LECTURE NOTES

ON

DISASTER MANAGEMENT

III B. Tech II semester

AUTONOMOUS

Mr. Gude Ramakrishna

Associate Professor

ELECTRICAL AND ELECTRONICS ENGINEERING

INSTITUTE OF AERONAUTICAL ENGINEERING

DUNDIGAL, HYDERABAD - 500 043

INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

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ELECTRICAL AND ELECTRONICS ENGINEERING

COURSE LECTURE NOTES

Course Name	**DISASTER MANAGEMENT**
Course Code	**ACE551**
Programme	**B.Tech**
Year	**2019-2020**
Semester	**VI**
Course Coordinator	**Mr. Gude Ramakrishna, Associate Professor**
Course Faculty	**Mr. Gude Ramakrishna, Associate Professor, CE** **Mr. S.Siva Ramkrishna, Assistant Professor, CE** **Mr. S.Selva Prakash, Assistant Professor, CE** **Mr. G.N.V.Sai Teja, Assistant Professor, CE** **Ms. N. Sri Ramya, Assistant Professor, CE** **Mr..J.Tirupathi, Assistant Professor, CSE**

COURSE OBJECTIVES:

I.Identify the major disaster types and develop an understanding of modern disaster management.
II. Recognize and develop awareness of the chronological phases of natural disaster response and refugee relief operations.
III. Understand the key concepts of disaster management related to development and the relationship of different disaster management activities..
IV. Categorize the organizations that are involved in natural disaster assistance and relief system.
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COURSE OUTCOMES:

I. Describe the concept of environmental hazards and disasters: meaning of environmental hazards, environmental disasters and environmental stress; concept of environmental hazards.
II. Types of environmental hazards and disasters: Natural hazards and disasters.
III. Understand the concept of endogenous hazards, volcanic eruption, earthquakes, landslides, volcanic hazards/ disasters, causes and distribution of volcanoes,
IV. Categorize the organizations that are involved in natural disaster assistance and relief system
V. Understand the concept ofEmerging approaches in disaster management i.e pre, disaster stage (preparedness),emergency stage and post disaster stage, rehabilitation.
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COURSE LEARNING OUTCOMES (CLOs):

CLOCode	Description
ACE551.01	Integrate knowledge and to analyze, evaluate and manage the different public health aspects of disaster events at a local and global levels, even when limited information is available.
ACE551.02	Analyze and evaluate the environmental, social, cultural, economic, legal and organizationalAspects influencing vulnerabilities and capacities to face disasters. and to know about different types of environmental hazards
ACE551.03	Obtain knowledge on different types of natural and man- made disasters. Work theoretically and practically in the processes of disaster management (disaster risk reduction, response,and recovery)
ACE551.04	Describe endogenous and exogenous hazards their harmful effects to the environment. Case studies of India

CLOCode	Description
ACE551.05	Analyze, and communicate information on risks, relief needs and order to formulate strategies for mitigation.
ACE551.06	Understand the Mitigation and control measures of exogenous hazards.
ACE551.07	Understand different approaches of different phases
ACE551.08	Capacity to analyze and evaluate research work on the field of emergencies and disaster.
ACE551.09	Demonstrating insight into the potential and limitations of science, its role in society and people's responsibility for how it is used. And emerging approaches of disasters.
ACE551.10	Analyze the future scenarios with the ability to clearly present and discuss their conclusionsand the knowledge and arguments.
ACE551.11	Understand integrated approach for disaster preparedness, mitigation & awareness;Mitigation.
ACE551.12	Understand different types of institution for disaster mitigation and management
ACE551.13	Design and perform research on the different aspects of the emergencies and disaster.
ACE551.14	Design and perform research on the different aspects of the emergencies and disaster
ACE551.15	Understand different approaches to prevent disasters.
ACE551.16	Understanding the race process of dealing with work place hazards.
ACE551.17	Obtain knowledge on dentification of natural calamities that tends to hazards and disasters.

I. SYLLABUS

Unit-I	ENVIRONMENTAL HAZARDS AND DISASTERS
Meaning of Environmental hazards, Environmental Disasters and Environmental stress. Concept of Environmental Hazards, Environmental stress &Environmental Disasters. Different approaches & relation with human Ecology. Landscape Approach - Ecosystem Approach -Perception approach- Human ecology & its application in geographical researches.	
Unit-II	**TYPES OF ENVIRONMENTAL HAZARDS AND DISASTERS**
Man induced hazards & Disasters Natural Hazards- Planetary Hazards/ Disasters - Extra Planetary Hazards/ disasters–Planetary Hazards-Endogenous Hazards - Exogenous Hazards.	
Unit-III	**ENDOGENOUS HAZARDS**
Endogenous Hazards - Volcanic Eruption Earthquakes - Landslides - Volcanic Hazards/ Disasters - Causes and distribution of Volcanoes - Hazardous effects of volcanic eruptions - Environmental impacts of volcanic eruptions - Earthquake Hazards/ disasters - Causes of Earthquakes - Distribution of earthquakes - Hazardous effects of - earthquakes - Earthquake Hazards in India - Human adjustment, perception & mitigation of earthquake.	
Unit-IV	**EXOGENOUS HAZARDS**
Hazards/ Disasters- Man induced Hazards /Disasters- Physical hazards/ Disasters-Soil Erosion.	
Unit-V	**EMERGING APPROACHES IN DISASTER MANAGEMENT**
Emerging approaches in Disaster Management. Three Stages 1. Pre, disaster stage (preparedness) 2. Emergency Stage 3. Post Disaster stage, Rehabilitation.	
Text Books:	
1. Pardeep Sahni, "Disaster Mitigation: Experiences and Reflections", PHI Learning Pvt. Ltd., 1 st Edition, 2001. 2. J. Glynn, Gary W. Hein Ke, "Environmental Science and Engineering", Prentice Hall Publishers, 2 nd Edition, 1996.	
Reference Books:	
1. R.B.Singh (Ed), "Environmental Geography", 2 nd Edition, 1990. 2. R.B. Singh (Ed), "Disaster Management", 2 nd Edition, 2006.	

UNIT-1

Environmental hazard' is the state of events which has the potential to threaten the surrounding natural environment and adversely affect people's health. This term incorporates topics like pollution and natural disasterssuch as storms and earthquakes. Hazards can be categorized in five types:

1. Chemical
2. Physical
3. Mechanical
4. Biological
5. Psychosocial

What are chemical hazards and toxic substances?

Chemical hazards and toxic substances pose a wide range of health hazards (such as irritation, sensitization, and carcinogenicity) and physical hazards (such as flammability, corrosion, andreactivity).

This page provides basic information about chemical hazards and toxic substances in the workplace. While not all hazards associated with every chemical and toxic substance are addressed here, we do provide relevant links to other pages with additional information about hazards and methods to control exposure in the workplace.

A **natural disaster** is a major adverse event resulting from natural processes of the Earth; examples include floods, volcanic eruptions, earthquakes, tsunamis, and other geologic processes. A natural disaster can cause loss of life or property damage, and typically leaves some economic damage in its wake, the severity of which depends on the affected population's resilience, or ability torecover.[1]

An adverse event will not rise to the level of a disaster if it occurs in an area without vulnerable population.[2][3][4]In a vulnerable area, however, such as San Francisco, an earthquake can have disastrous consequences and leave lasting damage, requiring years to repair.

In 2012, there were 905 natural catastrophes worldwide, 93% of which were weather-related disasters. Overall costs were US$170 billion and insured losses $70 billion. 2012 was a moderate year. 45% were meteorological (storms), 36% were hydrological (floods), 12% were climatologically (heat waves, cold waves, droughts, wildfires) and 7% were geophysical events (earthquakes and volcanic eruptions). Between 1980 and 2011 geophysical events accounted for 14% of allnatural

Avalanches

During World War I, an estimated 40,000 to 80,000 soldiers died as a result of avalanches during the mountain campaign in the Alps at the Austrian-Italian front, many of which were caused by artillery fire.[6]

Earthquakes

An **earthquake** is the result of a sudden release of energy in the Earth's crust that creates seismic waves. At the Earth's surface, earthquakes manifest themselves by vibration, shaking and sometimes displacement of the ground. The vibrations may vary in magnitude. Earthquakes are caused mostly by slippage within geological faults, but also by other events such as volcanic activity, landslides, mine blasts, and nuclear tests. The underground point of origin of the earthquake is called the *focus*. The point directly above the focus on the surface is called the *epicenter*. Earthquakes by themselves rarely kill people or wildlife. It is usually the secondary events that they trigger, such as building collapse, fires, tsunamis (seismic sea waves) and volcanoes, that are actually the human disaster. Many of these could possibly be avoided by better construction, safety systems, early warning andplanning.

Volcaniceruptions

Volcanoescan cause widespread destruction and consequent disaster in several ways.The effects include the volcanic eruptionitself that may cause harm following the explosion of the volcano or the fall of rock. Second, lavamay be produced during the eruption of a volcano. As it leaves the volcano, the lava destroys many buildings and plants it encounters. Third, volcanic ashgenerally meaning the cooled ash - may form a cloud, and settle thickly in nearby locations. When mixed with water this forms a concrete-like material. In sufficient quantity ash may cause roofs to collapse under its weight but even small quantities will harm humans if inhaled. Since the ash has the consistency of ground glass it causes abrasion damage to moving parts such as engines. The main killer of humans in the immediate surroundings of a volcanic eruption is the pyroclastic flows, which consist of a cloud of hot volcanic ash which builds up in the air above the volcano and rushes down the slopeswhen the eruption no longer supports the lifting of the gases. It is believed that Pompeiiwas destroyed by a pyroclastic flow. A laharis a volcanic mudflow or landslide. The 1953 Tangiwai disasterwas caused by a lahar, as was the 1985 Armero tragedyin which the town of Armero was buried and an estimated 23,000 people were killed.

A specific type of volcano is thesupervolcano. According to theToba catastrophe theory75,000 to 80,000 years ago a super volcanic event atLake Tobareduced the human population to 10,000 or even 1,000 breeding pairs creating a bottleneck in human evolution.[8]It also killed three quarters of all plant life in the northern hemisphere. The main danger from a supervolcano is the immense cloud of ash which has a disastrous global effect on climate and temperature for manyyears.

Hydrologicaldisasters

It is a violent, sudden and destructive change either in quality of earth's water or in distribution or movement of water on land below the surface or in atmosphere.

Floods

A **flood** is an overflow of an expanse of water that submerges land.[9]The EU Floodsdirectivedefines a flood as a temporary covering by water of land not normally covered by water.[10]In the sense of "flowing water", the word may also be applied to the inflow of the tide. Flooding may result from the volume of water within a body of water, such as a riveror lake,which overflows or breaks levees, with the result that some of the water escapes its usual boundaries.[11]While the size of a lake or other body of water will vary with seasonal changes in precipitation and snow melt, it is not a significant flood unless the water covers land used by man like a village, city or other inhabited area, roads, expanses of farmland,etc.

Limnic eruptions

A cow suffocated by gases from Lake Nyosafter a limnic eruption

A limnic eruptionoccurs when a gas, usually CO_2, suddenly erupts from deep lake water, posing the threat of suffocating wildlife, livestock and humans. Such an eruption may also cause tsunamisin the lake as the rising gas displaces water. Scientists believe landslides,volcanicactivity, or explosions can trigger such an eruption. To date, only two limnic eruptions have been observed andrecorded:

Tsunami

Tsunamis can be caused by undersea earthquakes as the one caused by the 2004 Indian Ocean Earthquake, or by landslides such as the one which occurred at Lituya Bay, Alaska.

- The 2004 Indian Ocean Earthquake created theBoxing DayTsunami.
- On March 11, 2011, atsunami occurred near Fukushima, Japanand spread through the Pacific.

Meteorologicaldisasters

Blizzards

Blizzards are severe winter stormscharacterized by heavy snow and strong winds. When high winds stir up snow that has already fallen, it is known as a ground blizzard. Blizzards can impact local economic activities, especially in regions where snowfall is rare.

Significant blizzards include:

- TheGreat Blizzard of 1888in the United States in which many tons of wheat crops were destroyed.
- The2008 Afghanistanblizzard
- TheNorth American blizzard of1947
- The1972 Iran blizzardresulted in approximately 4,000 deaths and lasted for 5 to 7days.

Cyclonic storms

Tropical Cyclones

Cyclone, *tropical cyclone*, *hurricane*, and *typhoon* are different names for the same phenomenon a cyclonic storm system that forms over the oceans. The deadliest hurricane ever was the 1970 Bhola cyclone; the deadliest Atlantic hurricane was theGreat Hurricane of1780which devastated Martinique, St. Eustatius and Barbados. Another notable hurricane is Hurricane Katrinawhich devastated the Gulf Coast of the United States in2005.

Extra tropical Cyclones

Extratropical cyclones, sometimes called mid-latitude cyclones, are a group of cyclones defined as synoptic scale low pressure weather systems that occur in the middle latitudes of the Earth (outside the tropics) not having tropical characteristics, and are connected with fronts and horizontal gradients in temperature and dew point otherwise known as "baroclinic zones". As with tropical cyclones, they are known by different names in different regions (Nor'easter, Pacific Northwest windstorms, European windstorm, East Asian-northwest Pacific storms, SudestadaandAustralian east coast cyclones). The most intense extratropical cyclones cause widespread disruption and damage to society, such as the storm surge of the North Sea flood of 1953which killed 2251 people in the Netherlands and eastern England, the Great Storm of 1987which devastated southern England and France and the Columbus Day Storm of 1962which struck the PacificNorthwest.

Droughts

Drought is unusual dryness of soil, resulting in crop failure and shortage of water for other uses, caused by significantly lower rainfall than average over a prolonged period. Hot dry winds, high temperatures and consequent evaporation of moisture from the ground can contribute to conditions of drought.

Well-known historical droughtsinclude:

- 1900 India killing between 250,000 to 3.25million.
- 1921–22 Soviet Union in which over 5 million perished from starvation due todrought
- 1928–30 Northwest China resulting in over 3 million deaths byfamine.
- 1936 and 1941 Sichuan Province China resulting in 5 million and 2.5 million deaths respectively.
- The 1997–2009Millenium Droughtin Australian led to a water supply crisis across much of the country. As a result many desalination plants were built for the first time (seelist).
- In 2006, Sichuan Province China experienced its worst drought in modern times with nearly 8 million people and over 7 million cattle facing watershortages.
- 12-year drought that was devastating southwest Western Australia, southeast South Australia, Victoria and northern Tasmania was "very severe and without historical precedent".

- In 2011, the State ofTexaslived under a drought emergency declaration for the entire calendar year. The drought caused theBastropfires.

Hailstorms

Hailstorms are falls of rain drops that arrive as ice, rather than melting before they hit the ground. A particularly damaging hailstorm hit Munich, Germany, on July 12, 1984, causing about 2 billion dollars in insuranceclaims.

Heat waves

A heat wave is a period of unusually and excessively hot weather. The worst heat wave in recent history was the European Heat Wave of 2003.

A summer heat wave in Victoria, Australia, created conditions which fuelled the massivebushfiresin 2009.Melbourneexperienced three days in a row of temperatures exceeding 40°C (104°F) with some regional areas sweltering through much higher temperatures. The bushfires, collectively known as "Black Saturday", were partly the act of arsonists.

The 2010 Northern Hemisphere summerresulted in severe heat waves, which killed over 2,000 people. It resulted in hundreds of wildfires which causing widespread air pollution, and burned thousands of square miles of forest.

Heat waves can occur in the ocean as well as on land with significant effects (often on a large scale) e.g. coral bleaching.

Tornadoes

An exceptionally clearly developed single-cell Cumulonimbus incusBig displaying the classic anvil shape; associated gusts may occur from the direct proximity to several times the height of the cloud.

A tornadois a violent, dangerous, rotating column of air that is in contact with both the surface of the earth and a cumulonimbus cloudor, in rare cases, the base of cumulus. It is also referred to as a *twister* or a *cyclone*,[12]although the word cyclone is used in meteorology in a wider sense, to refer to any closed pressure circulation. Tornadoes come in many shapes and sizes, but are typically in the form of a visible condensation funnel, whose narrow end touches the earth and is often encircled by a cloud of debrisand dust. Most tornadoes have wind speeds less than 110 miles per hour (177 km/h), are approximately 250 feet (80 m) across, and travel a few miles (several kilometers) before dissipating. The mostextremetornadoes can attain wind speeds of more than 300 mph (480 km/h), stretch more than two miles (3 km) across, and stay on the ground for dozens of miles (perhaps more than 100km).

Well-known historical tornadoes include:

- TheTri-State Tornadoof 1925, which killed over 600 people in the UnitedStates;
- TheDaulatpur-Saturia Tornadoof 1989, which killed roughly 1,300 people in Bangladesh.

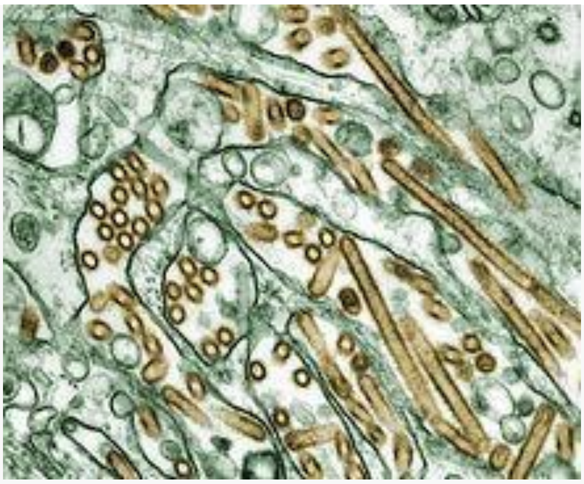
Wildfires

Wildfires are large fires which often start in wild land areas. Common causes include lightning and droughtbut wildfires may also be started by human negligence or arson. They can spread to populated areas and can thus be a threat to humans and property, as well aswildlife.

Notable cases of wildfires were the 1871 Peshtigo Firein the United States, which killed at least 1700 people, and the 2009Victorian bushfiresin Australia.

Healthdisasters

Epidemics



The A H5N1 virus, which causes Avian

An epidemicis an outbreak of a contractible diseasethat spreads through a human population. A pandemicis an epidemic whose spread is global. There have been many epidemics throughout history, such as the Black Death. In the last hundred years, significant pandemicsinclude:

- The 1918Spanish flupandemic, killing an estimated 50 million people worldwide
- The 1957–58Asian flupandemic, which killed an estimated 1 millionpeople
- The 1968–69Hong Kong water flupandemic
- The 2002-3SARSpandemic
- TheAIDSpandemic, beginning in1959
- TheH1N1 Influenza(Swine Flu) Pandemic2009–2010

Other diseases that spread more slowly, but are still considered to be global health emergencies by the WHO, include:

Spacedisasters

Fallen trees caused by the Tunguska meteoroid of the Tunguska in June 1908.

Impactevents

One of the largest impact eventsin modern times was the Tunguska eventin June 1908.

Solar flare

A solar flare is a phenomenon where the sun suddenly releases a great amount of solarradiation, much more than normal. Some known solar flares include:

- An X20 event on August 16,1989[16]
- A similar flare on April 2,2001[16]
- The most powerful flare ever recorded, on November 4, 2003, estimated at between X40 andX45
- Themost powerful flare in the past 500 yearsis believed to have occurred in September 1859

Gamma-ray burst

Gamma-ray bursts (**GRBs**) are flashes of gamma raysassociated with extremely energetic explosions that have been observed in distant galaxies. They are the brightestelectromagneticevents known to occur in the universe.[19]Bursts can lastfrom ten milliseconds to several minutes. The initial burst is usually followed by a longer-lived "afterglow" emitted at longer wavelengths

(X-ray, ultraviolet, optical, infrared, microwaveand radio).

All the bursts astronomers have recorded so far have come from distant galaxies and have been harmless to Earth, but if one occurred within our galaxy and were aimed straight at us, the effects could be devastating. Currently orbiting satellites detect an average of about one gamma-ray burst per day. The closest known GRB so far was GRB 031203.

UNIT-2

A **natural disaster** is a major adverse eventresulting from natural processesof the Earth; examples include floods, volcanic eruptions, earthquakes, tsunamis, and other geologic processes. A natural disaster can cause loss of life or property damage, and typically leaves some economic damage in its wake, the severity of which depends on the affected population's resilience, or ability torecover.

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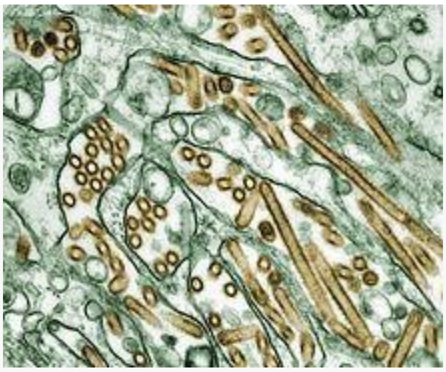
Healthdisasters

Epidemics



The A H5N1 virus, which causesAvian influenza

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Spacedisasters

Fallen trees caused by the Tunguska meteoroid of theTunguska eventin June 1908.

Impactevents

One of the largest impact eventsin modern times was the Tunguska eventin June 1908.

Solar flare

A solar flare is a phenomenon where the sun suddenly releases a great amount of solarradiation, much more than normal. Some known solar flares include:

- An X20 event on August 16,1989[16]
- A similar flare on April 2,2001[16]
- The most powerful flare ever recorded, on November 4, 2003, estimated at between X40 andX45
- Themost powerful flare in the past 500 yearsis believed to have occurred in September 1859

Gamma-ray burst

Gamma-ray bursts (**GRBs**) are flashes of gamma raysassociated with extremely energetic explosions that have been observed in distant galaxies. They are the brightestelectromagneticevents known to occur in the universe.[19]Bursts can lastfrom ten milliseconds to several minutes. The initial burst is usually followed by a longer-lived "afterglow" emitted at longer wavelengths

(X-ray, ultraviolet, optical, infrared, microwaveand radio).

All the bursts astronomers have recorded so far have come from distant galaxies and have been harmless to Earth, but if one occurred within our galaxy and were aimed straight at us, the effects could be devastating. Currently orbiting satellites detect an average of about one gamma-ray burst per day. The closest known GRB so far was GRB 031203

Anthropogenic hazards or **human-made hazards** can result in the form of a **human-made disaster**. In this case,*anthropogenic*means threats having an element of human intent, negligence, or error; or involving a failure of a human-made system. This is as opposed to natural hazardsthat cause natural disasters. Either can result in huge losses of life and property as well as damage to peoples' mental, physical and socialwell-being.

Sociologicalhazards[edit]

Crime[edit]

Main article: Crime

Crime is a breach of the lawfor which some governing authority (via the legal systems) can ultimately prescribe a convictionwhich will carry some form of penalty, such as imprisonment or a fine. At least in the view of the legislators, the criminal act will cause harm to other people. Each legal jurisdiction may define crime differently. While every crime violates the law, not every violation of the law counts as a crime: for example, breaches ofcontractand of other private lawmay rank as "offenses" or as "infractions". Modern societies generally regard crimes as offenses against the public or the state, distinguished from torts(offenses against private parties that can give rise to a civil cause ofaction).

In context, not all crimes constitute human-made hazards.

Arson[edit]

A building damaged by arson

Main article: Arson

Arson is the criminal intent of setting a firewith intent to cause damage. The definition of arson was originally limited to setting fire to buildings, but was later expanded to include other objects, such as bridges, vehicles, and private property. Arson is the greatest recorded cause of fire. Some human-induced fires are accidental: failing machinery such as a kitchen stove is a major cause of accidental fires.[1]

Civil disorder[edit]

Main articles: Civil disorderand Riot

Civil disorder is a broad term that is typically used by law enforcement to describe forms of disturbance. Although civil disorder does not necessarily escalate to a disaster in all cases, the event may escalate into general chaos. Rioting has many causes, including large-scale criminal conspiracy, socioeconomic factors (unemployment, poverty), hostility between racial and ethnic groups and mass outrage over perceived moral and legal transgressions. Examples of well-known civil disorders and riots are the Poll Tax Riotsin the UnitedKingdomin 1990; the 1992 Los Angeles riotsin which 53 people died; the 2008 Greekriotsafter a 15-year-old boy was fatally shot by police; and the 2010 Thai politicalprotestsin Bangkokduring which 91 peopledied.

Terrorism[edit]

Main articles: Terrorismand Asymmetric warfare

September 11 attacks, which are in multiple categories of human made disaster: terrorist attack, air disaster, arson, and structural collapse

Terrorism is a controversial term with varied definitions. One definition means a violent action targeting civilians exclusively. Another definition is the use or threatened use of violence for the purpose of creating fear in order to achieve a political, religious, or ideological goal. Under the second definition, the targets of terrorist acts can be anyone, including civilians, government officials, military personnel, or people serving the interests of governments.

Definitions of terrorism may also vary geographically. In Australia, the Security Legislation Amendment (Terrorism) Act 2002, defines terrorism as "an action to advance a political, religious or ideological cause and with the intention of coercing the government or intimidating the public", while the United States Department of Stateoperationally describes it as "premeditated, politically-motivated violence perpetrated against non-combatant targets by sub national groups or clandestine agents, usually intended to influence an audience".[2]**War**[edit]

Main article: War

War is a conflict between relatively large groups of people, which involves physical force inflicted by the use of weapons. Warfare has destroyed entire cultures, countries, economies and inflicted great suffering on humanity. Other terms for war can include armed conflict, hostilities, and police action. Acts of war are normally excluded from insurance contracts and sometimes from disaster planning.

Technologicalhazards[edit]

Industrial hazards[edit]

Industrial disastersoccur in a commercial context, such as mining accidents. They often have an environmental impact. TheBhopal disasteris the world's worst industrial disaster to date, and the Chernobyl disasteris regarded the worst nuclear accident in history. Hazards may have longer-term and more dispersed effects, such as dioxinand DDTpoisoning.

Structural collapse[edit]

Structural collapsesare often caused by engineering failures. Bridge failures may be caused in several ways, such as under-design (as in the Tay Bridge disaster), by corrosion attack (such as in the Silver Bridgecollapse), or by aerodynamic flutter of the deck (as in *Galloping Gertie*, the original Tacoma Narrows Bridge). Failure of dams was not infrequentduring the Victorian era, such as the Dale Dyke damfailure in Sheffield, Englandin the 1860s, causing the Great Sheffield Flood. Other failures include balcony collapsesor building collapses such as that of the World Trade Center.

Power outage[edit]

Main article: Power outage

A power outage is an interruption of normal sources of electrical power. Short-term power outages (up to a few hours) are common and have minor adverse effect, since most businesses and health facilities are prepared to deal with them. Extended power outages, however, can disrupt personal and business activities as well as medical and rescue services, leading to business losses and medical emergencies. Extended loss of power can lead to civil disorder, as in the New York City blackout of 1977. Only very rarely do power outages escalate to disaster proportions, however, they often accompany other types of disasters, such as hurricanesand floods, which hampers relief efforts.

Electromagnetic pulsesand voltage spikesfrom whatever cause can also damage electricity infrastructure and electrical devices.

Recent notable power outages include the 2005 Java–Bali Blackoutwhich affected 100 million people, 2012 India blackoutswhich affected 600 million and the 2009 Brazil andParaguay blackoutwhich affected 60 million people.

Fire[edit]

An active flame front of the Zaca Fire

Main articles: Bush fire, Fire, Mine fire, Wildfireand Firestorm

See also category: Fire disasters involving barricaded escape routes

Bush fires, forest fires, and mine fires are generally started by lightning, but also by human negligence or arson. They can burn thousands of square kilometers. If a fire intensifies enough to produce its own winds and "weather", it will form into afirestorm. A good example of a mine fire is the one near Centralia, Pennsylvania. Started in 1962, it ruined the town and continues to burn today. Some of the biggest city-related fires are The Great Chicago Fire, The Peshtigo Fire(both of 1871) and the Great Fire of Londonin1666.

Casualties resulting from fires, regardless of their source or initial cause, can be aggravated by inadequate emergency preparedness. Such hazards as a lack of accessible emergency exits, poorly marked escape routes, or improperly maintained fire extinguishersor sprinklersystemsmay result in many more deaths and injuries than might occur with such protections. **Hazardousmaterials**[edit]

Main article: Dangerousgoods

Radiationcontamination[edit]

Chernobyl nuclear power plant

When nuclear weapons are detonated or nuclear containment systems are otherwise compromised, airborne radioactive particles (nuclear fallout) can scatter and irradiate large areas. Not only is it deadly, but it also has a long-term effect on the next generation for those who are contaminated. Ionizing radiation is hazardous to living things, and in such a case much of the affected area could be unsafe for human habitation. During World War II, United States troops dropped atomic bombs on the Japanese cities of Hiroshimaand Nagasaki. As a result, the radiation fallout contaminated the cities' water supplies, food sources, and half of the populations of each city were stricken with disease. In the Soviet Union, the Mayakindustrial complex (otherwise known as Chelyabinsk-40 orChelyabinsk-65) exploded in 1957. The Kyshtym disasterwas kept secret for several decades. It is the third most serious nuclear accident ever recorded. At least 22 villages were exposed to radiation and resulted in at least 10,000 displaced persons. In 1992 the former soviet unionofficially acknowledge the accident. Other Sovietrepublics of Ukraineand Belarussuffered also when a reactor at the Chernobyl nuclear power planthad a meltdownin 1986. To this day, several small towns and the city of Chernobyl remain abandoned and uninhabitable due tofallout.

The Goiânia accident was a radioactive contamination accident that occurred on September 13, 1987, at Goiânia, in the Brazilian state of Goiás, after an old radiotherapy source was stolen from an abandoned hospital site in the city. It was subsequently handled by many people, resulting in four deaths. About 112,000 people were examined for radioactive contamination and 249 were found to have significant levels of radioactive material in or on their bodies.[1][2] In the cleanup operation, topsoil had to be removed from several sites, and several houses were demolished. All the objects from within those houses were removed and examined. Time magazine has identified the accident as one of the world's "worst nuclear disasters" and the International Atomic Energy Agency called it "one of the world's worst radiological incidents"

Another nuclear power disaster that is ongoing is Fukushima Daiichi.

In the 1970s, a similar threat scared millions of Americans when a failure occurred at the Three Mile IslandNuclear Power Plant in Pennsylvania. However, the incident was resolved and the area fortunately retained littlecontamination.

The Hanford Siteis a decommissioned nuclear production complex that produced plutonium for most of the 60,000 weapons in the U.S. nuclear arsenal. There are environmental concernsabout radioactivity released from Hanford.

Two major plutoniumfires in 1957 and 1969 at the Rocky Flats Plant, located about 15 miles northwest of Denverwas not publicly reported until the 1970s.

A number of military accidents involving nuclear weapons have also resulted in radioactivecontamination, for example the1966 Palomares B-52 crashand the 1968 Thule Air Base B-52crash.

Dermatitis (burn) of chin from vapors ofmustard gas

CBRNs[edit]

Main article: CBRN

CBRN is a catch-all acronym for chemical, biological, radiological, and nuclear. The term is used to describe a non-conventional terror threat that, if used by a nation, would be considered use of a weapon of mass destruction. This term is used primarily in the United Kingdom. Planning for the possibility of a CBRN event may be appropriate for certain high-risk or high-value facilities and governments. Examples include Saddam Hussein's Halabjapoison gas attack, the Sarin gas attack on the Tokyo subwayand the preceding test runsin Matsumoto,Japan100kilometersoutsideofTokyo,[3]andLordAmherstgivingsmallpoxladen blanketstoNativeAmericans

Transportation[edit]

Aviation[edit]

The ditching of US Airways Flight 1549was a well-publicised incident in which all on board survived

Main article: [Air disasters]

An aviation incident is an occurrence other than an accident, associated with the operation of an aircraft, which affects or could affect the safety of operations, passengers, or pilots. The category of the vehicle can range from a helicopter, anairliner, or a space shuttle. The world's worst airliner disaster is the Tenerife crashof 1977, when miscommunications between and amongst air traffic control and an aircrew caused two fully laden jets to collide on the runway, killing 583people.

Rail[edit]

Granville-Paris Express wreck at Montparnasse on 22 October 1895

Rail disasters

A railroad disaster is an occurrence associated with the operation of a passenger train which results in substantial loss of life. Usually accidents with freight (goods) trains are not considered disasters, unless they cause substantial loss of life or property. One of the most devastating rail disasters occurred in 2004 in Sri Lankawhen 1,700 people died in the SriLanka tsunami-rail disaster. Other notable rail disasters are the 1989 Ufa accidentin Russia which killed 574, and the 1917 Modanetrain accident in France which killed 540.

See also the listof train accidents by death toll.

Road[edit]

Traffic collisionsare the leading cause of death, and road-based pollution creates a substantial health hazard, especially in majorconurbations.

Space[edit]

Main article: Space accidents and incidents

Disintegration of the Space Shuttle Challenger

Space travel presents significant hazards, mostly to the direct participants (astronautsor cosmonautsand ground support personnel), but also carry the potential of disaster to the public at large. Accidents related to space travel have killed 22 astronauts and cosmonauts, and a larger number of people on theground.

Accidents can occur on the ground during launch, preparation, or in flight, due to equipment malfunction or the naturally hostile environment of space itself. An additional risk is posed by (unmanned) low-orbitingsatelliteswhose orbits eventually decay due to friction with the extremely thin atmosphere. If they are large enough, massive pieces travelling at great speed can fall to the Earth before burning up, with the potential to dodamage.

The worst space disaster to date occurred on February 15, 1996 in Sichuan, China, when a Long March 3Brocket, carrying the Intelsat 708 telecommunications satellite, suffered a guidance systemfailure two seconds after liftoff and crashed into a nearby village. The Chinese governmentofficially reported six deaths and 57 injuries, but some U.S. estimates run as high as 200deaths.

The second worst disaster was the Nedelin catastrophewhich occurred in the Soviet Unionon October 24, 1960, when anR-16intercontinental ballistic missileexploded on the launch pad, killing around 120 (best estimate) military ground support personnel. The Soviet government refused to acknowledge the incident until 1989, then claiming only 78 deaths.

One of the worst human-piloted space accidents involved the Space Shuttle*Challenger*which disintegrated in 1986, claiming all seven lives on board. The shuttle disintegrated 73 seconds after taking off from the launch pad in Cape Canaveral, Florida.

Another example is the Space Shuttle*Columbia*, which disintegrated during a landing attempt over Texasin 2003, with a loss of all seven astronauts on board. The debris field extended from New MexicotoMississippi.

Sea travel[edit]

The capsized cruise ship Costa Concordiawith a large rock lodged in the crushed hull of the ship

Ships can sink, capsize or crash in disasters. Perhaps the most infamous sinking was that of the Titanicwhich hit an iceberg and sank, resulting in one of the worstmaritime disastersin history. Other notable incidents include the capsizing of the Costa Concordia, which killed at least 32 people; and is the largest passenger ship to sink, and the sinking of the MV DoñaPaz, which claimed the lives of up to 4,375 people in the worst peacetime maritime disaster inhistory.

UNIT-3

EARTHQUAKE HAZARDS IN INDIA

Seismic zonation map shows that India is highly vulnerable for earthquake hazards. India has witnessed more than 650 earthquakes of Magnitude >5 during the last hundred years and earthquake disaster is increasing alarmingly here. In addition to very active northern and northeastern seismicity, the recent events in Killari (Maharastra) and Jabalpur (Madhya Pradesh) in the Peninsular India have raised many problems to seismologists.

The occurrence of earthquakes can be explained with the concept of "Plate Tectonics" Based on this three broad categories of earthquakes can be recognised. 1) those occurring at the subduction/collision zones (Inter-plates), 2) those at mid-oceanic ridges and 3) those at intra-plates (Acharrya, 1999). Seismic events in India mainly belong to the first category though a few third category events are also known. Earthquake events are reported from the Himalayan mountain range including Andaman and Nicobar Islands, Indo-Gangetic plain and Peninsular region ofIndia.

Subduction/collision earthquakes in India occur in the Himalayan Frontal Arc (HFA). This arc is about 2500km long and extends from Kashmir in the west to Assam in the east. In constitutes the central part of the Alpine seismic belt and is one of the most seismically active regions in the world. The Indian plate came into existence after initial rifting of the southern Gondwanaland in late Triassic period and subsequent drifting in mid-Jurassic to late Cretaceous time. The force responsible for this drifting came from the spreading of the Arabian sea on either side of the Carisberg ridge (Fig. 1; Chatterjee). It eventually collided with the Eurasian plate in Middle Eocene after NNE drifting along counter clockwise path. The NNE ward movement of the Indian plate caused continental collision with the rates of convergence varying from 44 - 66mm per year. This led to the creation of Himalayan mountain range. The present day seismicity of this is due to continued collision between the Indian and the Eurasian plates. The important earthquakes that have visited HFA are tabulatedbelow:

EARTHQUAKE PREDICTION

Research on earthquake prediction started since early sixties. Intensive work is going on all over the world in this regard involving expenditure of billions of dollars. The precise prediction of seismic events remains elusive and unattainable goal as yet in spite of these efforts. According to R.R. Kelkar, Director General of Indian Meteorological Department (IMD), "Earthquake cannot be predicted by anyone, anywhere, in any country. This is a scientific truth". But seismologists continue their efforts in the hope of a major breakthrough in prediction technology in the near future. The seismologists are, however, in a position to indicate the possibility of recurrence of earthquakes in potentially large areas based on palaeoseismicity, micro seismic activities and precursors.

It has been found that earthquakes are generally, but not necessarily, preceded by some signals like ground tilting, foreshocks, change in ground water levels, variations in the discharge of springs, anomalous oil flow from the producing wells, enhance emanations of radon and unusual animal behaviour. Perhaps the first successful prediction of earthquake in the world was made by the Chinese. They predicted Haicheng event of Lioning Province (February 4, 1975, Ma=7.3) on the basis of micro seismic activity, ground tilting and unusual animal behaviour (Nandi, 1999). They also foretold 4 out of 5 events of magnitude 7 during 1976-77. It is believed that the Chinese have mastered themselves in the art of closely monitoring and analysing animal behaviour to forecast earthquakes. Still they failed to predict Tangshan event of 1976 (Ma=7.8, casualty > 3lakhs).

The Indian subcontinent has a history of devastating earthquakes. The major reason for the high frequency and intensity of the earthquakes is that the Indian plate is driving into Asiaat a rate of approximately 47 mm/year.[1]Geographical statistics of India show that almost 54% of the land is vulnerable to earthquakes. A World Bank & United Nations report shows estimates that around 200 million city dwellers in India will be exposed to storms and earthquakes by 2050.[2]The latest version of seismic zoning map of India given in the earthquake resistant design code of India [IS 1893 (Part 1) 2002] assigns four levels of seismicity for India in terms of zone factors. In other words, the earthquake zoning map of India divides India into 4 seismic zones (Zone 2, 3, 4 and 5) unlike its previous version which consisted of five or six zones for the country. According to the present zoning map, Zone 5 expects the highest level of seismicity whereas Zone 2 is associated with the lowest levelof seismicity. The latest seismic zoning map can be accessed from The India Meteorological Department website.

The MSK (Medvedev-Sponheuer-Karnik) intensity broadly associated with the various seismic zones is VI (or less), VII, VIII and IX (and above) for Zones 2, 3, 4 and 5, respectively, corresponding to Maximum Considered Earthquake(MCE). The IS code follows a dual design philosophy: (a) under low probability or extreme earthquake events (MCE) the structure damage should not result in total collapse, and (b) under more frequently occurring earthquake events, the structure should suffer only minor or moderate structural damage. The specifications given in the design code (IS 1893: 2002) are not based on detailed assessment of maximum ground acceleration in each zone using a deterministic or probabilistic approach. Instead, each zone factor represents the effective period peak groundaccelerationsthat may be generated during the **maximum considered earthquake** ground motion in thatzone.

Each zone indicates the effects of an earthquake at a particular place based on the observations of the affected areas and can also be described using a descriptive scale like Modified Mercalli intensity scale[3]or theMedvedev-Sponheuer-Karnik

In India also efforts are going on for predicting earthquakes based on the statistical analysis of past events and their recurrence intervals, swarms activity and seismic gap. However, meaningful prediction is still alluding the seismologists. Khatri (1999) identified three seismic gaps in the Himalayan region, namely, the Kashmir gap, the Central gap and the Assam gap. The Kashmir gap lies west of Kangra event, the Central gap between Kangra and Bihar-Nepal events and the Assam gap between the two great earthquakes of Assam. He further said that the great event may occur in these gaps in near future. Das and Sarmah (1996) forecasted the occurrence of high magnitude earthquake in the western part of the northeastern region at any time within next few years. Negi (in Ahmad, 1998) has predicted "Mega Earthquake" in the northeast by 2010 on the basis of theory of cyclical earthquakes. Sarmah (1999) calculated an average return period of 55 years for the earthquakes of magnitude 8 or greater. The last big earthquake of magnitude 8.7 occurred in 1950. Therefore,northeasternregionisreadyforanearthquakeofsimilarmagnitude.Itisbarefact that the strain is accumulating in some parts of the region and any delay in the occurrence of earthquake will increase its magnitude and thus the devastation only.

EARTHQUAKE HAZARD ZONATION, RISK EVALUATION ANDMITIGATION

The importance of seismological studies lies in the fact that information generated can be used to mitigate the earthquake hazards. Preparation of seismotectonic/seismic zonation maps is the first step in this direction. The basic data required for the preparation ofthese maps are (i) A carefully compiled earthquake catalogue incorporating details about magnitude, location of epicenter, depth of focus *etc*., (ii) Delineation of seismic source zones from all possible sources like recurrence relation, tectono-geological consideration, palaeoseismicity *etc*., (iii) Estimation of upper bound magnitude through statistical procedure, cumulative seismic energy release, active fault length *etc*. and (iv) Attenuation of ground shaking for better results (Das Gupta, 1999). Seismic microzonation is recommended for better result. These maps give an idea about the possibility of occurrence of earthquakes in the region and are very useful for evaluating the risk involved before designing and constructing the heavy engineering structures like dam, bridges, flyovers and large towers *etc*. These are also useful for planning human settlements that would remain safe during the occurrence of an earthquake. Seismic risk evaluation is also possible from thesemaps.

Indian Meteorological Department, National Geophysical Research Institute, Department of Science & Technology, Bhabha Atomic Research Centre and Regional Research Laboratory have established a large number of seismic monitoring network in the country including northeastern region. These stations are recording useful seismic data, which enables to determine the location of epicenter, useful seismic data which enables to determine the location of epicenter, depth of hypocenter, energy within the focus, orientation of the geological structure that has undergone deformation and many other parameters of earthquakes. These parameters are then utilised for preparing seismo-tectonic and seismic zoning maps. The work in seismic zoning in India was started by Indian Standard Institute (now Bureau of Indian Standard) in the year 1960 and the first map was included in the code IS: 1893-1962. A significant progress has been made since then both in seismic zoning and instrumental monitoring of seismicity. However, many questions regarding the location and nature of potential seismic zones/faults still remain unsolved and need to be addressed to in the new millennium.

What are the Harmful Effects of Earthquakes?

(1) **Damage to human structures**- Earthquakes cause great damage to human structures such as buildings, roads, rails, factories, dams, bridges etc, and thus cause heavy damage to humanproperty.

(2) **Landslides**-The shocks produced by earthquakes particularly in hilly areas and mountains which are tectonically sensitive causes landslides and debris fall on human settlements and transport system on the lower slope segments, inflicting damage tothem.

(3) **Fires-**The strong vibrations caused by severe earthquakes strongly shake the buildings and thus causing severe fires in houses, mines and factories because of overturning of cooking gas, contact of live electric wires, churning of blast furnaces, displacement of other fire related and electricappliances.

(4) **Flash Floods-**Strong seismic waves cause damage to dams thereby causing severe flash floods. Severe floods are also caused because of blocking of water flow of rivers due to rock blocks and debris produced by severe tremors in the hill slopes facing the river valleys. Sometimes the blockage is so severe that rivers change their maincourse.

(5) **Deformation of Ground surface**- severe tremors and resultant vibrations caused by earthquakes result in the deformation of ground surface because of rise and subsidence of ground surface and faulting activity(formation offaults).

(6) **Tsunamis**- The seismic waves caused by earthquake(measuring more than 7 on richter scale) travelling through sea water generate high sea waves and cause great loss of life and property.

Several types of volcanic Eruptions

Several **types of volcanic eruptions**—during which lava, tephra(ash, lapilli, volcanic bombsand blocks), and assorted gases are expelled from a volcanic ventor fissure—have been distinguished by volcanologists. These are often named after famous volcanoes where that type of behavior has been observed. Some volcanoes may exhibit only one characteristic type of eruption during a period of activity, while others may display an entire sequence of types all in one eruptive series.

There are three different types of eruptions. The most well-observed are magmatic eruptions, which involve the decompression of gas within magma that propels it forward. Phreatomagmatic eruptionsare another type of volcanic eruption, driven by the compression of gas within magma, the direct opposite of the process powering magmatic activity. The thirderuptivetypeisthephreaticeruption,whichisdrivenbythesuperheatingofsteamvia contact with magma; these eruptive types often exhibit no magmatic release, instead causing the granulation of existing rock.

Within these wide-defining eruptive types are several subtypes. The weakest are Hawaiianand submarine, then Strombolian, followed by Vulcanianand Surtseyan. The stronger eruptive types are Pelean eruptions, followed by Plinian eruptions; the strongest eruptions are called "Ultra Plinian." Subglacialand phreatic eruptions are defined by their eruptive mechanism, and vary in strength. An important measure of eruptive strength is VolcanicExplosivity Index(VEI), an order of magnitudescale ranging from 0 to 8 that often correlates to eruptive types.

Harmful effects o volcanic eruptions

Volcanoes affect people in many ways, some are good, some are not. Some of the bad ways are that houses, buildings, roads, and fields can get covered with *ash*. As long as you can get the ash off (especially if it is wet), your house may not collapse, but often the people leave because of the ash and are not around to continually clean off their roofs. If the *ashfall*is really heavy it can make it impossible to breathe.

Lava flows are almost always too slow to run over people, but they can certainly run over houses, roads, and any other structures.

Pyroclastic flows are mixtures of hot gas and ash, and they travel very quickly down the slopes of volcanoes. They are so hot and choking that if you are caught in one it will kill you. They are also so fast (100-200 km/hour) that you cannot out-run them. If a volcano that is known for producing pyroclastic flows is looking like it may erupt soon, the best thing is for you to leave before it does.

Some of the good ways that volcanoes affect people include producing spectacular scenery, and producing very rich soils for farming.

Gases

Water vapor, the most common gas released by volcanoes, causes few problems. Sulfur dioxide, carbon dioxide and hydrogen are released in smaller amounts. Carbon monoxide, hydrogen sulfide, and hydrogen fluoride are also released but typically less than 1 percent by volume.Gases pose the greatest hazard close to the *vent*where concentrations are greatest. Away from the vent the gases quickly become diluted by air. For most people even a brief visit to a vent is not a health hazard. However, it can be dangerous for people with respiratory problems.

The continuous *eruption*at Kilauea presents some new problems. Long term exposure to volcanic fumes may aggravate existing respiratory problems. It may also cause headaches and fatigue in regularly healthy people. The gases also limit visibility, especially on the leeward side of the island where they become trapped by atmosphericconditions.

Source of Information: *Volcanic and Seismic Hazards on the Island of Hawaii by Christina Heliker, 1991, U.S. Geological Survey General Interest Publication.*

A deadly eruption

The 1815 explosive eruption of **Tambora volcano**in Indonesia and the subsequent *caldera*collapse produced 9.5 cubic miles (40 cubic kilometers) of ash. The eruption killed 10,000 people. An additional 80,000 people died from crop loss and famine.

Aircraft

To put it mildly, ash is bad for jet aircraft engines. Apparently the problem is much more severe for modern jet engines which burn hotter than the older ones. Parts of these engines operate at temperatures that are high enough to melt ash that is ingested. Essentially you end up with tiny blobs of *lava*inside the engine. This is then forced back into other parts where the temperatures are lower and the stuff solidifies. As you can imagine this is pretty bad. One problem that I heard about is that pilots start losing power and apply the throttle, causing the engine to be even hotter and melt more ash.Added to this is the fact that ash is actually tiny particles of glass plus small mineral shards–pretty abrasive stuff. You can imagine that dumping a whole bunch of abrasive powder into a jet engine is not good for the engine. This has been a pretty non-scientific explanation of the problem. I just found an article that describes the problem a little more technically.

“The ash erodes sharp blades in the compressor, reducing its efficiency. The ash melts in the combustion chamber to form molten glass. The ash then solidifies on turbine blades, blocking air flow and causing the engine to stall.” This comes from the *FAA Aviation Safety Journal, Vol. 2, No. 3.*

Safe distance

The distance you have to evacuate depends entirely on what kind of eruption is going on. For example, Pinatubo, one of the largest recent eruptions sent pyroclastic flows at least 18 km down its flanks, and *pumice*falls were hot and heavy even beyond that. For example, pumice 7 cm across fell at Clark Air base which is 25 km from the volcano! A 7 cm pumice won’t necessarily kill you but it does mean that there is a lot of pumice falling, and if you don’t get out and continuously sweep off your roof it may fall in and you’ll get squashed.On the other hand, the current eruption at Ruapehu is relatively small. In fact, there were skiers up on the slopes when the eruptions commenced, and even though they were only 1-2 km from the vent they managed to escape. The volcanologists routinely go up on the higher slopes of Ruapehu during these ongoing eruptions to collect ash and take photographs.

So you see, you need to know something about what you think the volcano is going to do before you decide how far to run away. I guess if you have no idea of what the volcano is planning, and have no idea of what it has done in the past, you might want to be at least 25-30 km away, make sure you have a good escape route to get even farther away if necessary, and by all means stay out of low-lying areas!

Cities and Towns

The effect an eruption will have on a nearby city could vary from none at all to catastrophic. For example, atmospheric conditions might carry ash away from the city or topography might direct lahars and pyroclastic flows to unpopulated areas. In contrast, under certain atmospheric, eruption and/or topographic conditions, lahars, pyroclastic flows, and/or ash fall could enter the city causing death and destruction.

This scenario brings up several interesting problems. How do you evacuate a large population if there is little warning before the eruption? Where do these people go? If an eruption is highly likely yet hasn't happened yet how long can people be kept away from their homes andbusinesses?

I should point out that in most volcanic crises geologists advise local civil defense authorities. The civil defense authorities decide what to do concerning evacuations, etc.

The IAVCEI has a program to promote research on "Decade" Volcanoes. Decade volcanoes are likely to erupt in the near future and are near large population centers. Mount Rainier in Washington and Mauna Loa in Hawaii are two Decade volcanoes in the U.S. Other Decade volcanoes include Santa Maria, Stromboli, Pinatubo, and Unzen.

What happens to the towns around a volcano when it erupts depends on many things. It depends of the size and type of eruption and the size and location of the town. A few examples might help. The 1984 eruption of Mauna Loa in Hawaii sent lava towards Hilo but the eruption stopped before the flows reached the town. The 1973 eruption of Heimaey in Iceland buried much of the nearby town of Heimaey under lava and cinder. The 1960eruption of Kilauea in Hawaii buried all of the nearby town of Kapoho under lava and cinder. In 1980, ash from Mount St. Helens fell on many towns in Washington and Oregon. The 1902 eruption of Mount Pelee on the island of Martinique destroyed the town of Saint Pierre with pyroclastic flows. In 1985, the town of Armero was partially buried by lahars generated on Ruiz. For more examples see Decker and Decker(1989).

1. How Are Earthquakes and Volcanoes Distributed?

Volcanoes

Distributed all over the world in different countries and continents but are not found it every country.

- Found mostly on the coastline
- Especially on tectonic plateboundaries

Volcano proneareas:

- **'The Ring ofFire'**
- **Around the Pacificplate.**
- Across the NOrth and South Atlanticocean
- There are still anomalies - Hotspots

Earthquakes

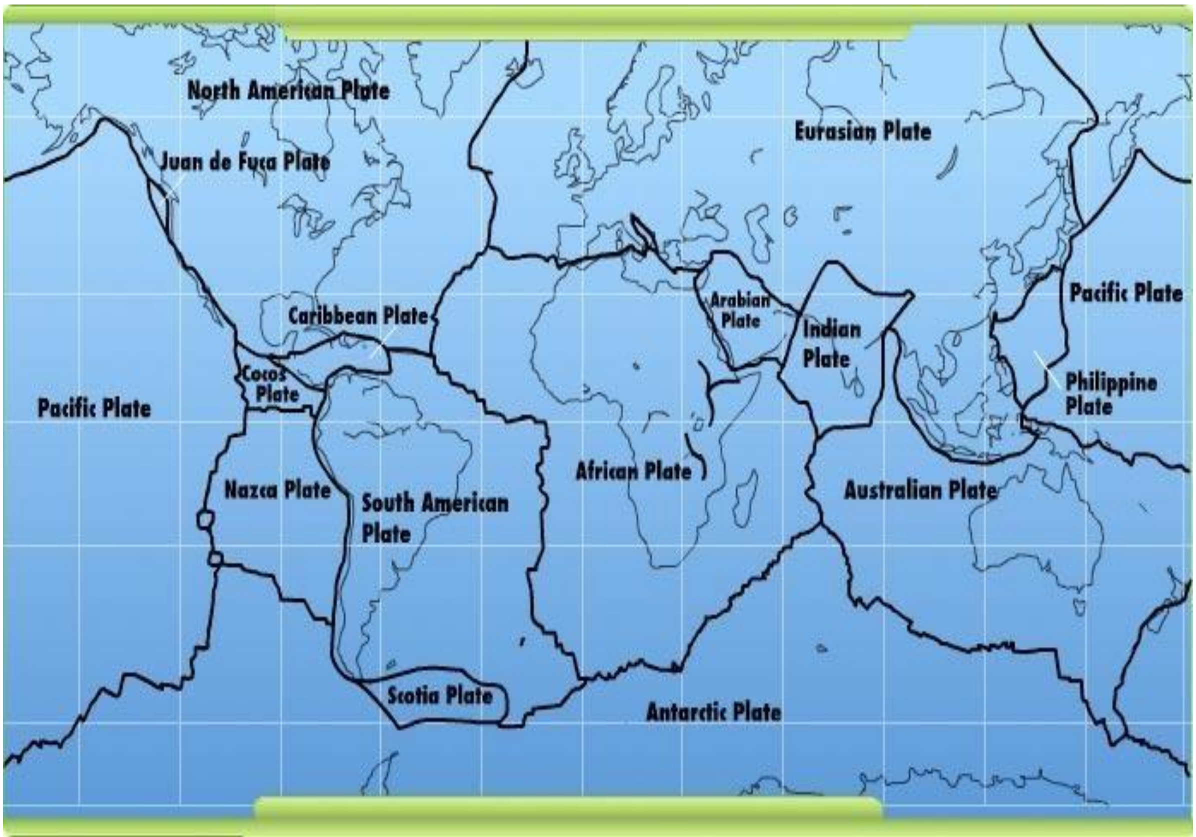
Millions of tiny earthquakes happen everyday, but we only manage to notice the bigger, major ones.

- Found on mainland andcoastlines
- Especially tectonic plateboundaries

Earthquake proneareas:

- Around PacificOcean
- Along the Indo-Australian pate boundary
- Eastern side of Eurasianplate
- Western side of North Americanplate

Volcanoes and earthquakes are both found on plate boundaries. However, there is a difference between the two since volcanoes are never found on conservative and divergent boundaries because there is no change in crust to allow more magma (molten rock) to be made.



UNIT-4

ATMOSPHERIC HAZARDS

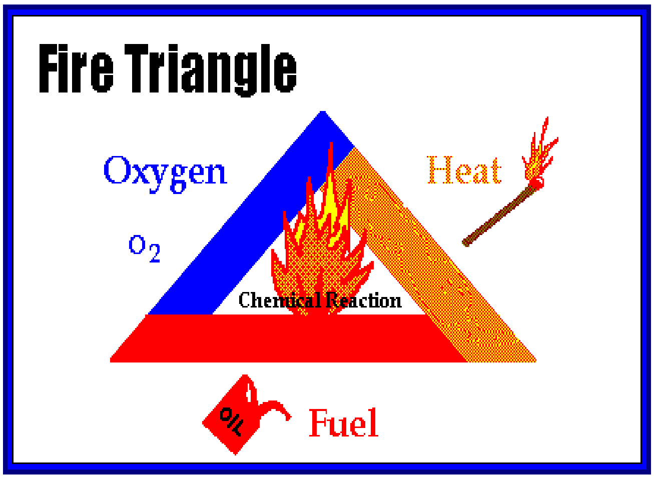
Atmospheric hazards include things such as oxygen deficiencies, dusts, chemical vapors, welding fumes, fogs, and mists that can interfere with the bodies ability to transport and utilize oxygen, or that have negative toxicological effects on the human body.

Before entry into most confined spaces, a multi-gas meter is commonly used to determine levels of oxygen, carbon monoxide, hydrogen sulfide, and the concentration of combustible gas. Other types of meters and sensors are available to detect concentration of specific gases (chlorine, sulfur dioxide, etc.) ifneeded.

Portable Multi-Gas Meter

The most common atmospheric hazards associated with confined spaces are:

- OxygenDeficiency
- OxygenDisplacement
- FlammableAtmospheres
- Toxic Gases
- OxygenDeficiency
- Low levels of oxygen can be caused by the consumption of oxygen during open flame operations such as welding, cutting, or brazing. In addition, low levels of oxygen can be present in manholes that are located near garbage dumps, landfills and swampy area where fermentation has caused the consumption ofoxygen.
-
- OxygenDisplacement:
- Some types of gases will "push" or displace oxygen from a confined space. An example of this is nitrogen. Nitrogen is commonly used to purge some types of tanks. If a person were to enter into the space before the nitrogen was properly removed and vented from the tank, death could result in a matter ofminutes.
- FlammableAtmospheres:
- Three components are necessary for an atmosphere to become flammable: fuel, oxygen, and a source ofignition.
- Some confined spaces my contain solvents, fuel oil, gasoline, kerosene, etc. which provide the fuel for combustion. In order for an atmosphere to become flammable, it must have the propermixture



- of fuel and oxygen. If the concentration of a specific gas is below the lower explosive limit (LEL) it is too lean to burn. If the concentration is above the upper explosive limit (UEL) it is too rich toburn.
-

Toxic gases:

Toxic gases can be present in a confined space because the type of manufacturing process uses toxic substances as part of the production process, or biological and chemical "breakdown" of the product being stored in a tank, and from maintenance activities (welding) being performed in the confinedspace.

Common types of toxic gases encountered in confined spaces are:

- *Hydrogen Sulfide* - "sewer gas" a colorless gas with the odor of rotten eggs. Excessive exposure has been linked to many confined space deaths. Hydrogen sulfide causes a loss of our sense of smell, causing people to mistakenly think that the gas has left the space. Hydrogen sulfide inhibits the exchange of oxygen on the cellular level and causes asphyxiation.
- *Carbon monoxide* - is an odorless, colorless gas that is formed by burning carbon based fuels (gas, wood). Carbon monoxide inhibits the bodies ability to transport oxygen to all parts of the body.
- *Solvents* - many solvents, such as kerosene, gasoline, paint strippers, degreasers, etc. are not only flammable, but if inhaled at high concentrations can cause central nervous system (CNS) effects. CNS effect can include dizziness, drowsiness, lack of concentration, confusion, headaches, coma anddeath.

Causes of tropical cyclone

A cyclone is formed over tropical seas. Winds from opposite directions meet. This air is heated by the warm seas and so evaporates moisture from the ocean. This warm air rises up rapidly, cools and condenses to form clouds and produces an area of very low pressure. When moisture and air mix, it makes a collection of thunderstorms from which a cyclone can develop. Water needs to be at least 26 degrees warm so a tropical cyclone can develop. More air is sucked in to take its place, and it too is heated and rises rapidly. This sucking in and risins movement of the air produces spiralling clouds. Eventually, an enormous storm system is built up, which can spread over two hundred kilometres. Heavy rain falls from the clouds. There is much thunder and lightning and the fast winds whip up the waves of the ocean.

In the middle of this system, air moves down. This produces a patch of drier, calm weather with few clouds. It is called the 'eye' of the storm and can last for an hour before the fierce winds and torrential rainstorms sweep in again. When the cyclone hits land, it soon weakens as there is no warm, moist air to 'feed' the storm.

A **chemical accident** is the unintentional refuse of one or more hazardous substances which could harm human health or the environment. **Chemical hazards** are systems where chemical accidents could occur under certain circumstances. Such events include fires, explosions, leakagesor releases of toxicor hazardous materialsthat can cause people illness, injury, disability ordeath.

While chemical accidents may occur whenever toxic materials are stored, transportedor used, the most severe accidents are industrial accidents, involving major chemicalmanufacturingand storage facilities. The most significant chemical accident in recorded history was the 1984 Bhopal disasterin India, in which more than 3,000 people were killed after a highly toxic vapour, (methyl isocyanate), was released at a UnionCarbidepesticidesfactory.

Efforts to prevent accidents range from improved safetysystems to fundamental changes in chemicaluse and manufacture, referred to as primary prevention or inherent safety.

In the United States, concern about chemical accidents after the Bhopal disaster led to the passage of the 1986 Emergency Planning and Community Right-to-Know Act. The EPCRA requires local emergencyplanning efforts throughout the country, including emergency notifications. The law also requires companies to make publicly available information about their storage of toxic chemicals. Based on such information, citizens can identify the vulnerable zones in which severe toxic releases could cause harm or death.

In 1990, the Chemical Safety and Hazard Investigation Boardwas established by Congress, though the CSB did not become operational until 1998. The Board's mission is to determine the root causes of chemical accidents and issue safety recommendations to prevent future

Safety Performance Indicators. It also organizes workshops on a number of issues related to preparing for, preventing, and responding to chemical accidents.[1]

In the European Union, incidents such as the Flixborough disasterand the Seveso disasterled to legislation such as theSeveso Directiveand Seveso planning and provide for safety reports to local authorities. Many countries have organisations that can assist with substance risk assessment and emergency planning that is required by a wide variety of legislation, such as the National Chemical Emergency Centrein the UK, Brandweerinformatiecentrum voorgevaarlijke stoffen/Fire service information centre for dangerous goods in Belgium.

In the UK, the UK Chemical Reaction Hazards Forumpublishes reports of accidents on its web site.[2]These accidents were, at the time, minor in nature, but they could have escalated into major accidents. It is hoped that publishing these incidents will prevent "Re- inventing the Wheel". At present, (Dec 2008), there are over 140 articles on the website.

A **nuclear explosion** is an explosionthat occurs as a result of the rapid release of energy from a high-speed nuclear reaction. The driving reaction may be nuclear fission, nuclearfusionor a multistage cascading combination of the two, though to date all fusion based weapons have used a fission device to initiate fusion, and a pure fusion weaponremains a hypotheticaldevice.

Atmospheric nuclear explosions are associated with mushroom clouds, although mushroom clouds can occur with large chemical explosions, and it is possible to have an air-burst nuclear explosion without these clouds. Nuclear explosions produce radiationand radioactivedebris.

Sedimentation is the tendency for particlesin suspensionto settle out of the fluid in which they are entrained, and come to rest against a barrier. This is due to their motion through the fluid in response to the forces acting on them: these forces can be due to gravity, centrifugalaccelerationor electromagnetism.In geology sedimentation is often used as the polar opposite of erosion, i.e., the terminal end of sediment transport. In that sense it includes the termination of transport by saltationor true bedload transport. Settlingis the falling of suspended particles through the liquid, whereas sedimentation is the termination o f the settlingprocess.

Sedimentation may pertain to objects of various sizes, ranging from large rocks in flowing water to suspensionsof dust and pollen particlesto cellularsuspensions to solutionsof single moleculessuch as proteinsand peptides. Even small molecules supply a sufficiently strong force to produce significantsedimentation.

The term is typically used in geology, to describe the depositionof sedimentwhich results in the formation of sedimentary rock, and in various chemical and environmental fields to describe the motions of often-smaller particles and molecules. Process is also used in biotech industry to separate out cells from the culture media.

Although agriculture contributes to a wide range of water quality problems, anthropogenic erosion and sedimentation is a global issue that tends to be primarily associated with agriculture. While there are no global figures, it is probable that agriculture, in the broadest context, is responsible for much of the global sediment supply to rivers, lakes, estuaries and finally into the world's oceans.

Pollution by sediment has two major dimensions.

One is the PHYSICAL DIMENSION - top soil loss and land degradation by gullying and sheet erosion and which leads both to excessive levels of turbidity in receiving waters, and to off-site ecological and physical impacts from deposition in river and lake beds.

The other is a CHEMICAL DIMENSION - the silt and clay fraction (<63 m fraction), is a primary carrier of adsorbed chemicals, especially phosphorus, chlorinated pesticides and most metals, which are transported by sediment into the aquatic system.

Erosion is also a net cost to agriculture insofar as loss of top soil represents an economic loss through loss of productive land by erosion of top soil, and a loss of nutrients and organic matter that must be replaced by fertilizer at considerable cost to the farmer in order to maintain soil productivity. The reader is referred to Roose (FAO, 1994a) for a detailed analysis of the social, economic and physical consequences of erosion of agricultural land and of measures that should be taken to control erosion under different types of land use, especiallyindevelopingcountries.WhereasRooseismainlyconcernedwiththeimpactof erosion on agriculture, this publication is primarily concerned with agricultural erosion from the perspective of its impacts on downstream water quality.

Control of agricultural pollution usually begins, therefore, with measures to control erosion and sediment runoff. Therefore, this chapter deals with the principal mechanisms which govern erosion processes, and those measures which can be taken to control erosion. Processes discussed here also apply to fertilizer and pesticide runoff presented in the following chapters.

Sediment as a physical pollutant

Global estimates of erosion and sediment transport in major rivers of the world vary widely, reflecting the difficulty in obtaining reliable values for sediment concentration and discharge in many countries, the assumptions that are made by different researchers, and the opposing effects of accelerated erosion due to human activities (deforestation, poor agricultural practices, road construction, etc.) relative to sediment storage by dam construction. Milliman and Syvitski (1992) estimate global sediment load to oceans in the mid-20th century at 20 thousand million t/yr, of which about 30% comes from rivers of southern Asia (including the Yangtze and Yellow Rivers of China). Significantly, they believe that almost 50% of the global total comes from erosion associated with high relief on islands of Oceania - a phenomenon which has been underestimated in previous estimates of global sediment production. While erosion on mountainous islands and in upland areas of continental rivers reflects natural topographic influences, Milliman and Syvitski suggest that human influences in Oceania and southern Asia cause disproportionately high sediment loads in theseregions.

Sediment, as a physical pollutant, impacts receiving waters in the following principalways:

 High levels of **turbidity** limit penetration of sunlight into the water column, thereby limiting or prohibiting growth of algae and rooted aquatic plants. In spawning rivers, gravel beds are blanketed with fine sediment which inhibits or prevents spawning of fish. In either case, the consequence is disruption of the aquatic ecosystem by destruction of habitat. Notwithstanding these undesirable effects, the hypertrophic (nutrient rich) status of many shallow lakes, especially in developing countries, would give rise to immense growth of algaeandrootedplantswereitnotforthelimitingeffectoflightextinctionduetohigh turbidity. In this sense, high turbidity can be "beneficial" in highly eutrophic lakes; nevertheless, many countries recognise that this situation is undesirable for both aesthetic and economic reasons and are seeking means to reduce both turbidity and nutrient levels. Box 4 presents the impact of sediment on coral reefs.

High levels of **sedimentation** in rivers leads to physical disruption of the hydraulic characteristics of the channel. This can have serious impacts on navigation through reduction in depth of the channel, and can lead to increased flooding because of reductions in capacity of the river channel to efficiently route water through the drainage basin. For example, calculations by the UFRGS (1991) of erosion and sediment transport in the Sao Francisco River Basin, a large drainage system in eastern Brazil, demonstrate that the central portion of the river basin is now dominated by sediment deposition. This has resulted in serious disruption of river transportation, and clogs hydraulic facilities that have been built to provide irrigation water from the main river channel. The sediment largely originates from rapidly eroding sub-basins due to poor agricultural practices.

Why Regional Sediment Management?

Sediment is an essential and dynamic part of the Harbor Estuary; its quality and quantity are integral to ecosystem health and a fundamental component of the regional economy. Although sediment and the pollutants that contaminate it originate throughout the 16,300-square mile watershed, our management of sediment has historically taken a highly localized and narrowly focused approach – one that is largely based on the tightly-defined concerns of agencies and authorities directly responsible for maintaining navigable waterways in the Harbor Estuary. This “end of the pipe” management approach does not address the causes of sediment-related problems, nor does it provide the policy and regulatory framework required to improve sediment management throughout the Harbor Estuary. Uncertainties and controversy have stalled sediment cleanup and restoration projects, deferred maintenance of our port infrastructure, and led to lost opportunities to beneficially reusing dredged material.

Coastal Hazards are physical phenomena that expose a coastal area to risk of property damage, loss of life and environmental degradation. Rapid-onset hazards last over periods of minutes to several days and examples include major cyclones accompanied by high winds, waves and surges or tsunamis created by submarine earthquakes and landslides. Slow-onset hazards develop incrementally over longer time periods and examples include erosion and gradual inundation

Introduction

Since early civilisation, coastal areas have been attractive settling grounds for human population as they provided abundant marine resources, fertile agricultural land and possibilities for trade and transport. This has led to high population densities and high levels of development in many coastal areas and this trend is continuing into the 21st century. At present, about 1,2 billion people live in coastal areas globally, and this number is predicted to increase to 1,8-5,2 billion by the 2080s due to a combination of population growth and coastal migration.[2]Along with this increase follows major investments in infrastructure and the buildenvironment.

The characteristics of coastal environments, however, pose some great challenges to human habitation. Coastlines are highly dynamic natural systems that interact with terrestrial, marine and atmospheric processes and undergo continuous change in response to these processes. Over the years, human society has often failed to recognize the hazards related to these dynamics [3]and this has led to major disasters and societal disruption to various degrees. Even today, coastal development is often taking place with little regard to the hazards present in these environments, although climate change is likely increase the general hazard levels.[4]Societal activities in coastal areas can also pose a hazard to the natural balance of coastal systems, thereby disrupting e.g. sensitive ecosystems and subsequently human livelihood.

Coastal hazard management has become an increasingly important aspect of coastal planning in order to improve the resilience of society to coastal hazards. Possible management options include hard engineering structures, soft protection measures, various accommodation approaches as well as a managed retreat from the coastline. For addressing coastal hazards, it is also important to have early warning systems and emergency management plans in place to be able to address sudden and potential disastrous hazards e.g. major flooding events. Events as the Hurricane Katrina affecting the southern USA in 2005 and the cyclone Nargis affecting Myanmar in 2008 provides clear examples of the importance of timely coastal hazard management.

Coastal hazards & climate change

The predicted climate change is adding an extra risk factor to human settlement in coastal areas. Whereas the natural dynamics that shape our coastlines have been relatively stable and predictable over the last centuries, much more rapid change is now expected in processes as sea level rise, ocean temperature and acidity, tropical storm intensity and precipitation/runoff patterns.[18]The world's coastlines will respond to these changes in different ways and at different pace depending on their bio-geophysical characteristics, but generally society will have to recognize that past coastal trends cannot be directly projected into the future. Instead, it is necessary to consider how different coastal environments will respond to the predicted climate change and take the expected future hazards into account in the coastal planning processes.

Cyclonic Disaster Hudhud

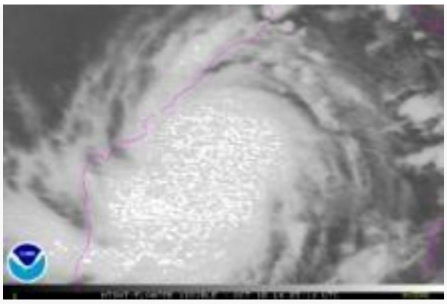
Very Severe Cyclonic Storm Hudhud was the strongest tropical cyclone of 2014 within the North Indian Ocean, as well as the costliest storm in the basin since Cyclone Jalin 2010.

Hudhud originated from a low pressure that formed under the influence of an upper-air cyclonic circulation in the Andaman Sea on October 6. The system drifted westward and intensified into a depression and subsequently into a deep depression the following day. Owing to favorable environmental conditions, Hudhud intensified into a cyclonic storm on October 8. Its convection consolidated in the following hours, and Hudhud became a Severe Cyclonic Storm on October 9. Hudhud underwent rapid deepeningin the following days and was classified as a Very Severe Cyclonic Storm by the IMD. Shortly before landfall near Visakhapatnam, Andhra Pradeshon October 12, Hudhud reached its peak strength with three minute wind speeds of 175 km/h (109 mph) and a minimum central pressure of 960 mbar (28.35 inHg). The system drifted northwards over land and was last noted as a well-marked low pressure area over east Uttar Pradeshon October14.[4]

The name *Hudhud*, suggested by Oman, refers to the bird Hoopoe.[5]The bird is known as the "hudhud" in the Quran, and appears in the story of Sulayman

Under the influence of an upper air cyclonic circulation, a low pressure area formed over Andaman Sea on October 6.[7]It slowly consolidated and was upgraded to a depression by the India Meteorological Department (IMD) on October 7. While over open waters, the depressioncontinuedtoencounterfavorableenvironment,andatropicalcycloneformation alert (TCFA) was issued by the Joint Typhoon Warning Center (JTWC), followed by IMD upgrading the storm into a deep depression.[8][9]

In the early hours of October 8, the JTWC started issuing its advisories for the system as it recorded tropical storm winds at the storm's centre.[10]The IMD later reported that the deep depression made its first landfall over Long Island, Andaman and had reached cyclonic storm intensity, naming it *Hudhud*.[11]After entering the Bay of Bengal, Hudhud continued to intensify the following day, and was upgraded to a severe cyclonic storm.



An animation showing Hudhud developing an eye on October 11

Early on October 10, the JTWC classified the storm a Category 1 tropical cyclone after it formed a microwave eye feature and was located in an environment favorable for further intensification with moderate wind shear.[12]The IMD upgraded Hudhud to a very severe cyclonic storm later the same day, and the JTWC further upgraded the storm to a Category 2 tropical cyclone.[13]

On October 11, Hudhud underwent rapid intensification and developed an eye at its center. The storm later was monitored by the doppler radar stationed at Visakhapatnam. In the following hours, the storm reached its peak intensity with a minimum central pressure of 960 mbar (28.35 inHg) and three-minute average windspeeds of 175 km/h (109 mph). Maintaining intensity, it made landfall near Visakhapatnam, Andhra Pradesh in the early hours of October12.

Bringing extensive damage to the coastal districts of Andhra Pradesh, Hudhud gradually weakened as it curved northwards over land. The storm continued its weakening trend and was last noted as a well-marked low pressure area over east Uttar Pradesh on October 14.[14]

Preparations andimpact[edit]

In light of the storm, the National Disaster Response Force(NDRF) mobilized 35 teams in Andhra Pradeshand Odisha.[15]The East Coast Railwaycancelled the services of 38 trains on October 12 when the cyclone madelandfall.[16][17]

Andaman and Nicobar Islands[edit]

On October 8, while Hudhud was gaining Cyclonic Storm intensity, the authorities closed schools and cancelled ferry services in and around Andaman Islands. Fishermen were warned about the storm. The Andaman Trunk Road, one of the major roads traversing the island, was shut down after trees were uprooted due to the storm's force. Landslides were reported in the island causing some power and communication lines to fail.[18]

Andhra Pradesh[edit]

An alert was sounded in nine out of thirteen districts of Andhra Pradesh where standing crop of paddy, followed by groundnut, sugarcane, pulses and other horticulture crops were yet to be harvested. Over 700,000 people, including 500,000 people in AP, have been evacuated and put up in relief camps. The local government made adequate arrangement to shift half a million people inall.[19][20]

Hudhud crossed the coast of Andhra Pradesh at 11:30 AM IST of October 12 near Pudimadaka, about 50 km fromVisakhapatnamwith winds exceeding 185 km/h (115 mph). As per initial reports, 3 people were killed due to heavy rainfall accompanied by strong winds in coastal areas.[21]Within hours after hitting the coast, the cyclone severed off the radar link of Visakhapatnam Cyclone WarningCentre.[22]

On October 13th it was announced that Hudhud had caused at least 24 deaths within Andhra Pradesh[23]and early estimates peg total damage costs at 100 billion rupees(US$1.63 billion)[24]This makes Hudhud the first storm in the basin to cause at least $1 billion in damage since Jalin2010.

Visakhapatnam, also known as Vizag, bore the brunt of Hudhud, which hit its coast with the speed of 185 kmph. Hundreds of vehicles parked on roads were damaged while heavy rains inundated few colonies. [25]

Odisha[edit]

The Odisha government had placed 16 districts under high alert. The districts alerted in Odisha
were Balasore, Kendrapara,Bhadrak, Jagatsinghpur, Puri, Ganjam, Mayurbhanj, Jajpur, Cuttack, Khurdha, Nayagarh, Gajapati, Dhenkanal, Keonjhar,Malkangiriand Koraput.

At the time of the storm's landfall, strong winds and heavy rainfall commenced in southern Odisha districts leading to disruption in power supply. Wind speeds reaching 90 km/h (56 mph) were predicted in theregion.[26]

Relief Fund[edit]

PM Narendra Modi announced Rs 1000 crore-aid for the cyclone affected areas in Andhra Pradesh by the Centre.[

A **cold wave** (known in some regions as *cold snap*) is a weather phenomenon that is distinguished by a cooling of the air. Specifically, as used by the U.S. National Weather

Service, a cold wave is a rapid fall in temperature within a 24 hour period requiring substantially increased protection to agriculture, industry, commerce, and social activities. The precise criterion for a cold wave is determined by the rate at which the temperature falls, and the minimum to which it falls. This minimum temperature is dependent on the geographical region and time of year.[1]

In the United States, a *cold spell* is defined as the national average high temperature dropping below 18 °F (−8 °C).[2]

Effects[edit]

A cold wave can cause damage to livestock and wildlife. Exposure to cold mandates greater caloric intake for all animals, including humans, and if a cold wave is accompanied by heavy and persistent snow, grazing animals may be unable to reach needed food and die of hypothermia or starvation. They often necessitate the purchase of foodstuffs at considerable cost to farmers to feedlivestock.

Extreme winter cold often causes poorly insulated water pipelines and mains to freeze. Even some poorly protected indoorplumbing ruptures as water expands within them, causing much damage to property and costly insurance claims. Demand for electrical power and fuels rises dramatically during such times, even though the generation of electrical power may fail due to the freezing of water necessary for the generation of hydroelectricity. Some metals may become brittle at low temperatures. Motor vehicles may fail as antifreeze fails and motor oil gels, resulting even in the failure of the transportation system. To be sure, such is more likely in places like Siberia and much of Canada that customarily get very coldweather.

Fires become even more of a hazard during extreme cold. Water mains may break and water supplies may become unreliable, making firefighting more difficult. The air during a cold wave is typically denser and any cold air that a fire draws in is likely to cause a more intense fire because the colder, denser air contains more oxygen.

Winter cold waves that aren't considered cold in some areas, but cause temperatures significantly below average for an area, are also destructive. Areas with subtropical climates may recognize unusual cold, perhaps barely freezing, temperatures, as a cold wave. In such places, plant and animal life is less tolerant of such cold as may appear rarely. The same winter temperatures that one associates with the norm for Kentucky, northern Utah, or Bavaria would be catastrophic to winter crops in southern Florida, southern Arizona, or southern Spain that might be grown for wintertime consumption farther north, or to such all-year tropical or subtropical crops as citrus fruits. Likewise, abnormal cold waves that penetrate into tropical countries in which people do not customarily insulate houses or have reliable heating may cause hypothermia and evenfrostbite.

Cold waves that bring unexpected freezes and frosts during the growing season in mid-latitude zones can kill plants during the early and most vulnerable stages of growth, resulting in crop failure as plants are killed before they can be harvestedeconomically. Such cold waves have caused famines. At times as deadly to plants as drought, cold waves can leave a land in danger of later brush and forest fires that consume dead biomass. One extreme was the so-called Year Without a Summer of 1816, one of several years during the 1810s in which numerous crops failed during freakish summer cold snaps after volcanic eruptions that reduced incomingsunlight.

meteorology, a **cyclone** is an area of closed, circular fluid motion rotating in the same direction as the Earth.[1][2]This is usually characterized by inward spiralingwindsthat rotate anti-clockwiseintheNorthernHemisphereand clockwisein the SouthernHemisphereof the Earth. Most large-scale cyclonic circulations are centered on areas oflowatmospheric pressure.[3][4]The largest low-pressure systems arecold-corepolar cyclones and extratropical cyclones which lie on thesynoptic scale. According to the NHCglossary, warm- core cyclones such as tropical cyclonesand subtropical cyclonesalso lie within the synoptic scale.[5]Mesocyclones, tornadoes and dust devils lie within the smaller mesoscale.[6]Upper level cyclones can exist without the presence of a surface low, and can pinch off from the base of theTropical Upper Tropospheric Troughduring the summer months in the Northern Hemisphere. Cyclones have also been seen on extraterrestrial planets, such as Marsand Neptune.[7][8]Cyclogenesisdescribes the process of cyclone formation and intensification.[9]Extratropical cyclonesform as waves in large regions of enhanced mid-latitude temperature contrasts called baroclinic zones. These zones contract to form weatherfrontsas the cyclonic circulation closes and intensifies. Later in their life cycle, cyclones occludeas cold core systems. A cyclone's track is guided over the course of its 2 to 6 day life cycle by the steering flow of the cancer or subtropical jetstream.

Weather fronts separate two masses of airof different densitiesand are associated with the most prominent meteorological phenomena.Air masses separated by a front may differ in temperatureor humidity. Strong cold fronts typically feature narrow bands of thunderstormsand severe weather, and may on occasion be preceded by squall linesor drylines. They form west of the circulation center and generally move from west to east. Warmfrontsform east of the cyclone center and are usually preceded by stratiformprecipitationand fog. They move polewardahead of the cyclone path.Occluded fronts form late in the cyclone life cycle near the center of the cyclone and often wrap around the storm center.

Tropical cyclogenesisdescribes the process of development of tropical cyclones. Tropical cyclones form due to latent heat driven by significant thunderstorm activity, and are warm core.[10]Cyclones can transition between extratropical, subtropical, and tropical phases under the right conditions. Mesocyclones form as warm core cyclones over land, and can lead totornadoformation.[11]Waterspoutscan also form from mesocyclones, but more often develop from environments of high instability and low vertical wind shear.[12]In the Atlantic basin, a tropical cyclone is generally referred to as a hurricane(from the name of the ancient Central American deity of wind, Huracan), a cyclone in the Indian Ocean and parts of the Pacific, and a typhoonin the Northwest Pacific region.[13]

Drought in India has resulted in tens of millions of deaths over the course of the 18th, 19th, and 20th centuries. Indianagricultureis heavily dependent on theclimate of India: a favorable southwest summer monsoonis critical in securing water for irrigating Indian crops. In some parts of India, the failure of the monsoons result in water shortages, resulting in below-average crop yields. This is particularly true of major drought-prone regions such as southern and eastern Maharashtra, northern Karnataka, Andhra Pradesh, Odisha, Gujarat, and Rajasthan.

In the past, droughts have periodically led to major Indian famines, including the Bengalfamine of 1770, in which up to one third of the population in affected areas died; the 1876– 1877 famine, in which over five million people died; and the 1899 famine, in which over
4.5 million died

Factors Influencing Erosion

he **climatic factors** that influence erosion are rainfall amount, intensity, and frequency. During periods of frequent rainfall, a greater percentage of the rainfall will become runoff. This is due to high soil moisture or saturated conditions.

Temperature is another climatic factor influencing erosion. While frozen soil is highly resistant to erosion, rapid thawing of the soil surface brought on by warm rains can lead to serious erosion. Temperature also influences the type of precipitation. Falling snow does not erode, however, heavy snow melts in the spring can cause considerable runoff damage.

Temperature also influences the amount of organic matter that collects on the ground surface and incorporates with the topsoil layer. Areas with warmer climates have thinner organic cover on the soil. Organic matter protects the soil by shielding it from the impact of falling rain and soaking up rainfall that would otherwise become runoff.

Physical **characteristics of soil** have a bearing on erodibility. Soil properties influencing erodibility include texture, structure and cohesion. Texture refers to the size or combination of sizes of the individual soil particles.

Three broad size classifications, ranging from small to large, are clay, silt, and sand. Soil having a large amount of silt-sized particles are most susceptible to erosion from both wind and water. Soil with clay or sand-sized particles are less prone to erosion.

Structure refers to the degree to which soil particles are clumped together, forming larger clumps and pore spaces. Structure influences both the ability of the soil to absorb water and its physical resistance to erosion.

The last property to consider is cohesion. Cohesion refers to the binding force between soil particles and influences the structure. When moist, the individual soil particles in a cohesive soil cling together to form a doughy consistency. Clay soils are very cohesive, while sand soils are not.

Vegetation is probably the most important physical factor influencing soil erosion. A good cover of vegetation shields the soil from the impact of raindrops. It also binds the soil together, making it more resistant to runoff. A vegetative cover provides organic matter, slows runoff, and filters sediment.

On a graded slope, the condition of vegetative cover will determine whether erosion will be stopped or only slightly halted. A dense, robust cover of vegetation is one of the best protections against soil erosion.

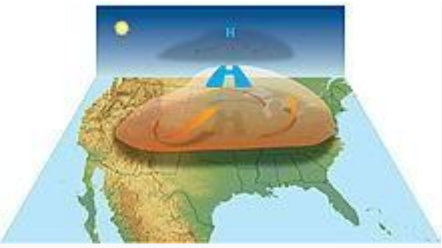
Slope length, steepness and roughness affect erodibility. Generally, the longer the slope, the greater the potential for erosion. The greatest erosion potential is at the base of the slope, where runoff velocity is greatest and runoff concentrates.

Slope steepness, along with surface roughness, and the amount and intensity of rainfall control the speed at which runoff flows down a slope. The steeper the slope, the faster the water will flow. The faster it flows, the more likely it will cause erosion and increase sedimentation.

A **heat wave** is a prolonged period of excessively hot weather, which may be accompanied by high humidity, especially in oceanic climatecountries. While definitions vary,[1]a heat wave is measured relative to the usual weather in the area and relative to normaltemperatures for the season. Temperatures that people from a hotter climate consider normal can be termed a heat wave in a cooler area if they are outside the normal climatepattern for that area.[2]

The term is applied both to routine weather variations and to extraordinary spells of heat which may occur only once a century. Severe heat waves have caused catastrophic crop failures, thousands of deaths from hyperthermia, and widespread power outages due to increased use of air conditioning. A heat wave is considered extreme weather, and a danger because heat and sunlight may overheat the human body.

How theyoccur[edit]



High pressure aloft traps heat near the ground, forming a heat wave

Heat waves form when high pressure aloft (from 10,000–25,000 feet (3,000–7,600 metres)) strengthens and remains over a region for several days up to several weeks. This is common in summer (in both Northern and Southern Hemispheres) as the jet stream 'follows the sun'. On the equator side of the jet stream, in the middle layers of the atmosphere, is the high pressure area.

Summertime weather patterns are generally slower to change than in winter. As a result, this mid-level high pressure also moves slowly. Under high pressure, the air subsides (sinks) toward the surface. This sinking air acts as a dome capping the atmosphere.

This cap helps to trap heat instead of allowing it to lift. Without the lift there is little or no convection and therefore little or no convective clouds (cumulus clouds) with minimal chances for rain. The end result is a continual build-up of heat at the surface that we experience as a heat wave.[11]

In the Eastern United States a heat wave can occur when a high pressure system originating in the Gulf of Mexico becomes stationary just off the Atlantic Seaboard (typically known as a Bermuda High). Hot humid air masses form over the Gulf of Mexico and the Caribbean Sea while hot dry air masses form over the desert Southwest and northern Mexico. The SW winds on the back side of the High continue to pump hot, humid Gulf air northeastward resulting in a spell of hot and humid weather for much of the EasternStates.[12]

In the Western Cape Province of South Africa, a heat wave can occur when a low pressure offshore and high pressure inland combine to form a Bergwind. The air warms as it descends from the Karoo interior, and the temperature will rise about 10 °C from the interior to the coast. Humidities are usually very low, and the temperatures can be over 40 °C in summer. The highest official temperatures recorded in South Africa (51.5 °C) was recorded one summer during a bergwind occurring along the Eastern Cape coastline.[13][14]

Global warming boosts the probability of extreme weather events, like heat waves, far more than it boosts more moderate events.[15][16][17]

Unit-5

Rehabilitation, Reconstruction, and Recovery Phase

5.1 Recovery Targets and Actual Progress

The government planned the reconstruction and rehabilitation phase to be spread over three to five years (GOSL, 2005c). Nevertheless, there were pronouncements at the political level that all permanent housing needs would be met within a year. Over time, it has become clear that these were optimistic pledges. In fact, housing needs, for example, had not been met fully even by the end of 2006, while reconstruction of damaged schools and hospitals, and rehabilitation of roads, bridges, etc. is likely to take longer thanenvisaged.

5.1.1 Infrastructure

A total of 182 schools and 222 health institutions were affected by the tsunami. Targets in the education and health sectors included the reconstruction and renovation of 183 schools, four universities, seven Vocational Training Authorities, 444 internally displaced person (IDP) schools (schools used as refugee camps), and the reconstruction and renovation of 102 health institutions.

The pace of recovery, particularly of larger scale infrastructure projects, has been slow with an estimated 50 per cent of construction projects yet to commence by end 2006 (GOSL, 2006). By end 2006, 57 per cent of damaged schools were estimated to be in various stages of construction with only 10 per cent of projects completed and handed over (GOSL, 2006). Similarly, in the health sector only 55 of a total of 102 damaged buildings have been completed (**Table 4**[PDF 62.2KB | 1 page]).

The bulk of infrastructure damage was to roads and railways (**Table 5**[PDF 62.2KB | 1page]). A total length of approximately 800 kilometres of national road network and 1,500 kilometres of provincial and local government roads were damaged. The railway infrastructure on a 160- kilometre-long stretch along the tsunami-affected coastline was also severely damaged. The target date for completion of road and bridge reconstruction was set at 2009. As we shall discuss below, this target date may prove difficult to meet becauseof serious capacity constraints and cost escalations. The government itself has recognised that the construction industry does not have the necessary contractors, equipment, or skilled workforce for such a major reconstruction effort (GOSL, 2005a).

In addition to the rehabilitation of damaged infrastructure, new demands for infrastructure services were created by relocated communities. As described in detail later, a significant proportion of relocated households was found to have inadequate access to water, roads, pre-schools, and health clinics, and was worse-off than before.

5.1.2 Housing

The immediate requirement in housing was to provide "transitional" shelters where a total of 57,057 transitional shelter units were estimated to be needed to accommodate 50 per cent of the 500,000 internally displaced (GOSL, 2005a). The remainder of the displaced were assumed to have received shelter from friends, relatives, etc. Progress on providing transitional shelters, by and large, was fairly good; by end-2005 over 56,000 units had been completed.[7]

Table 6: Post-tsunami Numbers of Displaced Persons in Transitional Shelters[PDF 62.8KB | 1 page]

The total number of displaced persons as of January 2005 was estimated at 98,525, of whom 56,000 were in government camps (transitional shelter) while the rest were with families/friends (RADA, 2006). By end December 2005 the numbers of displaced had dropped to 85,525, of whom 53,000 were in transitional shelters. This figure was estimated at around 40,000 by end 2006.

There have been significant revisions regarding housing policy. An initial declaration by the government of a buffer zone between land and sea of 100 metres on the south and southwest coast and 200 metres on the north and east coast of the country led to the initiation of two types of housing programmes: (i) donor-built housing reconstruction and (ii) home owner-driven housing reconstruction. No reconstruction of houses (partially or fully damaged) was to be allowed within the buffer zone. Thus, all affected households within the demarcated buffer zone were to be provided with a house built with donor assistance on land allocatedby the state while allowing them to retain ownership of the original land. Households were not required to demonstrate ownership of the land to qualify for such assistance.

For those whose damaged houses were deemed to be outside the designated buffer zone, the government agreed to provide grants and loans for households to re-build at the same location. In order to qualify for the entitlement, households were required to prove ownership of the land. The criteria set down in terms of financing such reconstruction included an assessment of damages on a points basis where a house deemed to be more than 40 per cent damaged would qualify for a grant of SLRs.250,000 (US$2,500) in four instalments, based on progress. A grant of SLRs.100,000 (US$1,000) was made available to rebuild a house deemed to be less than 40 per cent damaged, disbursed in twostages.

Predictably, the buffer zone became a politically controversial issue from the very outset. The limits were set in a fairly arbitrary manner, not taking into account topographical and other relevant features of the land that would affect hazard risk. There was also dissatisfaction that the rules were not to be applied across all building units, with tourist enterprises being permitted to rebuild within the designated zone. Many of the tsunamiaffected fishermen, for example, argued the need to retain land close to the sea to sustain their livelihoods.

However, IPS-TS 2006 results showed that about 60 per cent of surveyed households thought that the government's original buffer zone rule was a "good idea." Data at the Grama Niladari Division (GND) level agreed with this finding; almost all Grama Niladaris (GNs) (village level government officers) interviewed agreed that the government's original buffer zone policy was "good." Paradoxically, they were also happy with the relaxation of the buffer zone in 2006. Although there were delays in providing housing because of the buffer zone rule, most households saw the prospect of better housing because of this policy: IPS-TS 2005 results found that most houses that were destroyed were smaller than the minimum floor area of 500 square feet specified for new houses under the donor-driven programme; in other words, a majority of households would get superior replacement houses, at least in terms of floor area.[8]Moreover, while all new houses are to be built with permanent housing materials, a large share of destroyed houses had been made of temporary housing material.[9]Also, householdsthatdidnothavelegalownershipoflandweregivenhousesunderthedonordriven programme.[10]These factors may have outweighed the costs incurred by many households due to delays in housing progress caused by the 2005 buffer zone rule.

But there was widespread popular opposition on many levels to the buffer zone policy. By end 2005, the government had largely abandoned the idea of enforcing the buffer zone restrictions. In particular, the scarcity of land with which to relocate affected households highlighted the impracticality of enforcing such a zone in the face of the need to ensure permanent housing within a reasonable period of time. A more relaxed buffer zone policy was announced in May 2006 along with a "Revised Tsunami Housing Policy."[11]It was essentially aimed at ensuring that all tsunami-affected people return to their houses or get new houses by the end of 2006. The policy document promised "a house for a house, regardless of land ownership." It defined two zones (not buffer zones)[12]with four housing options with the cost being shared by the government and donors (see **Box 2**[PDF 79.3KB | 1 page]).

The revised housing policy pushed the total housing needs to around 110,000 units. The key change was a decision to extend house eligibility to those without legal ownership of land outside the former buffer zone and to offer housing to extended family members living in the affected households.

Secondly, in contrast to the earlier policy, the government and donors were to jointly provide for a minimum of SLRs.500,000 (US$5,000) cash support to a tsunami-affected family to build a house. The significant cost escalation of construction material and labour, already clearly visible by end 2005, undoubtedly forced a revision of the earlier estimates. Under the revised policy, the GOSL was to provide the cash grant, initially reimbursed by different development banks and bilateral donors.[13]The grant of SLRs.250,000 (US$2,500) each from the government and donors was to be given in instalments; a first instalment of SLRs.50,000 (US$500) by the government matched equally by the donor and thereafter followed accordingly. The beneficiary was to receive full title to the property in the resettlement area (while retaining legal ownership of property within the re-designated buffer zone).

Finally, under the donor-built reconstruction programme, standard building requirements were set down by the GOSL of a floor area of 500 square feet; the donor was tomake available common infrastructure for housing clusters, and the government was to provide services up to the relocation site. The technical specifications were revised to ensure a more equitable basis. This was primarily a response to the initial experience where donors build houses of widely varying quality, with some houses costing only SLRs.400,000 and others being valued at over SLRs.1 million (US$4,000 to over US$10,000), causing friction amongstrecipients.[14]

The new housing policy requirements are identified under a homeowner-driven programme and a relocation housing programme. Overall, revisions to the housing policy (involving a higher cash grant component and a significant increase in the number of housing units deemed necessary) meant that questions would be raised about the ability to meet the costs of reconstruction within the commitments made by donors. It also created much confusion amongst the beneficiary households. Only about a quarter of the households surveyed in the IPS-TS 2006 were clear about their housing entitlements. Close to 60 per cent indicated that they would like legal advice regarding their rights as ahomeowner.

Table 7: Housing Requirements[PDF 62.9KB | 1 page]

As of November 2006, 46,531 partially or fully damaged houses had been rehabilitated, recording an 85 per cent completion rate. Nevertheless, a funding gap of US$ 107 million has been identified to complete most of the fully damaged houses (GOSL, 2006). In contrast to the progress in the homeowner-driven rehabilitation, progress in relocating tsunami-affected families has been much slower at only 50 per cent of required units having been completed by November 2006. As the target in this scheme was reduced substantially, the government estimates that sufficient funds are available to successfully complete this programme (GOSL, 2006).

The lack of clarity regarding housing entitlements and distribution was apparent from the survey results. The IPS-TS 2005 and 2006 data give information on the location of households with respect to the 2005 buffer zone, and house and land tenure for 559 households. Of these, 268 were eligible for the donor-driven new housing and 157 were eligible for owner-driven housing reconstruction. A total of 134 households were not eligible for a new house either because they were not homeowners before the tsunami(70 per cent of

134) or because they were outside the 2005 buffer zone, and were homeowners without land tenure (30 per cent of 134).

The survey found considerable inequities in the distribution of new houses. Housing progress was worst for people who were actually eligible for donor-driven new housing. About 65 per cent of such households were still to be found in temporary housing as of mid-2006. At the same time, about 56 per cent of households who were not eligible for a new house had received a house. There appeared to be inconsistencies between official government policy on housing and actual practice. Some households eligible to relocate under the donor-driven housing programme had rebuilt (19 per cent), while others eligible to rebuild under the owner-driven housing programme had relocated (16 per cent). Some households had received houses outside both these programmes, and others who were not eligible to receive a house under either programme had also received houses (see **Table 8**[PDF 64.8KB | 1 page]).

There were coordination problems across various donors, especially those who provided houses without adhering to government plans. According to local-level government officials, the reluctance of local non-government agencies to share information on aid distribution and their beneficiaries exacerbated the problem of coordination and monitoring.

Table 9[PDF 67.2KB | 1 page] confirms the significant regional variation in housing progress across the country. The uneven progress is, in part, due to the resurgence of conflict in the north and east of the country from end 2005 (**Figure 1**[PDF 67.2KB | 1 page]). The Eastern Province with the highest requirement of housing is lagging well behind. The Western Province was also behind the Southern Province, most likely due to greater difficulties in obtaining suitable land. The survey results were consistent with national data and showed that housing progress was best in the Southern Province for those outside the 2005 buffer zone. Less than 6 per cent of surveyed households in this region were in temporary housing. Housing progress was worst for those in the Eastern Province—for households both within and outside the 2005 buffer zone. Progress was especially poor for households affected by theconflict.

Key reasons cited for the overall slow progress in housing relocation have included a lack of commitment by nongovernment organizations (NGOs), impact of the conflict, lack of infrastructure in new locations, and poor communications strategies. In the case of donor housing, it has been pointed out that many donors that had large amounts of funds at their disposal and had pledged to build large numbers of housing units failed to meet even 50 per cent of their original targets (GOSL, 2006).

These findings are consistent with the survey results: lack of land and delays in obtaining donor assistance were cited as the main reasons for the slow progress in the donor-driven housing programme. The survey results also suggested that some people found that they were worse-off in terms of quality of housing and access to services (**Table 10**[PDF 85.4KB | 1 page]). There were claims that people's lifestyles were not taken into consideration when designing the new houses. For instance, the percentage of households using expensive sources of fuel for cooking such as gas and electricity increased from 10 per cent to 18 per cent, primarily because many of the new houses did not include a kitchen with a chimney to allow use of firewood forcooking.

The relatively smooth progress of the homeowner-driven housing programme vis-à-vis the relocation programme has encouraged the Reconstruction and Development Agency (RADA) to consider converting donor-driven housing projects to owner-driven programmes. Owner-driven housing programmes were reportedly more effective because families got the funds directly into their own hands.[15]Owner-driven housing projects not only progressed faster but also proved to be cheaper than donor-driven projects. The cost of a single donor-assisted housing unit was estimated to range between SLRs.0.4–1.6 million (US$4,000–16,000) even without the additional costs of site preparation, land-filling, drainage, and infrastructure provision (GOSL, 2006).

Considering these factors, RADA urged the international NGOs (INGOs) to transfer their tsunami reconstruction funds to the Treasury so that the government could direct funds to the victims. Additional funding of around US$50 million was needed to shift house construction previously under donor-driven programmes into owner-driven programmes (MFP, 2006). RADA argued that this would be the most practical way of resolving the logistical problems that INGOs faced in constructing houses themselves. Many donors had concerns about allowing the government to choose beneficiaries. To address those concerns and to ensure transparency, it was proposed that donors who opted to convert to the owner-driven programme could be given a list of beneficiaries, so that they could verify their needs and make payments directly to those families. However, with the sole exception of the Red Cross (which had complied with the request to cooperate with the government and converted two-thirds of their pledges (US$25 million)), INGOs showed no enthusiasm to transfer funds to the government.[16]

Escalating costs of building materials and skilled construction labour may also have contributed to slow progress in housing. All interviewed key informants reported that the cost of building materials and the wages of carpenters and masons had increased since the tsunami, with more than three-quarters stating that construction costs had increased by "a lot."

5.1.3 Livelihoods

An estimated 150,000 people lost their main source of income because of the tsunami.[17]About 50 per cent of these were in the fisheries sector, with others distributed among agriculture (4–5 per cent), tourism, and small and micro enterprise-related sectors (GOSL, 2005a). In all surveyed districts, people received some livelihood support. Types of livelihood assistance have included grants in kind (income-generating assets such as fishing boats and equipment), cash grants, loans, training (vocational, business support, etc.), cash-for-work, and temporaryemployment.

According to official sources, around 75 per cent of the affected families had regained their main source of income by end 2005 (GOSL, 2005a). This is supported by the survey results where 71 per cent of interviewed households claimed they had regained their previous source of livelihood. Only 8 per cent of heads of households had changed their livelihood,[18]while 21 per cent were still unemployed.[19]Thus, within a year of the tsunami, most people were back in their previous occupations. However, this did not mean that people regained their previous level of income. According to our householdlevel survey, on average close to 60 per cent of households considered their real family income—in terms of their ability to cover basic needs such as food and health—to be lower than their pre-tsunamiincome.

There were regional variations in income recovery patterns. Compared to the Southern Province, a higher proportion of Eastern Province households felt that they were worseoff. [20]According to the survey data—in both the Southern and Eastern provinces—poor distribution of livelihood-related assets, the buffer zone rule, and damages to work places have affected livelihood recovery. In addition to these, inability to participate in employment training (due to security reasons) has also slowed down livelihood recovery in the Eastern Province.

The damage to tourism infrastructure was quite significant and affected tourism-related livelihoods. A total of 53 (out of 242) large hotels and a further 248 small hotels were damaged or destroyed. In terms of hotel rooms, about 3,500 out of a total of 13,000 rooms available in medium to large-scale hotels were out of service in February 2005. Approximately 210 small enterprises that rely on the tourism industry were also destroyed along the coastline. They were mostly enterprises engaged in informal sector activities, and 190 of them were not formally registered with the tourist board. Of the 53 large-scale hotels damaged, 41 were back in operation by end 2005.

Despite the gradual restoration of infrastructure damage to tourist facilities, recovery in livelihoods in the sector was slow. Sri Lanka saw the largest ever number of tourist arrivals in 2004 and although recorded "tourist" arrival numbers did not fall steeply in 2005, many of those counted as tourists were aid workers visiting the country rather than genuine tourists. Tourism earnings, in fact, dropped sharply in 2005 (see**Table 3**[PDF 79.1KB | 1 page]). This suggests that many potential tourists were discounting Sri Lanka as a desirable travel destination in the aftermath of the tsunami. Recovery in tourism was further constrained by an escalation in ethnic conflict-related incidents from the end of 2005 that deterred the return of tourists in numbers comparable to pre-tsunami levels. Thus, while damage to infrastructure was relevant, it was the negative psychological impact of the tsunami and the subsequent political conflicts that seem to have played a more significant role in hampering recovery in the touristsector.

By contrast, recovery of fisheries-related livelihoods was swifter despite the fact that this was the most badly affected sector. Those engaged in fishing or related activities made up over one-third of the affected households. In total, over 100,000 people in the fisheries sector were displaced, 16,434 houses were damaged and 13,329 destroyed, and nearly 4,870 fishermen lost their lives with a further 136 reported missing (MFAR, 2006). In terms of equipment,as set out in **Table 11**[PDF 63.3KB | 1 page] an estimated 75 per cent of the fishing fleet (32,000 boats) had been totally destroyed or severely damaged (around 23 per cent were made un-seaworthy and 54 per cent were destroyed), and one million fishing nets were lost. Apart from these, the basic infrastructure of the fishing industry, such as boatyards, cold rooms, ice plants, and fish markets, were damaged. Damage to fishery harbours and other infrastructure facilities, government services facilities, coast conservation structures, etc., was placed at US$275 million, while repair and replacement costs for the damaged fleet were estimated at US$60million.

By end 2006, the fisheries harvest had been restored to 70 per cent of the pre-tsunami level with most of the affected fishers returning to their occupation (GOSL, 2006) The relatively rapid recovery of the fisheries sector can be attributed primarily to the relatively rapid progress in replacement of the fishing boats and equipment. The fisheries sector received more immediate assistance than other affected sectors and was able to replace most of its productive assets fairly quickly. A large proportion of destroyed boats had been replaced, and all damaged boats were repaired by end2005.[21]

However, there have been complaints about the poor quality of repairs. According to results of a survey carried out in December 2005, 8 per cent of the repaired boats were not being used due to dissatisfaction with the repairs.[22]Inadequate technical inputs and/or supervision, lack of boat-building knowledge and expertise on the part of NGOs (as well as the fishers), and the absence of proper contracts for after-sales services are blamed for poor-quality repairs, with boat-builders using low-quality material, reducing the thickness, etc., to meet deadlines and profit from theopportunity.

By end 2005, 78 per cent of the destroyed fishing fleet had been replaced (this figure had risen to 95 per cent by mid-2006)[23]with pledges for more than 6,000 boats still outstanding. But 19 per cent of the new boats provided were found not to be seaworthy. Lack of coordination in distribution efforts also led to conflicts and problems over the increasing numbers of boats, the quality of boats, etc. For many NGOs, the provision of small fishing boats was seen as an “attractive” tsunami aid programme that had high visibility but was easy to implement and not tooexpensive.

The result of this focus on providing small fishing boats, however, may be an oversupply of boats. Such an oversupply is likely to be unhealthy for the fisheries sector in the longer term due to the prospect of over-fishing. The oversupply can be attributed to several factors. There was no reliable data on the fishing fleet prior to the tsunami, and the damage assessments done by a large number of agencies had their weaknesses. Sometimes, people who were not familiar with the community of fishers were responsible for gathering data on previous boat ownership; this permitted many nonfishers to acquire boats. Misidentifications and overlaps occurred as a result of delays in issuing Entitlement Cards by MFAR. Also, the same beneficiary list was sometimes provided to more than one NGO to speed up the recovery process. There was a lack of coordination between the fisheries authorities and the NGOs, poor coordination between NGOs themselves, and competition amongst these agencies which led to errors and miscalculations (MFAR, 2006). Anecdotal evidence from district-level authorities indicated that reluctance to share information on the part of some NGOs made the task of coordinating even moredifficult.

Many genuine beneficiaries did not receive new boats because allocations were not properly targeted. Based on extrapolations from the findings of a survey done by the authorities in December 2005, only 6,067 of the 13,190 (46 per cent) boats distributed went to "genuine" beneficiaries. Some small, local agencies had provided boats to "friends and relatives" and had bypassed the fishing authorities.[24]

Access to credit is a vital element for livelihood recovery. Most of the tsunami-affected businesses were informal, small-scale industries—an estimated 25,000 microenterprises were damaged in the disaster. In addition, 15,000 tsunami survivors were previously involved in self-employed and informal sector activities such as food processing, coir manufacture, carpentry, and tailoring. While over forty organizations were involved in a host of micro-finance programmes established to assist small- and medium-sized enterprises (SMEs), the primary sources of credit were two major government finance schemes.

Prior to the tsunami, the Central Bank of Sri Lanka had been implementing a microfinance scheme (Susahana) through the two state-owned commercial banks. The Susahana loan is provided with no repayment required for the first year and interest at a fixed rate of 6 per cent thereafter. The National Development Trust Fund (NDTF) also offered similar terms through its partner organizations. Following the tsunami, lending escalated and by June 2006, 25,735 loans and grants of SLRs.4,769 million (US$47 million) had been provided to micro-, small-, and medium-sized enterprises (RADA, 2006). The majority of these loans were disbursed in the south and west of the country. The Susahana scheme had reportedly disbursed US$36 million to 8,000 borrowers in the tsunami-affected areas by September 2005. Of these loans, 75 per cent were in the south and west of the country. 60 per cent of the NDTF scheme was also disbursed in the south, with only 40 per cent going to the north and east of the country (GOSL, 2005a).

Unfortunately, the procedures and processes associated with loan approval and disbursement seemed weighted against those worst-affected by the tsunami, with the emphasis placed on ensuring high probability of repayment or loan recovery rather than on meeting the credit needs of those most in need. Despite claims to the contrary, and its stated intention to reach the micro-entrepreneurs, the Susahana lending scheme had been set up in a way that made it very difficult for small tsunami-affected microentrepreneurs to obtain access to the loans. The conditions for access were quite onerous. Guarantors with a permanent income above a certain threshold level were required before a loan was approved. Collateral was required, for which land within the buffer zone was not acceptable. Loans were only to be given to businesses registered before the tsunami, which ruled out many smaller, unregistered businesses. These conditions ruled out, in most cases, people hoping to take up new livelihoods in response to their changed post-tsunami circumstances, from causes such as, for example, the death of the main earner, disability, or new responsibilities for the care of family members.

In fact, it has been acknowledged that the many affected businesses in the buffer zone were hit especially hard because they were unable to access bank credit, and that banks have been reluctant to relax their collateral requirements (GOSL, 2005a). It was also found that very few new clients were reached by the subsidized schemes and a considerable number of small entrepreneurs were left with no access to credit. The survey results confirm these findings: Only a few households (16 per cent of the sample) even applied for credit. Many households did not apply for loans because they were not aware that they were eligible to receive them, orbecausetheyfeltthattheirapplicationswouldberejected.Mostofthosewhoapplieddid receive a loan, but they had to provide collateral and sometimes a guarantor in order to obtain it. The average size of the loan was fairly small at less than SLRs.100,000 (US$1,000).

On a positive note, there is evidence to suggest that micro-credit providers improved cooperation and coordination in an attempt to try to maintain the micro credit culture that the post-tsunami supply of micro-credit funds at low interest rates was in danger of undermining.

In the immediate aftermath of the tsunami, a cash grant livelihood assistance programme was announced in January 2005, offering a monthly cash grant of SLRs.5,000 (US$50) to each tsunami-affected household for a period of four months. Over 250,000 households received the first two instalments on time immediately following the introduction of the programme.[25]However, concerns were soon expressed in some quarters about the need for proper targeting. The Ministry of Finance Directives then directed local government officials to revise the lists of eligible beneficiaries according to a set of eligibility criteria. There were complaints from both affected families and even some government officials that the criteria were not very clear, or were not in the public domain. This created much confusion and payments halted at a time of acute need. The government circulars announcing the revised criteria were quite broad. This meant that local government officers had considerable room to exercise discretion, resulting in wide variations in interpretation, allegations of corruption, and delays and long back-logs of appeals. Interviews with relevant stakeholders, including both affected families and government officials, suggested that households having access to "regular income" were no longer eligible. It took several months to draw up new lists of those eligible to receive the grant, with the number of recipients eligible for the third payment declining by 25 per cent to 165,000 while the fourth monthly payment was still "on-going" a year after the tsunami (GOSL,2005a).

In assessing the value and benefits of changes to this programme, it should be noted that even households with a "regular" post-tsunami income had suffered a major loss of wealth in terms of property and possessions, and were cash poor. There was a high probability that they would have to borrow from high interest, informal sector lenders to meet many pressing needs. The decision to take recipients with a regular income off the list after only two monthly payments generated perverse incentives, effectively penalizing not only those who had held on to previous jobs, but perhaps, even more importantly, those who had managedto obtain regular employment after the tsunami. If donor assistance was available for this programme—and it is hard to see why funds were not available if the May 2005 pledges were honoured—these cutbacks seem hard to justify. Moreover, since bank accounts had to be opened for the cash grant transfer, the system was extremely cost effective—many other tsunami livelihood projects had far higher transactions costs with as much as 30 per cent spent on administrativeoverheads.

This experience with trying to shift the livelihoods grants programme to a targeting scheme only a couple of months after the disaster holds lessons of much wider applicability for post-disaster situations. By all accounts, the initial grants scheme was very effective in reaching most of the affected population. It provided cash at a time of great need, and even helped to link people with little prior engagement to the formal financial sector because they had to set up bank deposit accounts to receive the funds. Unfortunately, the scheme only provided two timely grants before the emphasis shifted to targeting. In theory, it seems obvious that grants should be distributed to those who are "truly needy," and therefore that grants should be properly targeted. But, in practice, the costs of such narrow targeting must also be taken into account. In the immediate aftermath of a major disaster, particularly in a poor country, the vast majority of affected people are "truly needy." Markets are dislocated, assets have been destroyed, and records are destroyed or missing. In such circumstances, the cost of trying to exclude a relatively small proportion of people from the small temporary grants scheme through targeting can far exceed any benefits.

In Sri Lanka's case, grants were delayed for all recipients, including those in dire need; administrative resources were diverted away from the urgent tasks of recovery and reconstruction, which created room for petty officials to engage in corruption and aggravated community divisions and tensions. Any expected benefits from the rush to implement targeting, only two months after tsunami, must be contemplated in the light of the "success" with targeting achieved in Sri Lanka's long-established national poverty alleviation programme (Samurdhi): the leakage in the Samurdhi programme is estimated to be 40 per cent!

5.1.4 Trauma andStress

The survey found some evidence of mental and physical health problems related to the tsunami. About 11 per cent of the households knew someone who had committed suicide because of the tsunami. There were reports of more sleeping difficulties, and children experiencing nightmares that were linked to trauma associated with the tsunami. A large number of households—33 per cent of households in the sample—had been offered or given counselling for distress. The percentage of people who received counselling was higher in the Eastern Province, possibly because counselling was already taking place in those areas for sufferers of conflict-related mental health problems.

Twelve per cent of households had family members who had been injured in the tsunami or whose health had deteriorated afterwards: A large proportion of such households (77 per cent) claimed that this affected their income-earning capacity and/or day-to-dayactivities.

In many cases, the decline in school attendance after the tsunami has not been fully reversed and attendance was reported to be poor even at the end of 2006, with over 25 per cent of children still not attending school (GOSL, 2006). These findings are supported by the survey; nearly 30 per cent of households reported having children who had not yet restarted schooling after the tsunami. The schooling problem existed in areas other than just those affected by conflict, indicating that the problem cannot solely be attributed to the conflict. Thirty-one per cent of the households reported that the performance of children who were attending school had fallen.

5.2 Assistance

There was a strong international public response to the appeal for recovery assistance. Multilateral and bilateral donors and NGOs pledged US$3.4 billion for post-tsunami recovery activities at the first Sri Lanka Development Forum held in May 2005 (MFP, 2005; GOSL, 2006).[26]This comprised (concessional) loans amounting to US$798 million and the balance in grants. NGOs pledged a total of US$853 million on a grant basis. The International Monetary Fund pledged US$268 million by way of both emergency relief and a debt moratorium. Bilateral donors extended the debt moratorium providing further relief of US$263million.

The government reported that around US$2.2 billion (of the total pledges of US$2.8 billion, which excluded debt relief) could be considered as firm commitments from the international community (GOSL, 2005a). In addition, an estimated US$150 million was reportedly received as contributions from domestic sources, without taking into account relief disbursements (for which figures are not available). However, actual committed funds made available to the government appear to have fallen over time to US$ 2 billion from the previous "firmly committed" figure of US$2.2 billion (**Table 12**[PDF 65.1KB | 1 page]). At the end of the second year of reconstruction, total foreign grant expenditure relative to commitments was only 35 per cent and foreign loan expenditure was 40 per cent. While individual agencies varied in performance, the bilateral and multilateral agencies had spent on average 29 per cent and 32 per cent respectively of committed funds by end 2006. In addition, although the initial needs assessment was placed at US$2.2 billion and a total of US$2.9 billion was secured as committed funds, the funding gap for the reconstruction process as at end 2006 was estimated at US$247 million (**Table 13**[PDF 79.1KB | 1 page]).

This low rate of expenditure (absorption of available assistance) is not surprising and highlights the constraints that hinder rapid reconstruction. Sri Lanka's past performance in aid absorption has been poor: The rate of aid utilization in recent years has been only around 20–22 per cent, having improved from around 13–15 per cent towards the end of the 1990s. Many reasons have been cited for such low levels of aid utilization, including political interference with regard to planning, implementation and allocation of funds; staffing and related problems in project management; implementation delays (including infrastructure bottlenecks, complex and costly procurement procedures), and excessive conditionality imposed by donors. Another important factor has been the non-availability of adequate counterpart funds (local funds withappropriation).

Despite the initial euphoria in the aftermath of the tsunami about the volume and adequacy of foreign assistance, it became clear over time that a substantial proportion of reconstruction would have to be domestically financed. In 2006, the government had committed US$1.5 billion in domestic funds (over one-third of total reconstruction costs as initially estimated) for tsunami reconstruction. Thus, at the end of two years, two problems with the funding of the reconstruction effort could be identified: the inability of the country to utiliseavailable foreign assistance in a timely manner, and a widening gap between the actual amount of foreign assistance received and reconstruction requirements.

5.3 Delivery and Coordination ofAssistance

Coordination of the relief and reconstruction effort emerged as a key issue from the beginning of the relief effort, and it continued to be a major issue as the reconstruction and recovery phase started. In Sri Lanka, coordination was required across three groups: (a) among the various government agencies, (b) between the numerous donor agencies, and (c) with the LTTE which was in de facto control of a part of the country that was heavily affected by the tsunami. Sri Lanka's governance structure is such that provincial government agencies have considerable powers, and this meant that coordination was required not only between the various central government agencies, but also between the central government and local government agencies. The involvement of major bilateral and multilateral donor agencies naturally required that their activities be coordinated, both among themselves and with the government. Sri Lanka has long experience working with major donor agencies and several INGOs maintain long established operations in the country. There had been some welcome moves towards donor coordination even prior to the tsunami in the context of conflictrelated donor reconstruction programmes. Thus, the World Bank, ADB, and JBIC had already established a partnership that enabled a needs assessment to be done immediately after the tsunami. However, coordination with donor agencies and NGOs became a vastly more complicated issue due to the numbers and practices of the numerous international NGOs (not counting large numbers of individuals and small groups) who came in after the tsunami. Before long, some 180 NGOs were operating in the tsunami-affected regions of Sri Lanka, making coordination a difficult and complex task. In addition, establishing effective coordination with the LTTE raised difficult and sensitive political and constitutionalissues.

As mentioned previously, the government initially set up a Centre for National Operations (CNO) and three task forces to address the coordination challenge. Subsequently, the Task Force for Rebuilding the Nation (TAFREN) became the lead agency charged with the task of overseeing the recovery and reconstruction phase.[27]While an overarching authority such as TAFREN was clearly necessary to coordinate post-disaster reconstruction, the structure and composition of TAFREN was such that it was not able to be fully effective in that role.

TAFREN was dominated by private sector representatives, and lacked links to line ministries and clear lines of authority. This greatly hampered its ability to efficiently coordinate activities among government agencies. Reconstruction activities had been divided into sectors, such as housing and water and sanitation. This meant that coordination across several agencies, often falling under different ministries, was needed to implement even relatively minor reconstruction activities. For example, three different agencies had to be brought together to ensure that new housing units could get access to water, sanitation, and electricity supplies. Though TAFREN attempted to monitor the line agencies and to play a coordinating role as a "one-stop-shop," its effectiveness was limited because its role and authority remaineduncle ar.

In November 2005, a decision was taken to amalgamate TAFREN, TAFOR, and the Task Force for Logistics and Law and Order (TAFLOL) into the Reconstruction and Development Authority (RADA). RADA was given wide powers by an Act of Parliament. It was given authority over organizations working on post-tsunami reconstruction and development, and could monitor and control their activities as well as issue "licenses" that would provide legal authority for them to carry out specific activities. In theory, this would enable RADA to exercise efficient coordination. However, potential drawbacks to the vesting of such wide powers in a single, centralised body are that it could overly limit the powers of all other agencies and actors, ignore inputs and feedback from line ministries and local-level agents, reduce flexibility and scope for local initiatives and actions, and make the reconstruction effort too centrally-driven.

Field observations confirmed that lack of adequate coordination resulted in considerable mal-distribution of aid. This was clearly visible, for example, in the way that the distribution of new boats had been conducted, and—as described in a report by the Auditor General—in payment of housing assistance.[28]Large payments were made for houses with minor or no damage, NGOs provided houses to families who were not at all affected by the tsunami, and government grants were given to people who had already received houses constructed by NGOs.

The lack of adequate coordination was not only due to weaknesses on the part of the government-established coordinating bodies. A major problem was that some NGOs were simply not willing to be "coordinated," preferring to act alone pursuing their own agendas. INGOs, as well as some domestic NGOs (particularly those with good foreign links), had access to relatively large amounts of money. With their own funds secure, they saw few incentives to improve coordination. In fact, some were openly hostile to any government action that seemed to place "controls" on their independence.

Further, the presence of large numbers of donors/NGOs at times led to competitive behaviour. In several places deep mistrust developed between local NGOs (who have often been working in the local area for many years) and some INGOs and other foreign agencies who came to distribute tsunami assistance. Local NGOs claim to have been "crowded out" by some of the better financially endowed larger INGOs, who "poached" staff and resources. INGOs varied widely in experience, skills, and operating styles. Many "new" INGOs lacked experience and local knowledge, and in their haste to spend funds and disburse goods and equipment often disregarded local circumstances and community needs. Certainly some INGOs and agencies had valuable expertise in largescale disaster relief (such as provision of transitional shelters and other relief measures), but domestic NGOs (and INGOs that have operated in Sri Lanka for a long period) usually have a much greater appreciation of local conditions and sensitivities. Greater interaction, engagement and coordination between them would have clearly benefited the overall relief and reconstruction effort. New mechanisms have since been put in place to improve coordination of donor activities at regional and local levels through regular meetings and consultations held by regional administrative officers. However, it is too early to judge theireffectiveness.

The problems caused by some INGOS should not, however, be seen as typical of all INGOs. In fact, in many cases INGOs played a very positive role. About 44 per cent of the households surveyed felt that INGOs were more effective in delivering aid, while only 11 per cent felt that the local NGOs were moreeffective.

Coordination with the LTTE proved to be the most difficult and contentious issue. While discussions to establish a mechanism for aid-sharing began soon after the tsunami, a mutually acceptable arrangement for aid-sharing to enable assistance to flow into the LTTE-controlled areas proved elusive. Sections within the government and within the majority community were opposed to any deal that even appeared to provide de facto recognition of the LTTE as the administrative power in regions controlled by it. The LTTE, for its part, was unwilling to accept an arrangement that diluted its administrative and political power in areas under its control. After long, drawn-out negotiations, a MOU setting out an aid-sharing deal between the GOSL and the LTTE, the Post-Tsunami Operation Management Structure (P-TOMS), was signed in June 2005. The P-TOMS agreement envisaged the setting up of a Regional Fund to allow donors to channel tsunami funds directly to the Northern and Eastern Provinces. A multilateral agency (anticipated to be the World Bank) was to be appointed as the custodian.

However, this agreement promptly ran into political opposition. It was challenged in the courts through a fundamental rights petition and the Supreme Court ruled in July 2005 that certain elements were to be put on hold pending clarification,[29] though the overall mechanism was not unconstitutional. The situation was aggravated further by the fact that several major donors who had supported the idea of a joint mechanism for aid distribution between the GOSL and the LTTE declined to channel aid directly to the Regional Fund once the MOU was signed, claiming that the LTTE remains a "proscribed terrorist organization" in their countries. After the presidential election in November 2005, with the election of a new President who publicly opposed the agreement, P-TOMS became totally inoperative. The conflict between the GOSL and the LTTE intensified soon after. The renewed violence disrupted not only the lives of the tsunami-affected people in the area, but also led to a sharp increase in internally displaced persons, placing further pressure on aid agencies. There can be little doubt that these problems led to inequitable distribution of aid, with the most severely affected North and East missing out on their fairshare.

While these political factors affected the distribution of aid across regions, there has been no strong evidence of widespread corruption or political influence in the distribution of aid within the provinces. Though some petty corruption appears to have affected the distribution of cash grants once targeting was introduced, the overall aid distribution appears to have been reasonably free of overt political interference and corrupt practices. According to the household survey respondents, very few households had paid bribes to government or NGO officials to receive aid, and very few were aware of instances where politicians had interfered directly.

5.4 CostEscalation

As mentioned, at the time of the May 2005 meeting of the Sri Lanka Development Forum, the aid promises of the international community seemed to more than cover all reconstruction financing needs. Unfortunately, there was a fundamental flaw in the estimates: They were based on costs and prices that prevailed immediately after the tsunami disaster, adjusted for some expected national-level inflation. These estimates have proven to be gross underestimates; clear evidence soon emerged that construction costs were rising rapidly over time. This was, of course, not surprising. The scale of construction that was envisaged was several times larger than that undertaken in a normal period, and naturally implied sharp increases in demand for construction labour andmaterials.[30]

Total construction costs for the planned houses for tsunami-affected families had already risen by 30–50 per cent by August 2005, according to data obtained from companies and organizations involved in house building and from field interviews. By September 2006, costs had exceeded initial estimates by 60–80 per cent ormore.

Information from field interviews indicated that these increases are driven primarily by higher wages for skilled labourers (such as carpenters, painters, and masons), whose wages have doubled in some locations. This is confirmed by data from the construction industry body, the Institute for Construction Training and Development(ICTA)

Prices of particular building materials, such as cement, sand and bricks, saw a sharp increase (**Figure 3**[PDF 68.6KB | 1 page]). However, it should also be noted that price increases for importable materials were significantly lower than overall construction cost increases (**Figure4**[PDF 68.6KB | 1 page]). These data are consistent with survey information: More than three-quarters of the surveyed key informants said that wages of carpenters and masons and prices of building materials had increased "a lot" since the tsunami. This has some important implications: Increased local demand can be met without major price increases when construction materials are importable, but price increases are unavoidable for domestically sourced ("non-tradeable") materials and labour. The faster the reconstruction programme, the higher the price and cost escalation will be, with less "construction" actually occurring for a given amount of expenditure.

5.5 Broader EconomicImpacts

The typical pattern for economies struck by unanticipated natural disasters has been to experience a brief deceleration in growth, followed by a rebound as a result of the stimulus from reconstruction programmes. GDP growth dipped in the first quarter of 2005 but subsequently showed a strong resurgence. Predictably, the fisheries and hotels and restaurants sub-sectors experienced a sharp contraction in output while the construction sub-sector experienced strong growth (**Table 15**[PDF 78.9KB | 1 page]). The recovery was better than initially anticipated, and was broad-based. There was continued expansion in industry and services, as well as a recovery in agriculture following improved weather conditions, and this good growth performance continued into 2006.

The tsunami reconstruction undoubtedly brightened prospects for Sri Lanka's short-term economic outlook. The total investment/GDP ratio increased by 1.5 percentage points in 2005, much of it driven by government investment. In fact, the investment/GDP ratio improved to 28.7 per cent in 2006. This was reflected in higher imports of investment goods and constructionactivities.

Table 16: Post-Tsunami Fiscal Outlook[PDF 78.9KB | 1 page]

While the additional tsunami-related expenditure was budgeted to be met by foreign grants, financing needs increased owing to cost escalation and the increase in the numbers of housing units required. Despite added fiscal pressures, there was little effort to curtail spending in other areas, fuelling inflationary pressures from policies unrelated to tsunami reconstruction.[32]Fiscal profligacy in the face of higher spending on tsunamirelated rehabilitation aggravated inflationary pressures in the economy. The initial response to rising inflationary pressure was slow, and interest rates remained unchanged allowing credit growth to expand at a rate of over 20 per cent. Broad money growth in 2006 was 17.8 per cent, and inflation rose from 11.6 per cent in 2005 to 13.7 per cent in2006.

The Sri Lankan electorate has traditionally been very sensitive to inflation. Elections were due in late 2005 and the government was keen to keep inflation in check. This generated political pressures to resist any exchange rate depreciation which could have intensified domesticinflation.Thereissomeevidencetosuggestthatthetsunamirelatedcapitalinflows were used to prop up the nominal exchange rate in 2005, and this may have been a factor in the slow absorption of aid flows. There was also a significant increase in inward remittances from 6.7 per cent of GDP in 2004 to 7.7 per cent by 2006. While some of the increase may reflect assistance provided to affected family and friends, the increase could also reflect better earnings performance of the majority of migrants employed in the oil rich Middle Eastern countries. Sri Lanka managed to record an overall surplus of US$500 million on the BOP in 2005 (compared with a deficit of US$205 million in 2004) and official reserves showed a sharp improvement.

Figure 5: Nominal and Real Effective Exchange Rate[PDF 67KB | 1 page]

The influx of increased foreign capital reversed the sharp devaluation of the rupee vis-àvis the US dollar at end 2004, leading to a nominal appreciation of over 5.5 per cent in the week following the disaster. [33]The nominal effective exchange rate (NEER) appreciated by 7.7 per cent in 2005 (compared to a depreciation of 11 per cent in2004).

The higher nominal appreciation in the context of relatively high domestic inflation led to a real effective exchange rate (REER) appreciation of 12.7 per cent (as against a depreciation of 1.1 per cent in 2004). To the extent that this real appreciation was a result of tsunami-related aid flows, it would have had the standard Dutch disease effects on Sri Lanka's exports.

Aid flows following a disaster are, by their nature, temporary. As the tsunami-related capital inflows eased over time, the government was compelled to seek other forms of external funds to finance the expanding fiscal deficit. In December 2005 Sri Lanka sought a sovereign credit rating as the first step to raising an estimated US$0.5–1 billion in the international bond market. Sri Lanka was assigned a BB- (below investment grade) and a B+ by two rating agencies. But, with the escalation in domestic hostilities the credit outlook was downgraded from stable to negative in April 2006. In 2006, for example, the government raised US$580 million by issuing 2–3-year maturity dollar bonds (Sri Lanka Development Bonds) at rates of 120–140 basis points above the London Inter-Bank Offer Rate (LIBOR) despite the inherent risks involved in recourse to foreign commercial borrowings.

Thus, the overall macroeconomic trends raised serious concerns about the sustainability of the country's post-tsunami burst of GDP growth once the temporary aid flowsceased.

5.6 SocialCohesion

The spontaneous solidarity that united communities immediately after the tsunami rekindled hopes that the ethnic divisions that had cost the country so dearly in recent years might finally be waning. However, the North and East have since seen an escalation in hostilities between the GOSL and the LTTE, and the country has been plunged back into large-scale conflict. We have already referred to the political problems that derailed the P-TOMS agreement on tsunami aid allocations to the LTTE-controlled areas and undermined the possibilities for a lasting peace. This is in sharp contrast to what happened in Aceh, Indonesia, where the tsunami created conditions for the cessation of a long-running secessionist war.

There is evidence that the post-tsunami relief and reconstruction activities may have contributed to increased social tensions among various groups in affected communities. Many poor households who were unaffected by the tsunami were unhappy because they were ineligible for tsunami aid. This was particularly important in the conflict-affected Eastern Province where large numbers of people have suffered from the two-decadelong conflict and have been internally displaced for long periods of time.

The manner in which tsunami-damaged physical assets were replaced in some instances undermined the social capital of an area by exacerbating existing tensions and rivalries. In some places, tensions developed between fishers and other groups because the latter felt that the fishing industry received greater attention. Similar tensions emerged in the housing sector. The substantial differences between different types of houses built by different organizations, and the different levels of grants given to different groups created perceptions ofinequity.[34]