### Chapter 5 – Hazards

#### The nature of storm hazards

**You need to know:**
- the characteristics and spatial distribution of tropical storms
- the hazards associated with tropical storms
- the magnitude, frequency, regularity and predictability of tropical storms.

**What is a tropical storm?**

A tropical storm (cyclone (India), hurricane (North Atlantic), typhoon (south-east Asia)) can cause extensive damage and loss of life in many parts of the tropics. A tropical storm must have average wind speeds in excess of 120 km/h (75 mph) and can be 500 km in diameter.

**Formation and development of a tropical storm**

Once a tropical storm has started to form, it will soon develop its distinct and clearly defined rotation:
- Warm, moist air rises rapidly in its centre, creating a central vortex, to be replaced by air drawn in at the surface.
- The eye is often characterised by a column of dry, sinking air. The eye wall is the most damaging part of a storm.
- The rising air cools, condenses and towering cumulonimbus clouds form.
- When condensation occurs, latent heat is released, which effectively powers the storm.
- Cloud and rain extend in a series of waves.
- A storm starts to decay as it reaches land, as the supply of energy and moisture is cut off.

**Factors in the distribution of tropical storms**

Figure 2 shows the distribution and frequency of tropical storms. The vast majority are formed in the tropics, although they do extend beyond this region, e.g. China, Japan and eastern USA.

**What are the hazards associated with tropical storms?**

**Strong winds**
- Wind with speeds in excess of 120 km/h (75 mph) are capable of causing significant damage to structures, infrastructure and communication networks.
- Damaged power lines often lead to disruption through electricity cuts and, occasionally, fires.

**Storm surges**
- A storm surge is caused by the intense low atmospheric pressure of the tropical storm (forcing the sea to rise vertically) together with the powerful surface winds.
- They are a major cause of widespread devastation and loss of life.
- They also inundate agricultural land with saltwater and debris, pollute freshwater supplies and destroy housing and infrastructure.

**Coastal and river flooding**
- A tropical storm can generate torrential rainfall in just a few hours.
- This can trigger flash flooding at the coast, particularly in urban areas where the drainage system cannot cope.
- A tropical storm weakens as it moves inland, but river flooding may still occur due to the intensity of rain.

**Landslides**
- Many landslides are triggered by tropical storms.
- Intense rainfall increases soil pore water pressure, weakens cohesion and triggers slope failure.
- The additional weight of water exacerbates the problem.
- In 1998 Hurricane Mitch triggered multiple landslides that killed 18,000 people in Central America.

**Frequency and magnitude**

There is no clear evidence that the numbers nor intensity (magnitude) of storms are increasing as global temperatures increase. Figure 3 shows no clear trend.

**Rotation of the Earth (the Coriolis effect)** – ‘spin’ is needed to initiate the rotation of a tropical storm, which increases with distance from the Equator. Storms do not usually form between 5°N and 5°S.

Uniform wind direction at all levels – winds from different directions at altitude ‘shear off’ the vertical development of a tropical storm, restricting height and intensity.

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**Figure 1** Cross-section through a tropical storm: note the degree of symmetry around the eye.

**Figure 2** The distribution and frequency of tropical storms. The percentages show the proportion of the total global number of storms in each region.

**Figure 3** Number of hurricanes in the North Atlantic and Caribbean, 1944–2010
5.15 The nature of storm hazards

5.14 The nature of storm hazards

Chapter 5 – Hazards

Impact of tropical storms

In common with all natural hazards, it is possible to identify a range of impacts of tropical storms (Figure 1).

<table>
<thead>
<tr>
<th>Impact</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>Initial and direct impacts of a tropical storm</td>
<td>Hurricane Sandy, USA (2012) caused extensive destruction to Eastern USA.</td>
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<tr>
<td></td>
<td>– strong winds, storm surge, heavy rain, flooding.</td>
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<tr>
<td>Secondary</td>
<td>A consequence of the primary impacts, such as</td>
<td>Landslides caused by Hurricane Mitch in Central America (1998) killed thousands.</td>
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<td>freshwater flooding and landslides.</td>
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<td>contamination of freshwater habitats and aquifers, destruction of coastal environments and pollution.</td>
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<tr>
<td>Social</td>
<td>Impacts on people, including death, injury and</td>
<td>Hurricane Katrina, USA (2005) displaced over one million people from New Orleans.</td>
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<td></td>
<td>disruption to people’s everyday lives.</td>
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<tr>
<td>Economic</td>
<td>The financial costs of a tropical storm to</td>
<td>Hurricane Katrina (2005) is the USA’s costliest tropical storm disaster, with damages estimated at US$150bn.</td>
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<td>local people and governments. Increasingly, the</td>
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<td>financial burden is supported by the</td>
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<td></td>
<td>insurance industry.</td>
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<tr>
<td>Political</td>
<td>Tropical storms can lead to political issues</td>
<td>The Myanmar government did not encourage international support in the wake of Cyclone Nargis. This left many local communities having to cope themselves. A total of 80,000 people died.</td>
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<tr>
<td></td>
<td>of command and control. To what extent is it a</td>
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<td>local, regional, national or even international</td>
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<td>issue? A disaster of national emergency status</td>
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<td></td>
<td>often receives greater personnel and financial</td>
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<td></td>
<td>support.</td>
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</table>

Preparedness, mitigation, prevention, adaptation

There are several approaches that can be adopted to reduce the impact of a natural hazard.

Preparedness

Increasing people’s awareness and through their actions minimise the likely impact of the hazard:
- through education and public awareness campaigns, people can make minor structural improvements to buildings (e.g. stronger doors and windows)
- by preparing emergency supplies and plan evacuation routes
- by insuring property
- by prediction of the likely course using satellite/radar tracking and computer models such as SLOSH.

Prevention

Prevention is actions aimed at reducing the chance of large-scale events from starting (e.g. wildfires). Scientists have unsuccessfully tried cloud seeding (dropping crystals into clouds to cause rain) to dissipate tropical storms. Now the focus is on forecasting, together with mitigation and adaptation, in reducing the impacts of tropical storms.
Mitigation

Actions aimed at reducing the severity of an event and lessening its impact, which can include structural intervention, disaster aid and insurance cover.

- Structural responses offer some protection from storm surges by soft engineering schemes (planting trees and building up beaches) or hard engineering, such as constructing sea walls. Grants are available to make householders homes more resilient.
- Disaster aid can take two forms:
  - immediate humanitarian relief in the form of search and rescue, food, water, medicine and shelter
  - longer-term reconstructional aid that seeks to support recovery and reconstruction.

Aid can also come from trading blocs such as the EU or from international bodies such as the World Bank or the United Nations. Charities and other NGOs also provide valuable support, often reflecting generous donations from members of the public.

- Insurance cover is widely used to mitigate the effects of tropical storms, particularly in HDEs. However, the rich can afford insurance, the poorest in society cannot. Many of those who were most affected by Hurricane Katrina in New Orleans 2005 were the poor who did not have insurance; they refused to be evacuated in order to safeguard their property.

Adaptation

Tropical storms cannot be prevented so people simply have to accept that natural events are inevitable and learn to live with the threat but do what they can to minimise the risks.

Land-use zoning aims to reduce the vulnerability of people and property at the coast. Most commonly this allows only low-value land uses (e.g. recreation) to occupy the coastal strip. In parts of north-eastern Florida, coastal properties are raised above the ground on stilts and have non-residential functions on the ground floor (Figure 2).

Preparedness involves increasing people’s awareness and ability to respond appropriately when warnings are issued.

Mitigation can involve structural responses (such as disaster aid and insurance). Preparedness involves increasing people’s awareness and ability to respond appropriately when warnings are issued. Mitigation can involve structural responses (such as disaster aid and insurance). Prevention is not really feasible given the nature of tropical storms.

There are several approaches to reducing the impacts of tropical storms which can be categorised as environmental, social, economic and political.

- There are several significant impacts of tropical storms which can be categorised as environmental, social, economic and political.
- There are several approaches to reducing the hazards associated with tropical storms – preparedness, mitigation, prevention and adaptation.
- Preparedness involves increasing people’s awareness and ability to respond appropriately when warnings are issued.
- Mitigation can involve structural responses (such as a sea wall) or behavioural responses (such as disaster aid and insurance).
- Prevention is not really feasible given the nature of tropical storms.
- Adaptation involves learning to live with the threat and being able to respond accordingly, (e.g. cyclone shelters).

Reducing the impacts of tropical storms

Although it is not possible to prevent a tropical storm from forming or making landfall, it is possible to take measures aimed at reducing its impacts.

These measures can be behavioural (e.g. increasing people’s preparedness) or structural, which can involve small-scale building adaptations, as well as larger-scale constructions, such as sea walls. In locations that are very prone to tropical storms, such as the Philippines and Bangladesh, people have had to adapt to the problems, making use of structures such as cyclone shelters.

Over to you

Produce a spider diagram to clarify the various impacts of tropical cyclones.

What is a wildfire?

Wildfire is the generic name used for an uncontrolled rural fire (brushfires in Australia, bushfires in North America). They affect different layers of vegetation (Figure 1).

Wildfires are a hazard of increasing threat because of enhanced physical pre-conditions, a growing population and an increase in urbanisation and landscape change.

What conditions favour wildfires?

Wildfires are the result of certain conditions.

Vegetation type – the fuel characteristics

The type and amount of fuel (vegetation) influences the intensity (the output of heat energy) and rate of spread (degree of threat).

- Grassland fires rarely produce the same intensity as forest fires.
- The eucalyptus is fire-promoting – oils within the leaves can explode!

Climate and weather conditions

Most wildfires occur during or after prolonged dry periods. Strong, dry winds blowing from continental interiors or deserts help the drying process and are ideal conditions for lightning storms – a common form of ignition. Wind strength determines the rate of spread (Figure 3).

1. Desert winds originate from a clockwise flow of air around a high-pressure system east of the Sierra Nevada mountains.
2. Air from the mountains is compressed and warmed, becoming less humid. This tower humidity dries out vegetation and can fan any existing fires.
3. Winds squeeze through canyons with gusts between 65 and 95 km/h
4. Strong winds create turbulence and can make intermittent travel difficult.

Fires spread from the forest floor to the tree canopy - the ‘ladder effect’

A crown fire spreads across tree canopies

A surface fire burns across surface vegetation

A ground fire burns underground in layers of dry organic peat

Student Book pages 262-7

See page 261 of the student book for a case study in Bangladesh.

See page 263 of the student book for details of El Niño, which can create conditions suitable for wildfires.
Wildfires can have a significant impact on local and global systems.

- Local ecosystems may be affected, with habitats destroyed, animals killed or displaced and soil nutrient stores depleted.
- Toxic ash washes into water courses affecting aquatic ecosystems.
- The loss of vegetation affects humidity (less transpiration) and transfer processes (surface runoff, evaporation and infiltration).
- Nutrient cycles will be impacted (Figure 4).

Wildfires cause secondary successions in forests (Figure 5).

- Nutrient stores depleted.
- Effects on ecosystem development – secondary succession uptakes.

Wildfires – positive feedback loop

- Carbon released from trees, plants and peat
- Biomass and litter stores burned
- Increased likelihood of wildfires
- Enhanced greenhouse effect
- Increased CO₂ in the atmosphere

**Causes of wildfires**

Most fires that occur close to urban areas are the result of human actions (such as discarded cigarettes and campfires).

Heat transfer processes (radiation, conduction, convection) preheat vegetation ahead of the flames, enabling rapid spread of the fire through spot fires.

**Figure 4** The heat transfer process

**Strategies for managing wildfires**

There are four strategies for managing wildfires: preparedness, mitigation, prevention and adaptation.

**Preparedness**

Preparedness by early detection and suppression of wildfires can take the form of:

- Rural firefighting teams staffed by volunteers
- Warnings are issued as the risk of fire increases
- Establishing firebreaks or a ‘defensible space’ around their property (Figure 6).

**Figure 6** Establishing firebreaks or a ‘defensible space’ around property

**Mitigation**

Mitigation involves reducing the impact of a fire before, during and after the event.

- Early fire detection by cameras and drones, satellites and infrared sensors.
- Back burning vegetation ahead of the fire front to remove the fuel. Natural barriers, such as rivers, may also control the spread.
- Disaster aid and fire insurance can mitigate the effects of wildfires.

**Prevention**

Public awareness can prevent fires starting. Many countries operate ‘fire bans’ during times of high risk. Controlled burning reduces the amount of dead vegetation but burning:

- may get out of control
- impacts on the natural ecosystems by reducing the litter store
- releases carbon dioxide into the atmosphere.

**Adaptation**

Adaptation involves learning to live with the threat and letting wildfires take their course.

- Wildfires burn away old and diseased wood enabling fresh growth and stimulating germination.
- Regulations can restrict access to areas at risk of wildfire.
- Simple, cheap building designs made of natural products will not cause pollution if they burn down.

**Sixty second summary**

- There are several types of wildfire, including ground, surface and crown fires.
- Wildfires are more likely when conditions (fuel, climate, ignition) are all met.
- Wildfires have environmental, social, economic and political impacts.
- Preparedness involves increased awareness and warnings.
- Mitigation is identification and intervention to reduce their impacts.
- Prevention is a realistic option, particularly in reducing human-induced fires.
- Adaptation involves allowing some fires to burn with regulation in fire-prone areas.

**Table: Primary and secondary impacts of wildfires**

<table>
<thead>
<tr>
<th>Category</th>
<th>Primary Impacts</th>
<th>Secondary Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental</td>
<td>Destruction of habitats and ecosystems</td>
<td>Lack of trees and vegetation causes depletion of nutrient stores, increased leaching and increased risk of flooding</td>
</tr>
<tr>
<td></td>
<td>Death and injury of animals, which impacts on food chains and food webs</td>
<td>Increased carbon emissions impact on the greenhouse effect and accelerate change</td>
</tr>
<tr>
<td></td>
<td>Short-term surge of carbon dioxide due to the burning of carbon stores (trees)</td>
<td>Effects on ecosystem development – secondary succession</td>
</tr>
<tr>
<td></td>
<td>Atmospheric and water pollution from smoke and toxic ash</td>
<td></td>
</tr>
<tr>
<td>Social</td>
<td>Loss of life and injury</td>
<td>New employment opportunities</td>
</tr>
<tr>
<td></td>
<td>Displacement of people</td>
<td>Behavioural adaptations based on wildfire experience – people may have to abide by new rules and regulations</td>
</tr>
<tr>
<td></td>
<td>Damage to power lines by strong winds</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Damage to communications</td>
<td></td>
</tr>
<tr>
<td>Economic</td>
<td>Damage/destruction of structures</td>
<td>Costs of rebuilding or possible relocation</td>
</tr>
<tr>
<td></td>
<td>Financial (loss of earnings, damage costs)</td>
<td>Replacement of farm infrastructure, crops, fruit trees, livestock</td>
</tr>
<tr>
<td></td>
<td>Destruction of businesses</td>
<td>Cost of future preparedness and mitigation strategies</td>
</tr>
<tr>
<td></td>
<td>Loss of crops and livestock</td>
<td>Strategies for preparedness and mitigation</td>
</tr>
<tr>
<td>Political</td>
<td>Actions of emergency services</td>
<td>Decisions about replanting forests, compensation, future regulations, etc.</td>
</tr>
<tr>
<td></td>
<td>Responses of government</td>
<td>Review law/ advice regarding use of countryside for leisure</td>
</tr>
<tr>
<td></td>
<td>Response of local authorities and emergency services in the immediate aftermath</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 5** Primary and secondary impacts of wildfires

- Increased likelihood of wildfires
- Carbon released from trees, plants and peat
- Biomass and litter stores burned
- Enhanced greenhouse effect
- Increased CO₂ in the atmosphere
The Alberta wildfire, 2016
In May 2016 a huge wildfire struck parts of Canada’s Alberta province, forcing the evacuation of 90,000 residents of Fort McMurray as the fire destroyed 2400 homes and businesses. Remarkably no one was killed or injured.

What were the causes and contributory factors?
The fire ignited in a forested area south-west of Fort McMurray but the precise cause remains unknown. A shift in the wind direction took the blaze into the outskirts of Fort McMurray, the largest settlement in the area.

Figure 2 shows how erratic the fires were. It clearly shows ‘spotting’, where wind-carried burning embers ignite fires well ahead of the fire front – even across a one-kilometre river in places.

A lack of winter snowfall and an early spring snowmelt, combined with above average temperatures provided dry conditions ideal for an outbreak. The intensity of the fire created its own weather patterns, including strong winds and lightning, which led to the ignition of additional fires in the area.

Climate scientists have linked the fire to a strong El Niño effect that may well have resulted in the unusually warm and dry early spring conditions.

What were the impacts of the wildfire?

<table>
<thead>
<tr>
<th>Environmental</th>
<th>Social</th>
<th>Economic</th>
<th>Political</th>
</tr>
</thead>
<tbody>
<tr>
<td>The fire severely affected the forest ecosystem due to the scorched soil and burned tree roots.</td>
<td>90,000 people forced to flee Fort McMurray.</td>
<td>Initial insurance company estimates suggested CAN$10bn of damage was inflicted upon Fort McMurray.</td>
<td>The fire has stimulated political debate about the possible impacts of climate change.</td>
</tr>
<tr>
<td>The scorched peaty soils were in danger of re-ignition.</td>
<td>2400 homes and other building burned down in parts of Fort McMurray.</td>
<td>About a third of the 25,000 workers in the nearby oil sands industry had to be evacuated from work camps. The fire is estimated to have cost the industry CAN$1bn.</td>
<td>Government lassied with emergency services in implementing evacuation programmes.</td>
</tr>
<tr>
<td>Toxins released from burning trees and buildings created air pollution; several million tonnes of carbon dioxide were released into the atmosphere.</td>
<td>Jobs and livelihoods were affected and movement in the area was restricted.</td>
<td>The Alberta government implemented a phased and safe re-entry.</td>
<td>The Alberta government provided evacuees with CAN$1250 per adult and CAN$500 per dependant to help cover living expenses.</td>
</tr>
<tr>
<td>Ash was washed into water courses leading to water pollution.</td>
<td>Increased levels of anxiety about the future.</td>
<td>Coordination of reconstruction programmes for buildings, services and infrastructure.</td>
<td>The Canadian government pledged long-term aid to support the rebuilding process.</td>
</tr>
</tbody>
</table>

An evacuation of the size as that of Fort McMurray created social, economic and political impacts.

Figure 3 shows some of the neighbourhoods that were most affected.

What were the responses to the wildfire?
The initial response to the outbreak was monitoring and forecasting of the track of the fire. Subsequent responses included:

- A well-organised evacuation of Fort McMurray prevented deaths and injuries. Aircraft were used to evacuate some of the oil sands workers.
- The Alberta government declared a state of emergency and this triggered support from the Canadian armed forces.
- The Alberta government provided evacuees with CAN$1250 per adult and CAN$500 per dependant to help cover living expenses.
- The Canadian government pledged long-term aid to support the rebuilding process. A benefit concert in Edmonton, ‘Fire Aid’, raised money for those affected by the disaster.

Sixty second summary

The Alberta wildfire devastated the Canadian city of Fort McMurray in May 2016.
- Very dry conditions, high temperatures and strong winds contributed to the enormity of the blaze (with possible links to an El Niño event).
- Impacts included evacuation of 90,000 people from Fort McMurray, temporary cessation of oil production from nearby oil sands and widespread forest destruction.
- Well planned and executed emergency procedures resulted in no deaths or major injuries.
- Political institutions provided relief and long-term responses.

Over to you
Produce a summary information poster or infographic outlining the causes, impacts and responses of the Alberta wildfire.
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Chapter 5 – Hazards

You need to know:
• the impacts of and responses to Hurricane Sandy
• the impacts of and responses to Cyclone Winston
• factors responsible for the contrasting impacts and responses of the two storms.

Impacts of Hurricane Sandy, USA, 2012

In October 2012, Hurricane Sandy began life as a tropical storm over the warm waters of the Caribbean. It passed through Jamaica, Haiti, Cuba and the Bahamas with sustained winds of 160km/h. The storm then travelled along the US east coast and merged with a weather system from the west, becoming an ‘extra-tropical cyclone’, devastating large areas of north-east USA.

The torrential rainfall, ferocious winds and powerful storm surges had huge impacts:
• 233 people were killed
• thousands of homes were destroyed; 200,000 were homeless in Haiti alone
• millions of people were left without electricity
• ruptured gas pipes caused many fires
• sand and debris disrupted the road network
• power lines were destroyed; 70% of Jamaica’s population were without power
• huge disruption in New York City as streets, tunnels and subway lines were flooded
• widespread disruption across a huge area of the Caribbean and 24 US states
• total cost of damage was US$75 billion.

Preparation for Hurricane Sandy

Measures were taken to reduce the impacts on people and property.

In Jamaica:
• schools and government buildings were closed
• houses were reinforced
• people stocked up on provisions
• Kingston Airport was closed.

In the USA:
• power companies were prepared to repair power lines
• the government prepared to supply aid
• the military were put on alert
• schools were closed, hurricane centres opened and people evacuated.

Responses to Hurricane Sandy

Short-term responses included:
• provision of food, water and shelter
• the UN and World Food Programme sent supplies for 500,000 people in Cuba
• restoration of power in the USA
• the American Red Cross supplied over 4000 volunteers to help those affected
• in New York, government provided emergency supplies of petrol.

Long-term responses included:
• a live telethon concert raised over US$20 million
• a ‘Day of Giving’ raised US$17 million
• the US government approved a US$50 billion relief package.

Impacts of Cyclone Winston, Fiji, 2016

In February 2016, Fiji was struck by the Southern Hemisphere’s strongest tropical cyclone in recorded history with sustained wind speeds of over 230km/h. Winston started as a small tropical storm to the east of Vanuatu, Cyclone Winston strengthened over the warm seas, then headed westwards directly for Fiji, increasing in intensity.

The exceptionally strong winds caused huge damage:
• 44 people were killed
• 350,000 people were significantly affected
• 250,000 people without clean water and sanitation
• over 40,000 homes were damaged or destroyed
• communications were disrupted for several days
• over 80% of the population lost power
• over 295 schools were damaged or destroyed.
• damage to crops caused food prices to rise
• the agriculture sector lost over US$64 million
• total cost of damage estimated at US$1.4 billion.

Preparation for Cyclone Winston

Many lives were saved by:
• monitoring and forecasting so warnings could be issued
• opening around 700 cyclone shelters
• encouraging people to leave their homes and seek shelter
• the military were put on alert to support the relief operation
• suspending public transport and advising people not to travel.

Responses to Cyclone Winston

Short-term responses included:
• provision of shelter, food, water and medicine
• declaring a state of emergency
• financial assistance and supplies from the international community
• the international airport reopened after two days
• telephone services were restored after three days
• power supplies were restored after three weeks
• clearing waste and debris to make way for reconstruction.

Long-term responses included:
• US$9 million of governmental financial support for reconstruction
• ‘Help for Homes’ – a programme of house building for those unable to rebuild
• New Zealand supplied personnel and financial relief, as well as aircraft and helicopters
• Australia provided financial relief and also sent air support and emergency personnel
• charities and NGOs raised money for those affected by the disaster.

Sample material

Over to you

Create a table to contrast the impacts of and responses to the tropical storms in the USA and Fiji. Focus on the similarities and differences.