage of total natural disaster projects in each Region, tropical storms accounted for the largest portion in Latin America and the Caribbean.[1]

Between 1984 and 2005, approved loans with some flood-related activity totaled $23.5 billion—almost 55 percent of the total for all projects involving disaster. Figure 2.3 shows the makeup of the Bank's flood and tropical storm portfolio, with comparisons to the rest of the Bank's natural disaster project portfolio.

Flooding

The vast majority of floods occur in countries that borrow from the World Bank (see figure 2.4). Developed countries have decades of investments in flood and storm water control, as well as strict land use planning, which help prevent disasters. Many developing countries are only just beginning to provide themselves with such protections.

The Bank's portfolio has generally kept pace with the rising borrower demand occasioned by the upward trend of floods. Although the ratio of Bank projects to flood events appears to be lower in the most recent period (since 2003), this is more an accounting phenomenon than a trend: reallocations tend to take place in the later

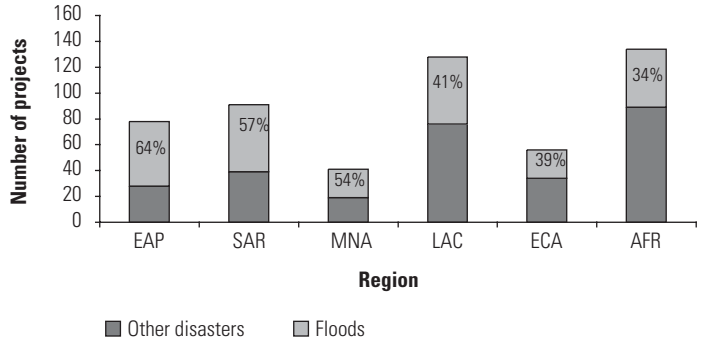
Table 2.1: Where in the World Are Disasters Increasing?

Region	Floods	Tropical storms	Drought	Wildfire	Earthquake	Volcano	Landslides
Africa	**+**	+	+				
East Asia/ Pacific	**+**		+		+		+
Europe	**+**	+	+	+			
Latin America/Caribbean	+	**+**	+	+		+	
Middle East/North Africa	**+**	+	+				
North America		+		+			
South Asia	**+**		+		+		

Data source: CRED-EM DAT.

Note: Bold plus sign means trend since 1972 has increased at an annual average > 5 %.

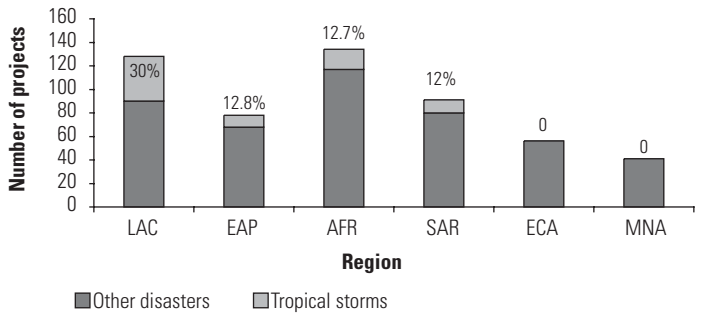
Figure 2.1: Flood-Related Projects by Region: 1984–2005



Source: IEG data.

Note: EAP = East Asia and Pacific; SAR = South Asia; MNA = Middle East & North Africa; LAC = Latin America & the Caribbean; ECA = Europe and Central Asia; AFR = Africa.

Figure 2.2: Tropical Storm–Related Projects by Region: 1984–2005



Source: IEG data.

Note: See figure 2.1.

years of a loan, and the most recent loans are not yet at that stage.

Of the 528 projects in the disaster portfolio, 243 (46 percent) are related to floods.[2] Not only is the portfolio related to flooding sizeable, but almost half of the projects (47 percent) are ongoing. The average cost of flood projects—$96.5 million—is smaller than that of earthquake, landslide, and tsunami disaster projects, but as noted previously, when individual loan amounts are added together, loans having to do with flooding receive the bulk of Bank disaster funding (see figure 2.5).

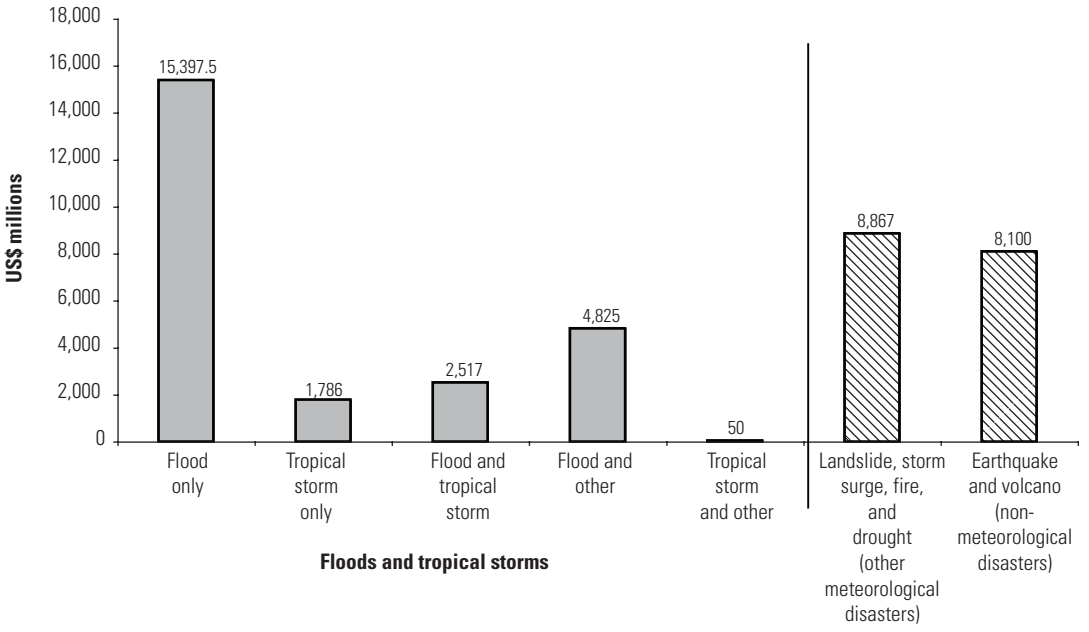
As disasters have become more costly, the average cost of individual Bank-financed flood projects has grown. The average flood project loan in 1984 was for $61 million, but in 2005 it was for $114 million, almost double. Reflecting the steep rate of increase in flood occurrences, the number of projects and the amount of Bank lending have increased. The number of hurricane and cyclone projects has only increased slightly, however.

Figure 2.6 shows the increase in actual loan amounts approved by the World Bank for these phenomena. The total amount of lending for floods has increased substantially over the years, while the total lending amounts for droughts and tropical storms have stayed relatively constant.

The 243 projects that addressed floods undertook 60 distinct activities (many projects included multiple activities). Eight of the top 20 activities in flood projects involved rehabilitation or restoration—of road infrastructure, flood control structures, irrigation/drainage infrastructure, urban and rural water systems, education facilities, health facilities, and urban water/sanitation infrastructure.

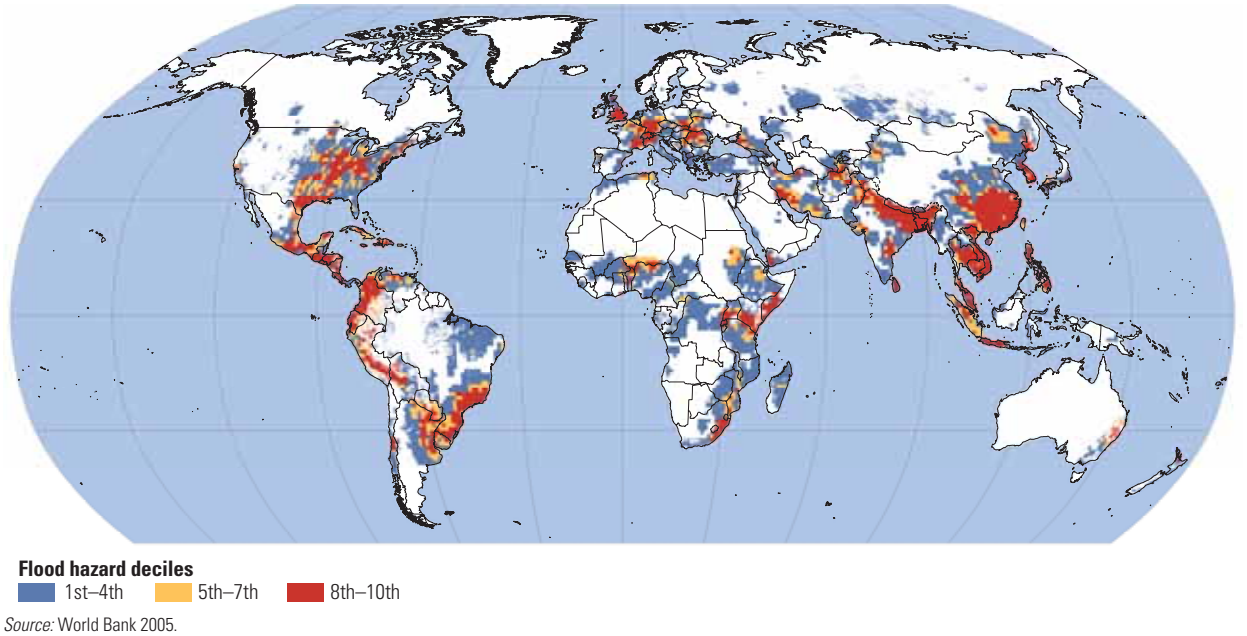
The emphasis on rehabilitation indicates that much public infrastructure does not hold up to flooding. A failure to perform maintenance on infrastructure, an entrenched problem, often leads to its premature deterioration. Disaster experts agree that this issue requires attention. The 2004 Caribbean Regional Disaster Conference "Managing Hazards in a Changing Environment" concluded that governments' investments in large-scale structures to reduce disaster vulnerability have been seriously compromised by failure to conduct and fund maintenance. This problem is not confined to small island states. For example, many Bank-financed cyclone shelters along the Bay of Bengal are no longer usable for lack of maintenance. IEG missions to South Asia noted that breached, failed, and crumbling embankments were common. In another case, the effectiveness of Bank-financed flood control infrastructure protecting a major South American city (that had previously experienced catastrophic flooding) was severely compromised by the presence of junked automobiles and refuse blocking the watercourses.

Figure 2.3: Total Lending Amount (in US$ millions) by Disaster Type: 1984–2005



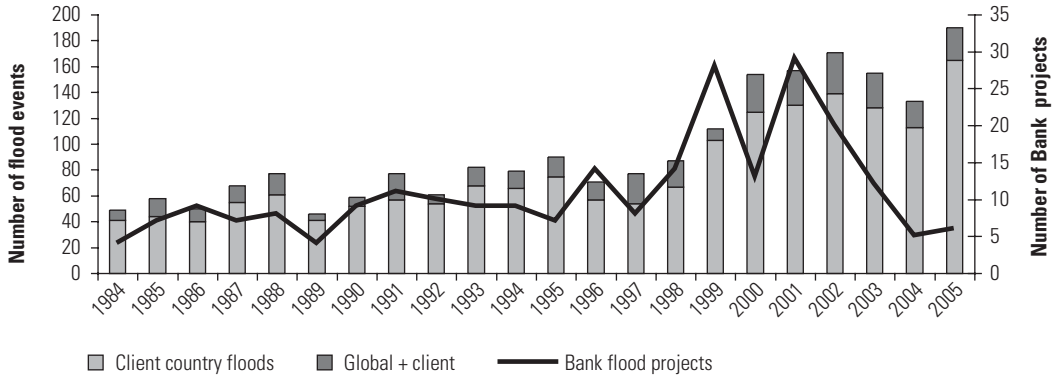
Source: IEG data.

Figure 2.4: Global Distribution of Flood Risk—Economic Loss as a Proportion of GDP Density



Source: World Bank 2005.

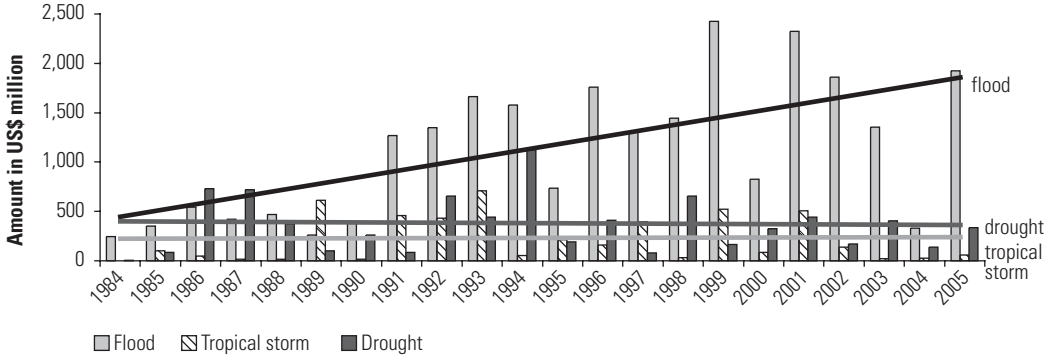
Figure 2.5: Floods Globally and the Bank Response



Source: IEG data.

Note: Total number of floods globally is shown by adding the client and non-client bars.

Figure 2.6: Flood Project Lending Is Rising



Data Source: EM-DAT: The OFDA/CRED International Disaster Database < www.em-dat.net> Université Catholique de Louvain, Brussels, Belgium.

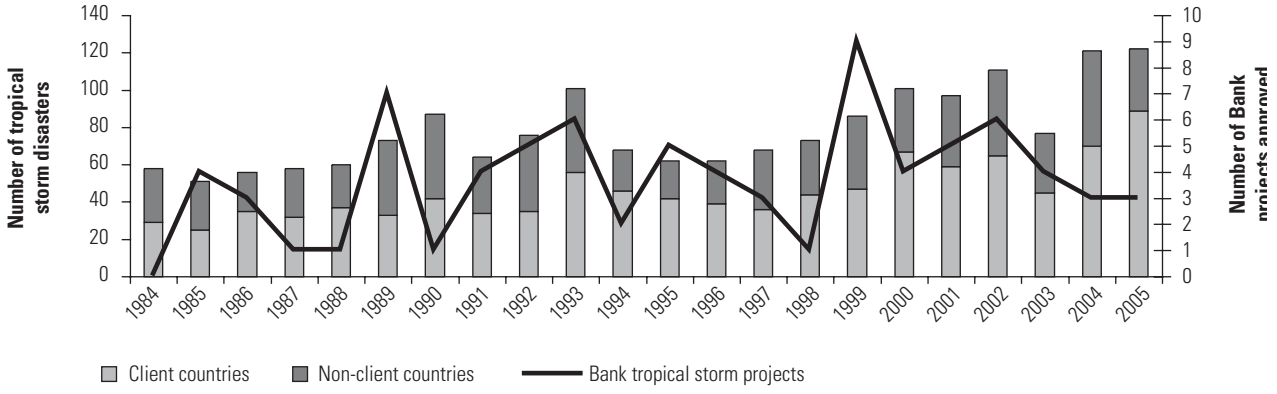
Tropical Storms

Tropical storms cause not only flooding but also extensive wind damage. Since the 1970s, cyclones, hurricanes, and other tropical storms have been increasing in frequency and destructiveness. With the increasing severity of storm events, new countries are falling victim. Brazil suffered its first hurricane ever in March 2004: Hurricane Catarina (not to be confused with Katrina) killed 3 people, injured 38, and rendered 2,000 homeless.

Figure 2.7 shows the number of major tropical storms in countries that borrow from the World Bank and in those that do not. Part I countries account for a larger share of events (compared with flooding), although Part II countries still predominate each annual tally. Some areas particularly vulnerable to tropical storms include the Bay of Bengal, East Asia, and the Caribbean.

Storms are a special challenge for small island states, which have extensive coastlines, reliance on trade, and economies based on tourism. Since storm impacts are worse at the shore, where tourism investments are concentrated, import/export infrastructure tends to be located, and most people live, they can paralyze activities for extended periods. Small island nations can—and often do—lose multiples of their GDP to

Figure 2.7: Number of Tropical Storm Disaster Projects by Year: 1984–2005



Data Source: IEG and OFDA/CRED EM-DAT.

Note: Total number of floods globally is shown by adding the client and non-client bars.

natural disasters: Grenada lost 200 percent of its GDP to Hurricane Ivan in 2004.

World Bank lending for tropical storms is noticeably cyclical. Over the past 20 years, the number of storm-related projects approved annually has ranged from one to nine. But other than an upward trend over time, no clear pattern is otherwise discernible. This is because the number of tropical storms that will strike land is determined by sea temperatures, wind patterns, and other factors. The number of storms thus oscillates considerably on an annual basis, with a bad storm year producing nearly five times as many tropical storms as the calmest years in some zones. Bank funding for tropical storm projects[3] has been flat over the period (see figure 2.6). In total, 76 projects were related to tropical storms: 20 are ongoing (26 percent) and 56 have been completed (74 percent).[4]

Tropical storms did not receive a large portion of Bank disaster-related funding in comparison with other disaster types, such as floods (see figure 2.6). In part this is because the severity of individual storms varies, and they sometimes hit coastal areas where there is no concentration of investments. Between 1984 and 2005, the Bank supported tropical storm projects with total lending of $4.6 billion, which represented almost 11 percent of the total investments in natural disaster projects.

Tropical storm projects have used a unique basket of activities, and the activity mix is significantly different from that of flood projects. Rehabilitation of roads is still the most frequent activity, but studies and research take place much more frequently (third most numerous activity, compared with thirteenth for flood activities). Early warning and public awareness are not even in the top 20 list of tropical storm activities, nor are engineering design and project management, all of which are prominent in flood projects. Conversely, restoring transport facilities and balance of payment support appear frequently in tropical storm projects and not in flood projects.

Notes

1. Since the 1970s, although droughts have been increasing slightly in frequency, the number of Bank-funded drought projects has not increased. This is presumably because agricultural projects in drought areas now routinely promote drought-resistant varieties, more sustainable use of water, and more appropriate crops. Of the 528 projects in the IEG disaster portfolio, 107 included drought activities. Of those, about two-thirds have been completed. The number of drought projects has held steady at an annual average of about five since 1984.
2. Because a project may respond to several different disaster events (for example, floods and

landslides), adding the percentages of projects dealing with each different type will lead to a sum greater than 100 percent.

3. Tropical storm projects, as with all the Bank's disaster-specific projects, include projects having any activity related to major tropical storm disasters (hurricanes, cyclones, and typhoons).
4. This number includes projects having any activity related to major tropical storm disasters (hurricanes, cyclones, and typhoons).

CHAPTER 3

Development Investments at Risk to Flooding and Storms

A rough estimate of potential flooding and storm impacts on the Bank's ongoing portfolio was derived by identifying the Bank sectors that tend to be the most affected and determining their exposure.[1] To estimate the percentage of Bank investments at risk in these sectors, the loan amounts of the active projects were multiplied by the percentage of GDP at risk for floods and tropical storms (numbers developed as part of the *Hotspots* study [World Bank 2005], which provides estimates of GDP at risk by disaster types for each country). Table 3.1 shows the number of countries that are considered to have some measure of risk to floods and storms. Since some countries are at risk of both, there is overlap. Of the sectors where investments are likely to sustain damage, the percentage of risk applicable to GDP for the country was applied to the sector portfolio. The amount of lending at risk is the product of portfolio percentage at risk and loan amounts (the country breakdown of risk data by disaster type is still embargoed, and is therefore not included in this Brief).

Clearly, the estimates derived from this exercise argue strongly that disaster vulnerability warrants serious consideration on financial grounds alone—if Bank investments are located in a manner that mirrors the distribution of investments generally, 60 percent of Bank investments in infrastructure, rural development, and environment are at risk to flooding, and 23 percent to tropical storms.[2]

When comparing the at-risk portfolios to the Bank's entire active lending portfolio, projects at risk to floods represent 38 percent of current Bank lending, and projects at risk to tropical storms represent 8 percent. And both disaster types are on the rise.

The study team analyzed two Bank activities in depth, road and port-building, because these are the most common activities in Bank-financed projects following disaster events (30 percent across all disaster types and 45 percent of all activities in response to floods and tropical storms).

Roads Are Highly Vulnerable to Disasters

As global and regional trade has intensified, societies have become much more dependent on services and infrastructure that facilitates the exchange of goods. Roads are unquestionably major "lifelines," in this sense, serving both urban and rural areas. In the event of a major disaster, roads are crucial in efforts to distribute emergency relief and to restore the local economy. A failure of these links following a natural disaster can have considerable consequences, even for people in areas not directly affected.

Failures have been common (see figure 3.1). Road construction and rehabilitation are the most common Bank response to floods and tropical storms. Looking only at completed flood projects with Bank involvement, 42 percent *rehabilitated* roads (just 2 percent constructed only new roads). A similar pattern prevails for

Table 3.1: Bank Investments at Risk to Floods and Storms

	Number of borrowers at risk, with active portfolios in vulnerable sectors	Percent of vulnerable sector portfolios at risk	Amount of Bank lending vulnerable (US$ billions)
Floods	84	60	36.0
Tropical storms	28	23	7.3

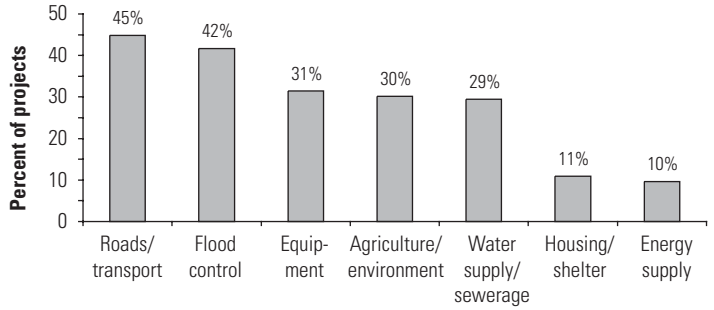
Source: IEG and World Bank data.

tropical storm projects—47 percent rehabilitated roads and none built only new roads.

Honduras provides a dramatic example of repetitive road failure in the face of storms. The World Bank has been helping Honduras to build its highway system since 1955, when it was estimated to have 2,500 kilometers of roads. In the course of seven transportation projects, the Bank financed construction of 1,270 kilometers of highways and feeder roads. While the Bank was trying to help improve the highway system, Hurricane Fifi (1974) destroyed 60 percent of all the roads in the country. After Hurricane Gert (1993), a relatively small event, roads had to be rehabilitated because of mudslides (no percentage data were found for road damage). By 1998, there were approximately 10,000 kilometers of roads in the country. Hurricane Mitch (1998) destroyed 6,000 kilometers of the better roads (60 percent)—almost five times what the Bank had helped to build. In addition, more than 163 bridges were damaged or destroyed. Estimates of the damage to roads from Mitch were on the order of $454 million (Münchener Rückversicherungs-Gesellschaft 1975).

In some geographic areas the construction of roads exacerbates the conditions that cause floods. When a road is built in a forested area, deforestation and erosion are not far behind (Alves 2002) (see box 1.2). Large-scale paving significantly reduces infiltration, and natural storage of groundwater is reduced by improved drainage (which, by definition, removes water to another area). Also, streams are often constricted by roads. Bridges may constrict the flow of water, especially when designers are unaware of peak rainy season flows, and they can act as unintended dams if debris jams their openings. The 2007 IEG transport study, *A Decade of Action in Transport*, identified 65 Bank-financed projects that constructed major (not rural) roads. Of those, only 14 (22 percent) constructed new (greenfield) roads, while the rest concentrated on rehabilitation and upgrading. The study cites flash floods and slope instability as threats to road sustainability, and notes that "having to rehabilitate paved roads too frequently because of neglect could conservatively be more than three times as expensive for the road authorities (based on undiscounted costs) as maintaining them on a regular basis." Since disaster-related problems generally also involve flash flooding and slope stability, providing adequate drainage, sufficiently dimensioned culverts, and designing road alignments to provide the maximum protection and stability possible pay significant dividends even when they double road cost.

Figure 3.1: Transportation Infrastructure Dominates Bank Response to Floods and Tropical Storms



Source: IEG data.

Roads can act as protective embankments and aid in mitigating the effects of flooding. With good local knowledge, road construction projects may raise roads above flood level. While this practice has saved many lives—Bangladesh is a notable example—adequate consideration is not always given to the number and size of openings necessary for local drainage or tributary inflow. In such cases the road can artificially raise water levels upstream and cause additional flood damage. Roads can also act as levees to channel runoff away from fragile lands and into established watercourses. When they are parallel to a river or stream, however, the water level upstream can increase, and in the absence of careful hydraulic study, result in additional flood damages there.

An example of how poorly designed road systems can be modified to take disaster and the environment more into account is provided by the 1994 Paraguay Natural Resource Management Project. The project's overall strategy was to use the road network to support watershed management

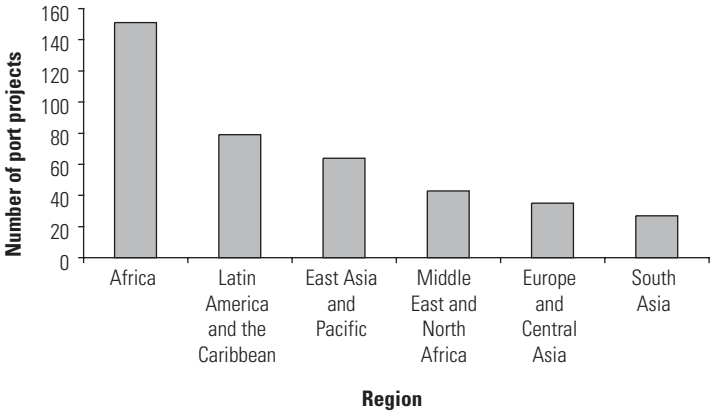
plans designed to achieve sustainable agriculture and the conservation of natural resources. Long before the project began, forest had been cleared to increase the amount of land under cultivation, and a network of rural roads had been constructed. But the forest clearing had paid little attention to appropriate land use, and led to soil degradation, erosion, and runoff. In many places the road network dumped water into tilled fields, creating gullies. But while the roads contributed to soil erosion in some areas, they were subject to it in others: large stretches of road were often flooded and certain sections regularly washed away. The project realigned, rebuilt, and provided for the continuing maintenance of the road network. Only selected roads were abandoned or closed, but in those cases trees were planted to definitively prevent further use. As a result of improved agricultural practices and road rehabilitation, the need for road maintenance was significantly reduced. In effect, road maintenance costs decreased by $540/km/year, and more roads became passable year round, even following major storms.

Lending for Ports Is at High Risk

Port infrastructure is often vulnerable to natural disasters such as tropical storms (both from storm surge and flooding) and earthquakes. Between 1983 and 2006, the Bank lent $30,508 million for the infrastructure or administration of about 399 ports. The study attempted to evaluate the vulnerability of Bank lending for ports—located at sea level, they are at least somewhat exposed to storms and abnormally high tides. The analysis only covers 307 of the ports because the documentation in Bank reports for the rest of the projects was not detailed enough to permit the clear identification of the latitude and longitude of each port.[3] Figure 3.2 shows the distribution of port projects by region (IEG has pinpointed project locations on Google Earth).

According to data presented in the Natural Disaster Hotspots Study (World Bank 2005), 52 percent of the 307 ports were in areas with high risk from flood, 34 percent in areas at high risk for earthquakes, and 25 percent in areas at high risk from tropical storms. Altogether, 70 percent of the 307 ports, representing 77 percent of the Bank's port lending, were at high risk from at least one of the three hazards (floods, earthquakes, or cyclones). Even more alarming, 40 percent of the ports, representing over $10.5 billion, or 41 percent of the Bank's port lending, were located in the top tenth percentile for risk from one of the hazards (see table 3. 2).

Figure 3.2: Port Projects by Region



Source: IEG data.

Another risk largely missing from project documents is that of higher mean high tides. The Bank's lending for ports may be threatened not only by stronger storms, but also by global warming and rising sea levels. In only two port projects were sea-level rise and climate change mentioned as a threat. In all cases, as far as can

Table 3.2: Analysis by Highest Risk

	Ports	Dollar investment
LOW: Ports at low risk from all three hazards	62 ports (20%)	$3,822M (15%)
MEDIUM: ports at medium risk from at least one of the hazards	29 ports (9%)	$2,417M (9%)
HIGH: ports at high risk from at least one hazard	215 ports (70%)	$19,908M (77%)
TOP 10th PECENTILE: ports for which risk of at least one hazard is in the top 10th percentile.	123 ports (40%)	$10,501M (41%)

be determined, no action was taken to adapt ports to rising risk levels.

The bulk of the 399 port projects approved since 1983 have supported better administration of port projects. This includes institutional development or privatization of ports aimed to increase efficiency of cargo handling (183 projects). New regulations and pricing were introduced in this context. An efficiency increase, an important objective in 199 projects, was to be achieved not only through privatization and better regulations, but also by improving the links between ports and the road or railway networks (138 projects). Studies were undertaken in 107 projects in order to monitor and improve efficiency. Projects in 99 countries improved links for exports such as log transport, as well as coal, metals, and agricultural products.

But not all port projects were geared toward major export ports. The Bank also supported secondary and tertiary ports as well as small fishing ports. Port improvements are heavily focused on the Africa Region (see figure 3.2).

Notes

1. This includes infrastructure (global infrastructure, energy and mining, transport, urban development, and water supply and sanitation), rural development, and environment.
2. An estimate of flooding and storm impact on the Bank's ongoing portfolio was derived by analyzing the Bank sectors that are the most affected by them. Some parts of other sectoral portfolios that could also be affected were not included as they were relatively small and difficult to accurately identify. To estimate the percent of Bank funding at risk in these sectors, the loan amounts of the active projects were multiplied by the percent GDP at risk for floods and tropical storms. The *Hotspots* study provided the information on the percent of GDP at risk to flooding and tropical storms, by country.
3. The analysis represents $25,904 million, or 85 percent of the Bank's investment in ports.

CHAPTER 4

Engineering and Planning Issues in Managing Watersheds for Flooding and Storms

Reducing vulnerability to disasters caused by storms and flooding is largely a matter of watershed management, which has engineering and planning as well as ecological aspects. The engineering aspects involve adaptation to the likely hazards. Planning involves land use and the placement of infrastructure to reduce exposure. The engineering and planning issues related to watershed management are slightly different in areas of high population density than in those with lower population density. In high-density areas, issues relate mainly to controlling the flow and location of water. In lower-density areas, the engineering and planning issues often relate to large infrastructure intended to control drainage and provide irrigation.

There is strong interplay between the urban and rural areas that can increase vulnerability to disasters related to storms and flooding. This can be seen in the type of areas in which flood projects are implemented: 42 percent take place in rural areas, 25 percent in urban areas, and 33 percent span both urban and rural. Changes in land use and water courses in rural areas can have catastrophic and unforeseen consequences for major urban areas. Conversely, demand for urban land can lead to the loss of productive agricultural plains and encourage deforestation on nearby hillsides, which in turn causes erosion, crop loss, and repetitive flooding. Runoff reduces the usable lifespan of expensive reservoirs.

Watersheds may be urbanized, but whether they are or not, they are can be damaged when forests, agriculture, industry, and drainage are not properly managed. Poverty can exacerbate the situation. Poor residents, out of financial necessity, often deplete the natural resources in and around the city in their daily quest for food, fuel, and shelter. Metropolitan development efforts can diminish either the rural or the urban resource base, or both, thereby contributing to creeping environmental degradation and disaster vulnerability.

Infrastructure can be adapted to hazards to withstand severe conditions with minimal damage. There is a generally accepted rule that a 10–15 percent increase in cost can usually make a building safe from all but the most extreme earthquakes and storms. Flooding involves different and even more complex dynamics. At some point the trade-off between cost and protection becomes onerous, however. Hardening structures so that they are protected from the 500-year or 1,000-year storm is unaffordable, especially when compared with the cost of insurance.

A key issue in project and policy design is the choice between adaptation to risk and insurance. While it is possible to ”gold-plate” infrastructure to make it impervious to storms and flooding, choosing whether to insure or adapt is, among other things, a function of expected storm/flood frequency, construction cost, maintenance costs, societal risk tolerance, and access to funds for reconstruction. The choice is never obvious, though roads tend not to be insured, and it becomes much more difficult given that historical storm frequency records provide poor guidance for the future, given climate change.

Effects of Rapid, Unplanned Urbanization

Avoiding catastrophic events in densely settled areas is critical: high population concentrations almost inevitably result in high death tolls, and high property values result in high losses.

High levels of urban vulnerability to disaster can be blamed on planning failures. Ineffective land use planning coupled with rapid urban growth and a lack of suitable and affordable housing means that poor families often end up in densely packed, poorly serviced, and dangerously located neighborhoods—slums. One in three urban dwellers lives in a slum—and that number will double in the coming 30 years if nothing is done to manage urban growth and migration.

Another part of rapid urban conversion involves road building, which brings air pollution (pavement, being for cars and trucks, contributes to air pollution and global climate change); siting and planning problems such as building on floodplains or on unstable slopes become an issue; and weakening of coastal defenses and the hardening of the coastline, including the construction of sea walls and embankments, contribute to increased urban vulnerability to disasters.

Cities also suffer from over-asphalting, a lack of green spaces, and a lack of investments in infrastructure, which can contribute to a host of issues that make an urban area more vulnerable to disaster— altered runoff patterns, less absorption, pollution, subsidence, and land scouring. Few cities have preserved the forests and watersheds once found within their boundaries, and the vast paved areas impede the natural recharge of aquifers (see box 4.1). Solid and liquid wastes and seawater have polluted many sources of freshwater that can no longer be economically reclaimed. Few cities, if any, still have tree-lined harbors, clean rivers and lakes, sufficient subterranean water, and protective ground cover. Because of environmentally disastrous urban development, any discussion of the vulnerability of cities to unusual weather events must consider restoring the natural resources essential to the survival of the cities, but which are now located too far from city boundaries to provide any protection.

Box 4.1: Runoff Increases Dramatically in Cities

Rapid expansion of metropolitan areas, and the impervious cover that accompanies such expansion, impedes rainwater from recharging aquifers and contributes to fast and polluted runoff, which in turn flows directly into streams and rivers. Under natural conditions, 15 to 20 percent of the volume of rainfall contributes to direct runoff, but over 80 percent does in urban areas. The volume and rate of runoff have been shown to increase dramatically when impervious cover exceeds 10 to 15 percent of the total surface area of any watershed.

Storm Drainage in High-Density Areas

In many developing countries, inadequate infrastructure or poor maintenance of existing infrastructure can lessen urban resistance to natural hazards, and even create additional dangers. In the absence of a functioning sanitary sewer system, human waste often turns a flooded area into an open breeding ground for disease following heavy rains. To give some dimension to this problem, inappropriate design and siting of housing, roads, bridges, and industry (in Tegucigalpa and elsewhere) were estimated to account for 50–75 percent of the economic losses associated with Hurricane Mitch in Central America.[1]

Likewise, constructing infrastructure without comprehensive planning for service provision can result in the loss of hard-won development gains. Where storm drains are built before refuse pickup has been established, sewers become blocked with trash, often requiring rehabilitation as expensive as the construction of a new system.

Comprehensive urban development strategies that include building codes, land use planning, and zoning will become increasingly critical to determining the best use of vulnerable areas. Local governments will need to play an increasing role in planning processes. Inattention to watershed dynamics can lead to urbanization of slopes without adequately planning for the volume of runoff to be managed during heavy rainfalls. Given the size and unplanned growth of metropolitan areas, this can drastically alter runoff patterns and, by impairing rainfall infiltration, increase the speed of water runoff and related damage.

If disaster *is* taken into account in settlement design, hazard-resistant infrastructure can make dangerous areas safe, and hazard-resistant building techniques can be incorporated into housing programs to protect lives, property, and employment.

The Bank has done a lot to reduce the runoff problem

The study team analyzed all Bank projects to see what the experience has been in providing loans to governments for storm drains. Since 1983, 171 Bank-financed projects supported the construction and/or maintenance of storm drains. Small to medium-size cities have been the most common beneficiaries.

There are complementary areas that may warrant increased attention, however. While storm drains can help lessen urban flooding problems, with seemingly minor imperfections in conception and design they end up exacerbating them. Three main issues were found in analyzing project documents (see box 4.2).

Bank-financed urbanizations would benefit by balancing structural and nonstructural measures, and especially by taking more account of the need for green spaces and trees, to improve the absorption capacity of the soil. Urban utility systems and "lifeline" systems, such as water, electricity, key transport links, and communications can be constructed (especially for hospitals) with local hazard risks in mind so that key facilities will be functional and able to aid victims in the aftermath of a disaster.

Finally, the rapid expansion and siting of slums and squatter settlements where vulnerability is highest has increased the cost and magnitude of urban disasters. In fact, the bulk of the investment that the poor make in their own settlements directly contributes to urban vulnerability. They build where others do not want to—on steep hillsides, near or on landfill sites, at the river's edge, in the wetlands, and in similarly marginal areas. In countries where the poor have moved into areas of water runoff, flash flooding is a major problem. IEG missions have observed that in Brazil, squatters' homes cling to Rio's steep hillsides; in Bangladesh, with nowhere else to go, the poor build their houses over the sea on dangerous

Box 4.2: Storm Drainage Can Exacerbate Flooding If Care Is Not Taken

Storm drains consist of canals or pipes above or below ground that transport excess water from storms and heavy rains into a receiving water body (for example, rivers, lakes, or the sea). Their function is to prevent local flooding and provide safety to surrounding houses and infrastructure, generally increasing the land value of settlements. While storm drainage provides an important service in the context of slum upgrading and flood protection, it may also exacerbate flooding in certain circumstances. Several IEG Project Performance Assessment Reports (PPARs) reveal the following:

Slope stabilization necessary to prevent silt build-up in storm drains. Storm drainage is easily put out of commission by mud and sand in storm runoff that fills and eventually blocks the pipes. Lack of maintenance allows routine rainfalls to destroy the infrastructure investment. The sequencing of service provision is also important. Solid waste can clog drainage whether silt is present or not, and unless waste collection services are provided before storm drainage, some provision for keeping garbage out of the system is essential. Of course, storm drains need regular maintenance and institutions need to be in place to maintain functioning storm drains.

Poor households may opt to illegally use storm drains as sanitary sewers to avoid having to pay sewerage connection fees. This poses health risks, since sewage reaches rivers untreated. It poses even higher health risks during floods, when untreated sewage runs through the streets and sets houses under water.

Design errors can undermine the functioning of storm drains. If storm drains are designed too small, or with the wrong height and slope, storm water may not reach the river. In St. Lucia, for example, contaminated water accumulated a few hundred meters from the outlet of the canal, resulting in a garbage trap that produced odors and encouraged mosquitoes to proliferate a few steps from the main street. Similar problems plagued a Bank-financed system in Sfax, Tunisia. In Turkey, one downtown area faced flooding from an under-dimensioned storm water recipient with hardened concrete banks.

floodplains; in the Philippines, squatters have even built precarious houses within and on top of large storm drainage culverts.

Drainage and Irrigation in Low-Density Areas

Unsustainable agricultural practices are increasing vulnerability in low-density areas. An IEG review (IEG 2002) found that the primary focus of the majority of agriculturally focused water resource projects is on improving in-field soil and water conservation, not on managing watersheds as a whole. Projects often deal with reducing siltation, less often with pollution reduction, and even less frequently (about 5 percent) with integrated water management. Sometimes, the construction of infrastructure may encourage degradation (see box 4.3).

One major difficulty is in linking water development to the Country Assistance Strategy (CAS) agenda. Water sector interventions in CASs are generally subsumed under broader development goals. The explicit valuation of water and recognition of its role in environmental maintenance is fraught with difficulty, leaving it undervalued and unrecognized until there are problems. The IEG water resources study, *Bridging Troubled Waters*, tied decisive action in this area with natural and manmade disasters: "water issues tend to attract political attention mainly for extreme events—Bangladesh's Flood Action Plan, El Niño Emergency Loans for Peru and Bolivia, or the Sudan and Zimbabwe Drought Recovery Credits—or when things go wrong—arsenic in Bangladesh's groundwater and India's Narmada Dam controversy."

Box 4.3: The Construction of Infrastructure Can Speed Degradation

In St. Lucia, only about 6 percent of all available land is considered prime for agriculture. IEG field visits found that, increasingly, farmers have been clearing forests to bring more land under cultivation, moving in the process to steeper, higher land. The government has constructed feeder roads to service these remote areas. This, in turn, encouraged further cultivation in adjacent areas and removed the vegetative cover from the country's most steeply sloping areas. Poor farmers have every incentive to continue degrading the island's steep hillside environment by clearing forests for agriculture, putting the more productive lowlands at risk, while they have no incentives to invest resources or efforts in environmental protections.

Source: IEG 2005a

Flood Control Infrastructure and Natural Drainage Patterns

Rivers and floodplains have long attracted human settlement, agricultural activity, and commerce. These and other human activities have altered the natural flow of rivers. Sometimes major alterations are the result of deliberate river-changing actions. An "unimproved" river flows through plains in large s-loops. Seasonally it swells and inundates the adjacent plains with nutrient-rich sediments. To reduce flooding and to make rivers navigable, river engineers and planners often channelize the flows. They widen and deepen rivers and cut the rivers' loops (meanders) to shorten the time water and ships take to reach the ocean or other bodies of water.[2] Vegetation is also removed from the rivers' edge, and floodplains are deforested, drained, and in parts paved over. These changes can reduce water retention capacity, increase water speed, and make rivers crest at higher levels, since all the water reaches the river at the same time.

Embankments consist of barriers along the river that separate the river from its floodplain. Others protect low-lying coasts. Embankments have enabled people to settle in floodplains, construct houses and infrastructure, and to plant crops on the nutrient-rich soils. While these structures protect people under normal weather conditions, they create a false impression of security. Unusually high water, constrained as it passes by the embankments and a much smaller floodplain, can no longer find the space as it travels along a river to deposit its extra water and sediments. Peak flows from heavy rain and snowmelt can overtop or even breach the embankments, creating damage in the floodplain. Once an area is flooded, standing water is trapped and separated from the river so that it is unable to recede. Therefore, embankments can interfere

Box 4.4: Bangladesh Focusing on Infrastructure-Based Approach to Flooding

Bangladesh contains the world's largest delta, complete with a highly complex system of over 700 rivers, stretching over 24,000 kilometers and covering about 7 percent of the country's surface. The Ganges, Brahmaputra, and Meghna Rivers all flow into Bangladesh, and out to the Bay of Bengal through one main outlet, the Lower Meghna (the world's third-largest river by volume). These rivers have a combined catchment area of 1,758,000 square kilometers. In other words, Bangladesh is dealing with all of the water collected in an area that is more than 12 times the size of the country. It funnels nearly all the runoff of five countries—itself, Bhutan, China, India, and Nepal.

To complicate matters, 95 percent of the total annual water inflow (844,000 million cubic meters) enters the country between May and October. Rainfall in Bangladesh contributes 187,000 million cubic meters to this during the same time period.

The Bangladeshi government opted to use infrastructure-based solutions, including embankments, and compartmentalized land within the embankments, to provide a controlled environment for social and economic development. The government has built over 5,700 kilometers of embankments (over 3,400 kilometers in coastal areas), more than 1,700 flood control/regulating structures, and over 4,300 kilometers of drainage canals over the past three decades.

Notwithstanding, flooding has increased over this time. Major floods (covering more than 30 percent of the land area) all occurred after 1974—in 1974, 1987, 1988, 1998, and 2004. That is a rate of one every six years. Land area affected has increased as well, from 35 percent in 1974 to 60 to 70 percent in 1998 and 2004. This increase, along with a sharp rise in population, has created a situation in which flooding is more likely to result in disaster. Increasing attention to environmental restoration needs to supplement the construction of any new infrastructure.

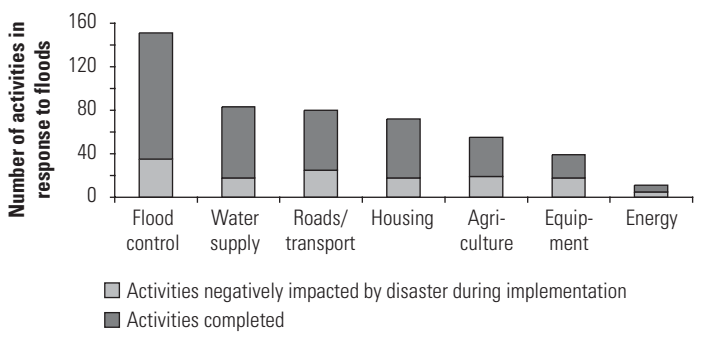
with natural drainage patterns, exacerbating flooding (see box 4.4).[3]

About 31 percent of activities in Bank-financed projects that respond to flooding build flood control structures—both preventative and curative. Top Bank borrowers for floods borrow repeatedly, with some borrowing over 20 times for flooding issues.

A first-order cause for concern is the resiliency of flood control investments. They regularly suffer significant damage from the very type of disaster they are designed to confront—in the Bank-financed work, 23 percent of projects shared this fate (see figure 4.1). The damage almost always was reparable and did not lead to the total loss of the structures in question.[4]

The Bank's experience with flood control infrastructure shows that, at least in cases where governments have no option but to self-insure, the importance of disaster resiliency needs to be stressed more strongly by sector leaders. Of course, no flood control infrastructure will resist when ongoing stakeholder activities in its watershed aggravate the problem the flood control structures were designed to address. Adapted, sustainable, and integrated management of natural resources, including reforestation schemes (particularly those that stabilize embankments), proper land use, and good management of rivers and coastal areas will increase the resilience of flood infrastructure to disasters, and, by extension, better protect the communities they are intended to serve by maintaining conditions as they were or, better, by reversing the prevalent types and trends of environmental degradation.

Figure 4.1: Flood Control Infrastructure Experiences More Flood Damage than Other Flood-Related Infrastructure



Source: IEG data.

Notes

1. Retrieved from: http://www.iadb.org/regions/re2/consultative_group/groups/ecology_workshop_1.ht
2. The Rhine River is one example how channelization contributes to increased flooding. "As a result of channelization projects on the Rhine River, the river was shortened in the braided section by 14 percent and in the meander zone by 37 percent. The loss of 130 km^2 of inundation through the damming up of the Rhine has caused a rise of the extreme flood discharge as well as an increase in flow velocity. Before 1955, the flood peak took a period of 65 hours from Basel to Karlsruhe; since the end of Rhine development in 1977, it takes only 30 hours" (Hunt 2004, p. 141).
3. Comprehensive data on the causes and impacts of flooding are scarce in developing countries. The amount of river channelization that occurs or the measurements of land subsidence are often anecdotal. The data on how much coastal hardening is occurring on any stretch of coastline or along rivers in developing countries is similarly limited. This is surprising, given the number of people affected by flooding and the amount of damage it causes.
4. In this regard, however, their track record was not a great deal worse than those of many other comparable activities. Additional research would be required to understand how significant a problem is involved: this figure only includes damage that occurred during implementation, before the loans closed, and performance over the medium term has not yet been analyzed.

CHAPTER 5

Ecological Issues in Managing Watersheds for Flooding and Storms

Floods are a natural and beneficial part of the ecosystem; they recharge aquifers and invigorate topsoil. Flooding becomes disastrous when more and more people are at risk because they live and work in dangerous areas and when their activities interfere with the working of an ecosystem (construction on wetlands, altered water courses). When precipitation patterns change and when development of an area leads to unsustainable ground and surface water extraction, water scarcity occurs. Infrastructure investments and location of populations, depending on how they are planned, can both set the stage for major losses.

Scientists have found that the risk of large floods with discharges exceeding those formerly considered to be 100-year-level events from basins larger than 200,000 km^2 (hereafter *great floods*) increased substantially during the twentieth century and predict that this trend will increase with rising greenhouse gas emissions and associated global warming.[1] Poorly conceived development investments can exacerbate several types of risk by having an adverse impact on a watershed or otherwise causing unintended increases in overall vulnerability. Some activities that the Bank engages in can have mixed results regarding disaster vulnerability.

Land Use Issues—Deforestation, Desertification, Unsustainable Agriculture, and Water Extraction

Too much and too little water are related, but equally problematic. An early effect of climate change will be potable water shortages in dry areas—a critical issue for many countries that borrow from the World Bank. Freshwater (in the form of runoff or groundwater) represents only 2.5 percent of the world's total water resources.[2] It is also distributed unequally around the world. According to one authority, "about three-quarters of the annual precipitation on our planet descends on areas that contain less than two-thirds of the world's population" (Hunt 2004, p. 42). For example, while the Congo River accounts for some 30 percent of total rainwater runoff in Africa, only 10 percent of the African population lives close enough to the river and its tributaries to make use of its ample resources. Today, more than one billion people live where there is no easily accessible fresh drinking water (Hunt 2004, p. 48). In a warming world, and with precipitation predicted to change regionally, freshwater shortages will increase in many regions where it is already scarce.

Water usage has increased faster than population growth in the past 100 years, making it even more difficult to overcome shortages in some areas (Hunt 2004, p. 40f). In addition, groundwater resources are being depleted through extraction, pollution, and salinization.[3] Along with the problem of decreasing snowmelt (see box 5.1), important freshwater resources are being depleted as well, contributing to more runoff in the short term, but reducing freshwater resources in the longer term.

IEG reviewed the results of the Bank's strategic approach to water resources in *Bridging Troubled Waters* (IEG 2002). The study concluded that groundwater mismanagement has had profound social and environmental impacts in borrower countries. The study showed that little is actually done to reduce inland and downstream risks.

Defined as the loss or continual degradation of forest cover, deforestation has both natural and human causes,[4] but little can be done about the former. Loss of forest habitat due to human

Box 5.1: Reductions in Potable Snowmelt

Temperature increases associated with climate change also increase rates of glacier loss and snowmelt. Where loss falls beyond annual replacement levels, this further contributes to increases in drought and water scarcity. The retreat of glaciers around the world is well documented and snowmelt has been observed to start up to one month earlier than previously (Barnett, Adam, and Lettenmaier 2005). One-sixth of the world's population and one-fourth of the world's GDP are in regions that depend on water from snowmelt and glaciers (Barnett, Adam, and Lettenmaier 2005). As a result of insufficient reservoir capacity in these regions, water is lost to its potential users for good, as runoff takes it through the rivers and to the sea, never to return. The scarcity of water also leads some regions to experience increased incidences of wildfires (Westerling and others 2006; Running 2006; Van Norden 2006).

causes is attributed to agriculture, urban sprawl, livestock grazing, unsustainable forestry practices,[5] mining, and petroleum extraction.

Rates of deforestation (this section is partially based on Chomitz 2007) have been driven up by poverty, as well as a demand for farmland and fuelwood (see box 5.2). If deforestation continues at the rate prevailing at the end of the last century—ranging from 55,000 to 120,000 square kilometers per year[6]— all tropical forests will be destroyed by 2090. Deforestation is continuing at a rapid pace: 130,000 square kilometers a year, according to the Food and Agriculture Organization (FAO), an area the size of Nicaragua (FAO 2006). Almost all of this loss is in the tropics. It imposes a host of local and global damages. In upland watersheds, loss of forests is associated with flash flooding and landslides. Forest loss over large areas may exacerbate chronic flooding.

Fires, used to clear forests for cropland and pasture, are a major source of health-threatening smog and can disrupt transport and industry. According to one estimate (Tacconi 2003), the Indonesian fires of 1997–98 imposed damages of about $700 million. Forest and land fires in Brazil are estimated to affect 39 million people. Deforestation also threatens the survival of many unique plant and animal species—a profound threat that is difficult to express in monetary terms.

It is crucial to recognize the widespread impact of forest loss on the climate. Forests affect the climate in two ways. First, they directly affect the climate by altering wind flows and water-cycling patterns. These effects are poorly understood, but a recent study (Feddema and others 2005) suggests that current patterns of deforestation could disrupt Asian monsoon patterns and boost Brazilian temperatures during this century by 2 degrees Celsius, in addition to the effects from global warming.

Second, tropical deforestation contributes almost twice as much greenhouse gases to the atmosphere as the world's car and truck fleet (Baumert, Herzog, and Pershing 2005), and thus is a major contributor to climate change. It is a profound market and policy failure that farmers continue to clear tropical forest for gains of as little as a few hundred dollars a hectare, while industrial countries are paying up to $10,000 to avoid the same amount of CO^2 emissions that are produced by that hectare's burnt forests (Chomitz 2007).

Floods are generally considered fast-onset disasters, but their root cause may be partly a history of progressive environmental degradation in rural and urban areas. Floods are generally triggered less by heavy rainfall than by the silting up of rivers, the reduced absorptive capacity of soil, flawed infrastructure planning, and inadequate maintenance of existing drainage and flood control facilities. Loss of forest cover and reforestation with inappropriate and/or nonnative species contributes heavily to soil erosion, the deposit of silt in rivers, and overly rapid water runoff. This sets the stage for flash floods and landslides. The unrestrained harvest of firewood accompanies rapid population growth. As pasturage degrades, pastoralists shift from cattle to sheep, and then goats, accelerating the degradation of semiarid ranges and increasing desertification of overgrazed arid lands.

While deforestation is a major issue in Indonesia and elsewhere, it is not found by scientists to increase the number of *great or major* floods.

Box 5.2: 2004 Flooding Affects Haiti and the Dominican Republic Differently

In May 2004, heavy rains inundated the southern part of the Caribbean island of Hispaniola in the border region between the Dominican Republic and Haiti. According to the International Federation of Red Cross and Red Crescent Societies (June 1, 2004), 400 people died in the Dominican Republic from floods and landslide and 274 were missing. Just across the border in the more densely populated Haiti, 1,000 people died and more than 1,600 people were reported missing. According to NASA, "A key factor in the intensity of the destruction is the extensive deforestation within the associated drainage basins and the presence of settlements within the floodplains of rivers."

The hillsides in this southern area of Hispaniola are drought-prone. They have been subject to logging ever since European settlers set foot on the island. The originally forested island was famous for its valuable pine trees, which were exported, while other trees were used for charcoal production. In the Dominican Republic, logging was banned in 1967. However, no such policies were in place on the Haitian side. Thus, viewed from above, the border between the Dominican Republic and Haiti is marked by green pine trees on the Dominican Republic's side, with sparse vegetation and a sudden lack of forest on the Haitian side. While the Dominican Republic retained some 28 percent of its forests, the Haitian side retained only 1 percent.

Source: Diamond 2005.

Small to medium-size floods are exacerbated by a lack of forest cover, but catastrophic floods, they contend, could not be avoided by any amount of forest cover. Major floods take place when the soil simply cannot hold any more water, yet more water comes.[7]

Unsustainable agricultural practices are also increasing vulnerability. An IEG review (IEG 2002) found that poor drainage spoils as much land as new irrigation creates. Desertification is also taking its toll, as improper land use and overexploitation of dryland resources have thrown fragile ecosystems into tumult, affecting one-third of the planet's surface and over a billion people. This has rendered populations more vulnerable to disaster than ever.

Noninfrastructural Approaches to Watershed Management

Borrowers' strong focus on infrastructure as the solution, combined with poor maintenance, leads to an almost constant need for rehabilitation. This common but unsustainable pattern militates for increased investments in noninfrastructural, protective solutions. These can consist of technology, the restoration of natural protections, or the relocation of settlements and facilities to less risky areas, among other measures. Sometimes creative thinking is all that is needed. For example, in a 1995 Yangtze River flood control project in China, several grants were provided to finance risk assessments and what was termed a Decision Support System to improve decision making for the Yangtze River flood operations. A flood risk model was also developed by local staff and international consultants to predict flood levels under the project.

The first real-time test of the Yangtze flood model came during devastating floods in 1996. As it turned out, the model accurately predicted flood levels and the decisions based on this model averted flood damage of $15 million. During floods in 1998 and 1999, the system allowed decision makers to avert millions of dollars more in flood damage. According to people involved in the project, the expenditure of $5 million on nonstructural flood prevention to date has brought a return estimated at more than 1,100 percent and led to an important technology transfer.

Wetlands Protect Their Surroundings

Losing wetlands means losing a buffer against disaster. Swamps, marshes, mangrove forests, bogs, and similar wetland areas intermediate between the mainland and open water bodies. Counterintuitively, softer coastlines often provide the best available protection at the lowest cost. Because wetlands are spongy and support a wide variety of plant life, they reduce the risk of flooding,[8] reduce the energy of waves, and trap sediments. As an added benefit, they also purify the water that flows through them.

Wetlands also provide moisture to the atmosphere that returns as rainfall. Worldwide, there are between 748 and 778 million hectares of wetlands.[9] However, 50 percent of wetlands have been lost over the past century due to land use changes, such as draining wetlands for agriculture, channelizing rivers, and turning floodplains into aquaculture zones.[10]

Loss of mangroves is particularly felt in coastal areas, where storms and storm surges are no longer met by these energy-absorbing buffers. Not only do the mangroves offer this natural protection, but they also trap runoff long enough for it to drop sediments, provide nesting areas for fish and crustaceans, and prevent coastal erosion. Since 1980, the world has lost 5 million hectares of mangroves (from 19.8 million hectares in 1980 to 15 million hectares in 2005 due to conversion of mangroves into aquaculture ponds, settlements, rice fields, and tourist resorts). South and Southeast Asia have experienced particularly dramatic losses due to aqua farming and other causes (see box 5.3) (Primavera 2005).

Wetlands and Mangroves Figure Largely in the Bank's Portfolio

To learn more about how the Bank's work is impacting wetlands and mangroves, appraisal documents for projects approved between 1983 and 2006 were analyzed.[11] A total of 329 projects (6 percent) were found to address one or both issues: 241 project appraisal documents discussed wetlands and 113 projects discussed the preservation or restoration of coastal mangroves (replanting).

Within Bank projects, attention to wetlands and mangroves has been steadily increasing during the review period (since 1983) (see figure 5.1). The number of projects that address these fragile ecosystems peaked (at least temporarily) between 1992 and 2003. The increased attention to wetlands can probably be explained by the adoption of environmental safeguard policies OP 4.00 in 1989 and OP 4.01 (1991 on environmental assessment), which stipulate the identification of potential impacts to wetlands during the environmental screening process. Since the adoption of environmental safeguards, task managers have paid a great deal of attention to wetlands, both along rivers and lakes and along the coast. The study did not find an explanation for the precipitous drop in the last four years.

Task managers had an additional concern in preserving and protecting wetlands—the Bank is signatory to the Ramsar Convention on Wetlands.[12] The 1983 Indonesia Second Provincial Irrigation Development Project justified its attention to mangrove preservation by noting the critical role that mangroves play as a source of food for coastal fish and shrimp. Project documents also call for strict monitoring and control of the use of pesticides to prevent toxic agricultural drainage effluents from reaching these critical feeding and breeding grounds.

While the preservation of wetlands is important, the reforestation of mangroves and the reclamation of wetlands warrant a higher priority, given that 50 percent of wetlands have been lost over the past century. The borrowers and the Bank agreed to replant mangroves and to expand wetlands in 40 projects (about 12 percent of the 329 projects identified).

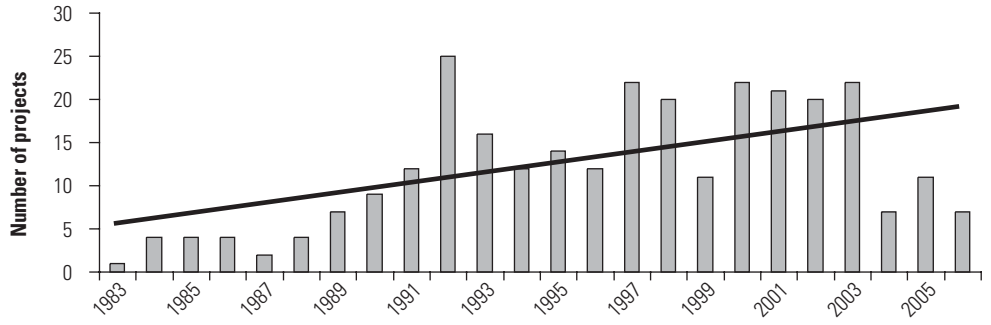
The 2002 Bulgaria Wetlands Restoration and Pollution Reduction Project represents good

Box 5.3: Shrimp and Fish Culture Raise Vulnerability

In 1992, the World Bank funded a shrimp and fish culture project in three Indian states (Andhra Pradesh, Orissa, and West Bengal). The Bank committed $85.0 million in order to alleviate poverty through employment creation at shrimp and fish farms. Mangrove forests were depleted to make space for shrimp farms. When cyclones hit the newly denuded coast, however, they found little resistance. And a significant part of the investment was lost. Two cyclones, one in Andhra Pradesh in 1997, and one in Orissa in 1999, destroyed the newly constructed sites for shrimp farming completely. In addition to the risk from hurricanes, shrimp farms, while clearly having some economic benefits, also breed fish and shrimp diseases, and cause the salinization of soil and fresh water, as well as coastal pollution due to wastes and unused food nutrients.

Source: IEG data.

Figure 5.1: Bank Focus on Wetlands and Mangroves Peaked Between 1992 and 2003



Source: IEG data.

practice, as far as can be determined by desk work. The project helped local communities and local authorities to demonstrate the use of wetlands as nutrient sinks, thus ameliorating to a small degree the pollution problems of the Danube River and Black Sea. The project also helped to conserve Bulgaria's globally significant biodiversity, and it demonstrated how ecologically sustainable agricultural activities can improve livelihoods.

The desk-based evaluation of Bank work with wetlands is challenged by the imbalance between lavish upstream attention and the lack of downstream reporting. During preparation, the Bank and the borrower discuss potential harm to wetlands and mangroves, as well as to endangered plant and animal species in these areas. Sixty-eight projects discussed potentially negative impacts of Bank-funded projects on wetlands and mangroves in the appraisal documents. By the time projects close, however, self-evaluation reports tend to be silent about project achievements in this area and they rarely pay any attention to the project's negative or unanticipated effects on these fragile ecosystems.

Notes

1. See Milly and others 2002, p. 514. Milly and others (2002) investigated risks of great floods—that is, floods with discharges exceeding 100-year levels from basins larger than 200,000 km^2—using both stream flow measurement and numerical simulations of the anthropogenic climate change associated with greenhouse gases and direct radiative effects of sulphate aerosols. What may be true for great floods does not seem to hold for smaller floods. For example, Kundzewicz and others (2004) analyzed information from 195 rivers, primarily in North America, Australia, the Pacific, and Europe. They examined information on extreme daily flows. According to the observed increases in precipitation, river flooding was expected to increase. However, Kundzewicz and others did not find a global increase in flooding. What they found was that instances of daily flow maxima increased regionally—for example, in Europe.
2. "The Earth contains a total of about 1.385 billion km of water; of this, approximately 35 million km, or 2.5 percent, is freshwater" (Hunt 2004, p. 41).
3. "When the natural equilibrium is disturbed by human activities such as over pumping (i.e., more water is taken away from the aquifer than is replenished by precipitation), the saline water body will move inland, replacing the depleted fresh water—with the progress of the interface determined mainly by the pumping rate" (Munasinghe 1990).
4. "Natural deforestation can be linked to tsunamis, forest fires, volcanic eruptions, glaciation and desertification." Retrieved on May 12, 2006 http://en.wikipedia.org/wiki/Deforestation
5. Logging and heavy grazing alone can reduce vegetation enough to increase erosion.
6. Between 1960 and 1990.
7. For more information see Kaimowitz 2005; Bonell and Bruijnzeel 2005; and FAO, CIFOR 2005.
8. "When precipitation and runoff are stored in wetlands and flood flow velocity is reduced, the timing and magnitude of flood peaks is altered.

This can lead to a more stable biological community downstream" (Hunt 2004, p. 27).

9. Retrieved on September 29, 2006 from: http://www.iucn.org/en/news/archive/2006/02/02_wetlands_day.htm
10. Retrieved on September 29, 2006 from: http://www.iucn.org/en/news/archive/2006/02/02_wetlands_day.htm Also see Bogena and others 2004.
11. Bank data show that 6,108 projects were approved between 1983 and 2006. IEG analyzed 5,804 project appraisal documents (Staff Appraisal Reports, Project Appraisal Documents, and Reports of the President) approved between 1983 and 2006. The remaining 304 documents were not available in ImageBank. A total of 329 projects (or 6 percent) considered wetlands (241 projects) and/or mangrove forests (113 projects).
12. By preserving wetlands, the Bank supports the Ramsar Convention on Wetlands, signed in Ramsar, Iran, in 1971, which currently lists 1,634 wetland sites totaling 145.6 million hectares in the Ramsar List of Wetlands of International Importance. Retrieved on December 13, 2006 from: http://www.ramsar.org

Chapter 6
Implications for the Bank

Climate Change and Sea Level Rise

With flooding and tropical storm disasters on the rise, countries would be well advised to consider increases in their protective investments. Unfortunately, while the Bank is lending for investments that reduce vulnerability, those loans have mostly focused on the reconstruction of infrastructure when environmental restoration may have been more strategically appropriate. More troublesome, even when infrastructure is the solution, what is being built by the borrowers is not a significant step forward because international assistance is being used simply to repair what was there already, and the institutions necessary to take charge of maintenance and management too often are not in place. This report has shown clearly that much publicly financed infrastructure is not holding up when weather-related disasters occur.

The degree to which climate change, itself a contributing factor in the increase in natural disasters, has been helping to accelerate the effects of disasters is not yet adequately understood. Nonetheless, former Bank chief economist Sir Nicholas Stern argues that, as a result of climate modification, the world is increasingly likely to experience major disruptions to economic and social activity on a scale similar to that associated with the great wars and the economic depression of the first half of the twentieth century.

Climate change theory and modeling predict that as the oceans become warmer, the power of tropical storms will increase (Emanuel 2005). Scientists have documented a more than doubling in tropical storm intensity in the North Atlantic and western North Pacific (Emanuel 2005). The National Center for Atmospheric Research and others have also observed an increase in the number and intensity of category four and five tropical storms (Webster and others 2005).

What impact will this have on flooding? Not surprisingly, total land precipitation in equatorial regions and high latitudes in the Northern Hemisphere is also increasing.[1] Increases are region-specific, however. Wet areas are becoming wetter and dry areas are becoming drier. The El Niño-Southern Oscillation, which appears to have increased in intensity and frequency, is a major driver behind observed changes, bringing more intense rain for some regions and severe droughts for others (Dore 2005, p. 1168).

Melting ice has led to a rise in sea levels that has contributed to an increase in flooding in coastal areas.[2] Not all of the observed increase is a function of receding ice caps of Antarctica and Greenland, however. Water expansion also occurs when ocean temperatures increase, although this phenomenon contributes less than half of the rise.[3] As noted, a percentage of the observed sea-level rise is due to the addition of water to the oceans from the melting of land ice.[4]

Sea-level rise has been identified as the most important factor leading to accelerating rates of coastal erosion (Zhang, Douglas, and Leatherman 2004, p. 55). While it is a slow process, the consequences of the possible 2 meter rise by the end of the twenty-first century[5] will affect the more than 100 million persons living within one meter altitude of mean sea level, not to mention the several hundreds of millions more that may be living there by then (Zhang, Douglas, and Leatherman 2004, p. 41). Bangladesh, China, and India have large low-lying and densely populated areas and one-quarter of Africa's population lives in coastal zones.[6]

Delta areas are especially vulnerable because they are made from loosely packed sediment and they rarely rise more than a few meters above sea level. They are prone to flooding from storm surges and also from river overflow. The scope of the problem is large: the 40 largest deltas of the world are home to about 300 million people. According to current predictions, by 2050 one million people living in the Ganges-Brahmaputra-Meghna delta in Bangladesh, the Mekong delta in Vietnam, and the Nile delta in Egypt will be directly affected by sea-level rise (Ericson and others 2006, p. 78). More broadly, the modeling that has been done suggests that storm surges and sea-level rise will affect developing countries disproportionately.

While the latest IPCC report predicts a range of 0.18 to 0.59 meters in sea level rise this century, some scientists caution that there are many aspects of sea level rise that are still poorly understood, including factors affecting the potential catastrophic collapse of ice sheets in Greenland and Antarctica (Kerr 2007). Hence policy making needs to take into consideration a small but salient probability of extreme outcomes. A forthcoming IEG study will look in more depth at climate change issues.

Reducing Vulnerability to Natural Disasters May Help with Adapting to Climate Change

As this report has shown, there are sometimes very effective nonstructural ways to reduce vulnerability. And even when it is possible to increase resiliency by building additional new protective infrastructure, the Bank and its borrowers often just repair decaying infrastructure that either was not designed well enough, was not well sited, did not take into account stakeholder needs, or was not maintained.

For the most vulnerable borrowers, emergencies of a scale that require international assistance can be nearly an annual occurrence. This implies that mitigation measures promoted by development institutions need to increase the attention they give to protecting country investments and protecting people and designing interventions that do not worsen the situation. But at the same time, they need to include in their calculus that people may not just be potential victims of disasters, but the cause of them as well (see box 1.2).

With more and more people settling in fragile areas, the level of social, environmental, and economic vulnerability to natural disaster is rising rapidly. This heightened vulnerability, combined with the increasing intensity of hydrometeorological hazards, can be expected to have strong impacts in the future. The good news is that for countries that have not yet adapted to rainfall variability, the same actions that reduce vulnerability to disaster also help with adaptation to climate change.

Findings of this Review

The review of Bank-financed development actions in the face of tropical storms and flooding suggests some preliminary conclusions that will need to be further examined in subsequent, more detailed evaluative work. Among the findings are the following:

- *It is easier to design infrastructure to reduce vulnerability than to reverse degradation.* Of course, underdimensioned or poorly sited actions taken to reduce disasters exacerbate them, but even well-designed infrastructure is not always a solution. Adaptation to climate change and reduction of vulnerability to natural disasters are essentially the same thing, especially for those countries that have not yet managed to cope with rainfall variability. In many instances long-term, maintenance-free sustainability requires environmental restoration.
- *Protecting human settlements against floods and tropical storms requires development strategies that include building codes and land use planning.* This is a particularly strong need in urban areas, where zoning is most appropriate. The nature of losses in rural areas is very different and requires approaches tailored to prevailing economic activities.
- *Measures to reduce vulnerability to storms and floods need to be taken in all appropriate sectors.* Ministries of environment and na-

tional disaster agencies are often weak. Hence it is important to engage other ministries in the work of vulnerability reduction. For example, the staff of the Ministry of the Environment cannot set out to build watershed-friendly roads. They have never built a road. Local governments also will need to play an increasingly larger role in planning processes.

- *Flooding and tropical storms are commonly transboundary problems and may require regional or global solutions.* The sensible management of disaster-related problems has varied scales, and points of intervention also vary. When the problem is transborder in nature, the solution needs to be as well.
- *The poor are most at risk and most affected by degradation and disasters.* But before identifying solutions, it is important to check whether they may also be contributing to the degradation. When they are, the solutions often have a livelihoods dimension. In many cases the people raising the disaster vulnerability of an area benefit economically by doing so.
- *Women do not have the same vulnerability profile as men.* Only one woman for every three men survived the flooding following the December 2004 tsunami in one district in Aceh. In two other districts, females accounted for nearly 80 percent of deaths. Evidence on women's deaths greatly outnumbering men's also can be found in studies of the flooding that followed the 1991 Bangladesh cyclone. Because of their place in society and the role they play (food for the family, water and firewood collection, agriculture) women are the most affected by changes in the environment and vulnerability levels. There is some evidence, however, that they are more likely than men to organize at the community level to limit their risk.
- *Land that has important environmental purposes provides large public, but few private, benefits.* Sometimes the source of a problem is found in places distant from where its impacts are felt. Governments have generally been unable to assert ownership or control of environmentally sensitive zones against population pressure from the poor or land grabs by the rich and well-connected.

Notes

1. The IPCC (2001) noted a statistically significant increase in land precipitation of the middle and high latitudes, primarily in the Northern Hemisphere, over the twentieth century. According to the Technical Summary of the IPCC (2001): "Overall, it is likely that for many mid and high latitude areas, primarily in the Northern Hemisphere, statistically significant increases have occurred in the proportion of total annual precipitation derived from heavy and extreme precipitation events; it is likely that there has been a 2 to 4 percent increase in the frequency of heavy precipitation events over the latter half of the 20th century." Retrieved on August 18, 1005 from: http://www.grida.no/climate/ipcc_tar/wg1/pdf/WG1_TAR-FRONT.PDF
2. Alley and others find that over the last century, "sea level rose ~1.0 to 2.0 mm/year, with water expansion from warming contributing 0.5 + 0.2 mm […] and the rest from the addition of water to the oceans […] due mostly to melting of land ice" (Alley and others 2005, p. 456).
3. Water expansion from warming contributes 0.5 to 0.2 mm to sea-level rise, (Alley and others 2005, p. 456).
4. It was also found that past changes in atmospheric CO_2 were correlated with global sea levels. (Alley and others 2005, p. 456).
5. Anthoff and others 2006. The work was prepared for the *Stern Review on the Economics of Climate Change.*
6. Nyong 2005, p. 13: "40 percent of the population of West Africa lives in coastal cities and it is expected that the coast between Accra (Ghana) and the Niger delta (about 500 km) become a continuous urban megalopolis with more than 50 million people by 2020 (Hewawasam 2002). The shoreline of East Africa (11,000 km long) is occupied by 30 to 35 million people. By 2015, three megacities with at least 8 million people will be present in coastal Africa (Lagos, Kinshasa and Cairo) (Klein and others 2002). These characteristics explain the main problems encountered in the coastal zone, mainly pollution, resource and land use conflicts, overexploitation of ecosystems and species." http://www.stabilisation2005.com/Tony_Nyong.pdf

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