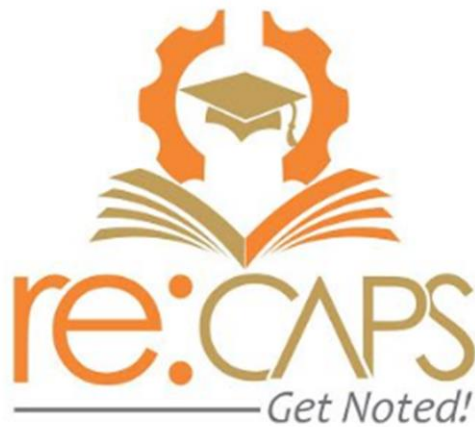


GEOGRAPHY GRADE 12

– TERM 1



Monya Le Hanie

Term 1:

Topic 1: Climate and weather

Unit 1: Mid-latitude cyclones

Key terms

Front	The transition zone between air masses of markedly different temperature and humidity over a relatively short distance of 50 – 100 km.
Cyclone	A low pressure system, sometimes called a depression.
Cyclogenesis	The development or strengthening of cyclonic circulation in the atmosphere.
Zulu time	UTC is sometimes communicated with the letter Z, which refers to the zone description of zero hours. The NATO phonetic alphabet name for Z is 'Zulu', therefore UTC is sometimes called Zulu time.
Apex of low pressure	The point at the centre of the mid-latitude depression.
Cold front	An area where cold air forces warm air up, causing clouds and rainfall.
Cold sector	An area of cold polar air behind the cold front.
Depression	Another name for a low pressure area or a cyclone.
Dissipate	Break up and disperse.
Isobar	Line joining all places with the same pressure.
Occlusion	When the mid-latitude depression dies out as a result of the warm and cold front meeting.
Unstable	Conditions associated with rising air in a low pressure area.
Warm front	An area where warm air rises gently over colder air, causing clouds.
Warm sector	An area of warm tropical air behind the warm front.

- Mid-latitude cyclones (also referred to as depressions or extra-tropical cyclones) occur throughout the year and play an important role in the weather and climate of many countries.
- These depressions are large areas of low pressure that are responsible for weather conditions in the mid latitudes (40°–60° north and south of the equator).
- This is where the subpolar low pressure belt is found.
- Isobars are arranged in a circular or oval pattern around a central apex where the lowest pressure is found.

1. What are the general characteristics of mid-latitude cyclones?

- Mid-latitude cyclones move from west to east.
- They are large systems ranging from 1 600 to 2 400 km.
- They move over large distances before they disappear.
- They occur throughout the year.
- They are low pressure systems associated with unstable conditions.
- They bring cloudy, cold and rainy weather.

- Air rotates into the systems in a clockwise direction in the southern hemisphere and in an anti-clockwise direction in the northern hemisphere.
- They occur in families or groups and form part of the polar front which occurs at 40°-60° north and south of the equator.
- The pressure at the apex is usually around 1 000 hPa (hectoPascals)

2. Where do mid-latitude cyclones form?

- These weather systems occur between approximately 30° and 60° north and south of the equator.
- Mid-latitude cyclones are rarely stationary and tend to follow definite paths.
- In both hemispheres they move from west to east within the westerly winds, at speeds of 40-90km/h.

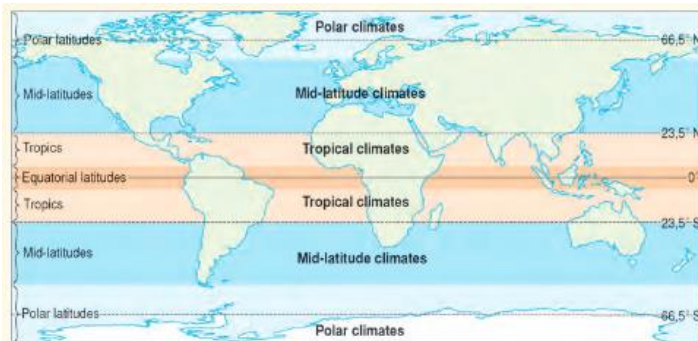


FIGURE 34 Mid-latitude climate zones (and other major latitudinal zones)

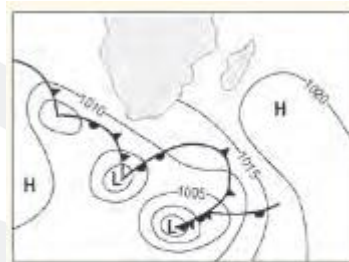
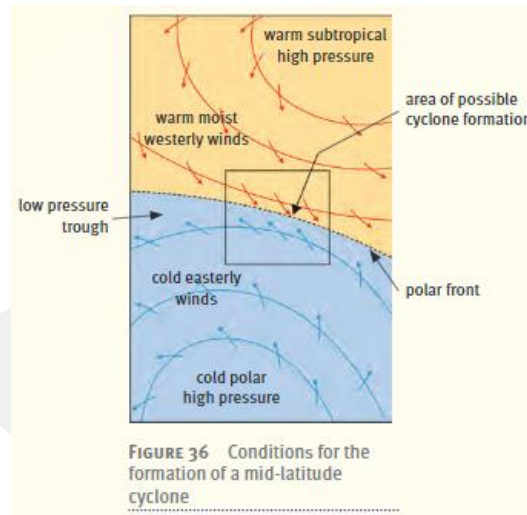


FIGURE 35 A linked series of depressions forming a 'family' of fronts

- Sometimes a series of fronts will develop, in which three or four fronts follow one after the other in a 'family' of fronts.
- In the Southern Hemisphere the oldest frontal system (which arrives first) will be furthest towards the south-east.
- Each successive younger member is slightly further north and west than its predecessor.
- The frontal zone can be 50-100 km wide.

3. What are the conditions necessary for the formation of mid-latitude cyclones?

- A mid-latitude cyclone is a large spiral of air that repeatedly forms, intensifies and dissolves along the polar front.
- The conditions favourable to the formation of a mid-latitude cyclone are:
 - Two large high-pressure systems (anti-cyclones) are in contact on the polar front.
 - The warm, subtropical high pressure contains a warm, moist maritime air mass.
 - The polar high pressure contains a cold, dry air mass.
 - The air flow converges from opposite directions on the two sides of the polar front.
 - Disturbances on the polar front result in an unstable situation, creating a local low pressure into which air will flow and around which air will circulate.



4. What are the stages of development and related weather conditions of mid-latitude cyclones?

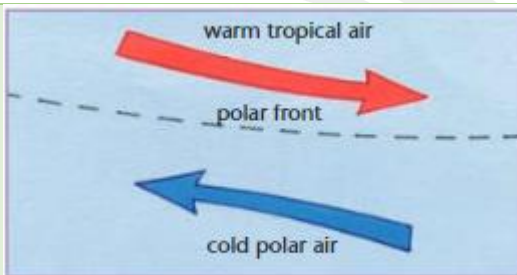


Figure 2.3a): The initial stage

Initial stage

- Cold air from the polar easterlies meets with warm air from the westerlies at the polar front (60°).

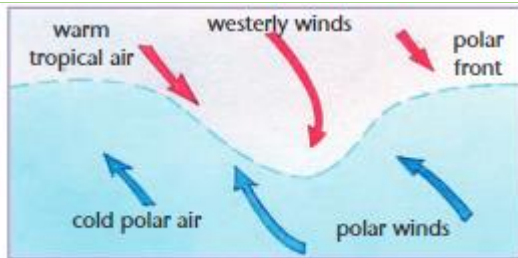


Figure 2.3b): The wave stage

Wave stage

- Wave movements develop along the polar front.
- The regular surface becomes disturbed and a vortex of low pressure develops at the apex of the wave.
- The air in circulation converges in a clockwise direction in the southern hemisphere around the low pressure centre.

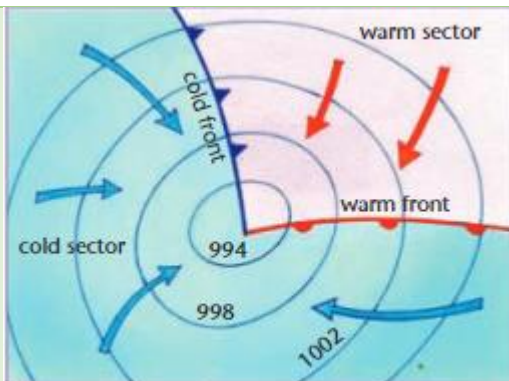


Figure 2.3c): The mature stage

Mature stage

- A clear low pressure centre has formed with a distinct cold front and warm front.
- Behind the warm front, the mass of warm air turns towards the poles and forms the warm sector.
- Behind the cold front the cold air mass turns towards the equator and forms the cold sector.
- The entire mid-latitude cyclone moves eastwards.

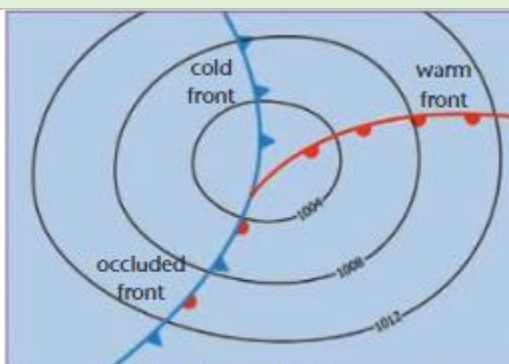


Figure 2.3d): The occlusion stage

Occlusion stage (the dissipating or dying out)

- While the mid-latitude cyclone is moving eastwards the cold front catches up with the warm front (cold air is more dense and therefore travels faster).
- The cold air then pushes the warm air from the warm sector up and out of the cyclone until the cold front merges with the warm front and they form an occluded front.

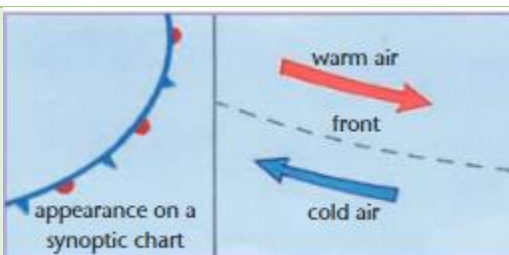
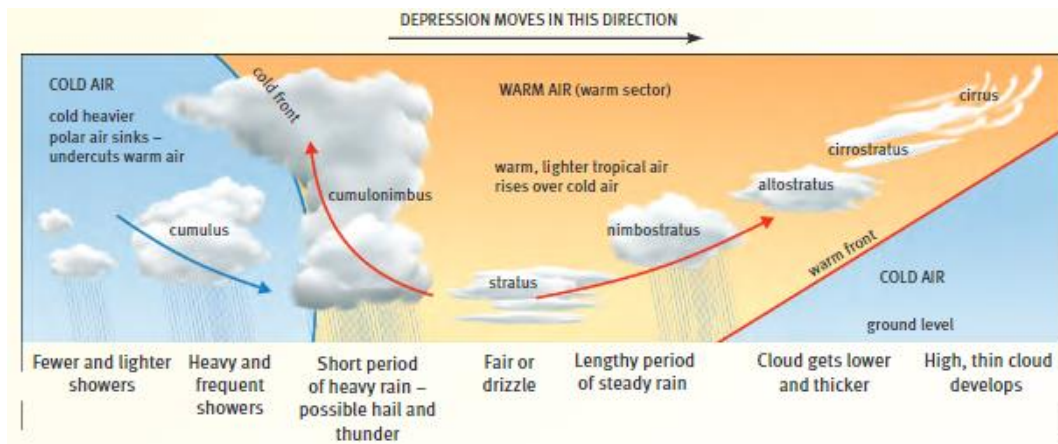


Figure 2.3e): The dissipating stage

Dissipating stage

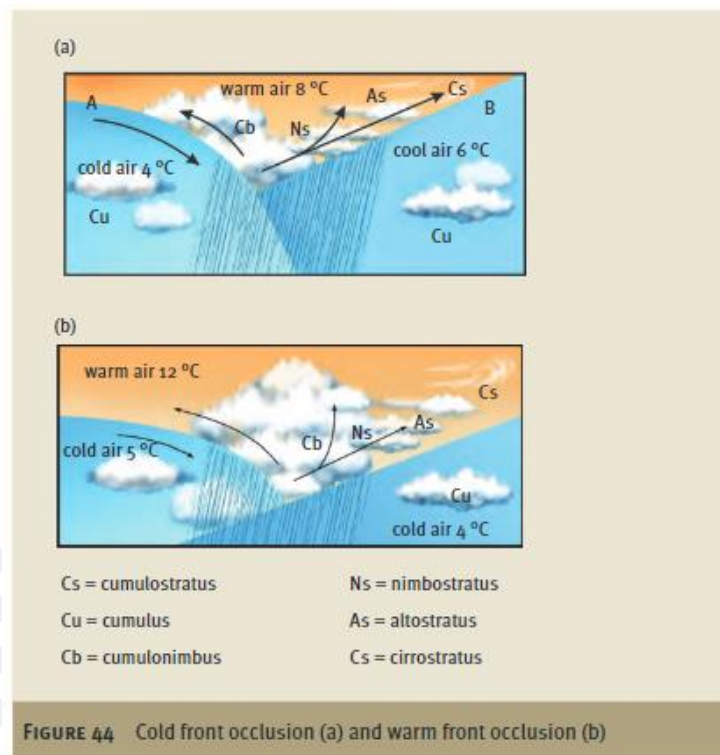
- Eventually the low pressure centre is surrounded entirely by cold air and the weather system dissipates.

5. What are the weather patterns associated with cold, warm and occluded fronts?



Weather	Behind the cold front	Cold front passing	Warm sector	Warm front	Cyclone approach
Air pressure	Increase continues at a slower rate	Sudden increase	Remains steady	Decrease stops	Steady decrease
Wind direction	South	Backing from west to southwest	West	Backing from northwest to west	Northwest
Wind speed	Gusty, decreases slowly	Very strong to gale force	Decreases	Strong	Increases slowly
Temperature	Cold, around 5°C	Sudden decrease	Warm to mild, around 12°C	Sudden rise	Cool, around 8°C
Relative humidity	Rapid fall	High during precipitation	Steady and high	High during precipitation	Slow rise
Cloud cover	Decreasing in succession – cumulonimbus to cumulus	Very thick and towering cumulonimbus clouds	Low stratus clouds, with clear patches in between	Low and thick nimbostratus	High and thinner clouds – altostratus, cirrostratus and cirrus
Precipitation	Heavy and later soft, persistent showers	Short period of heavy rain or hail	Intermittent drizzle or stop	Continuous rainfall – steady and quite heavy	None
Visibility	Very good, but poor in showers	Poor, especially in showers and fog	Often poor	Decreases rapidly	Good, but decreasing with nearing front

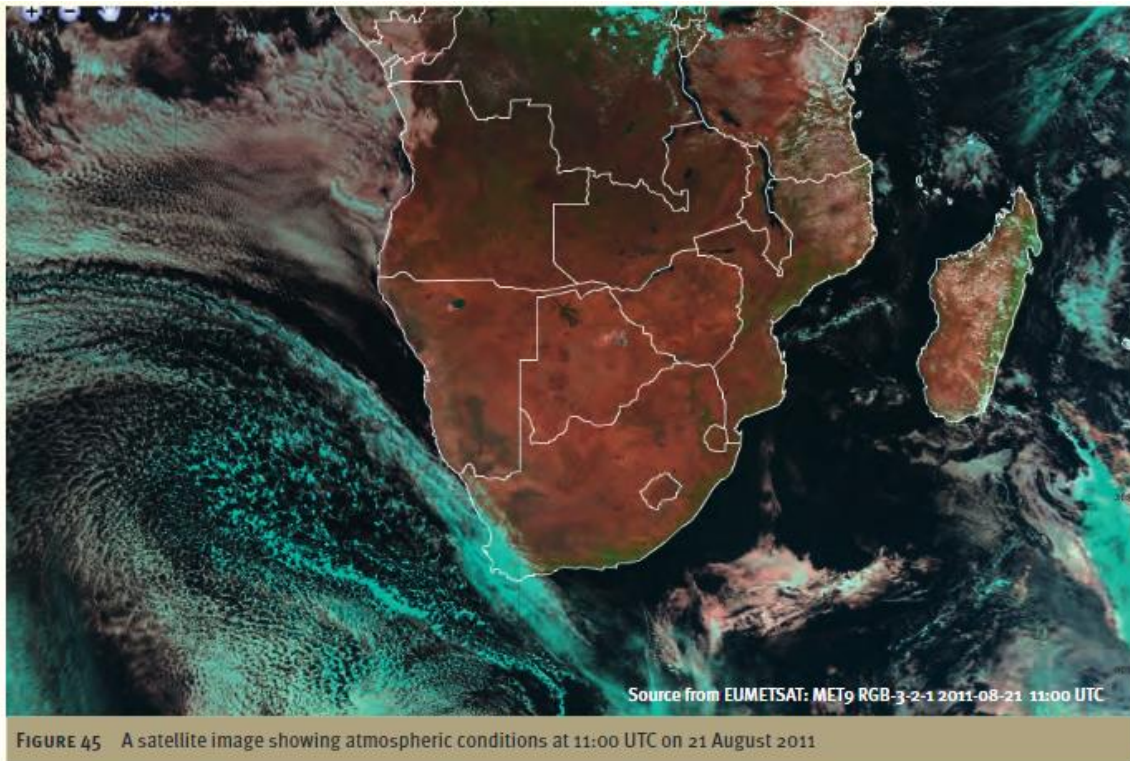
- In a cold front occlusion (Figure 44 (a)) the air at the forefront of an advancing cold front is warmer than the air behind it.
- As a result, both the warm air mass behind the warm front and the cooler air ahead of the cold front are lifted up above the advancing cold front.
- In a warm front occlusion (Figure 44 (b)) the air ahead of the warm front is colder than the air behind the advancing cold front.
- As the cold air catches up with the warm air, the advancing cool air rises above the colder air ahead of the warm front.
- In both cases, the warm air in the warm sector is forced to rise.
- As it cools, condensation occurs and rain falls from nimbostratus clouds.



6. Reading and interpreting satellite images and synoptic weather maps (Via)

- Satellite images are captured by satellites at regular intervals (usually hourly) and used by meteorologists to forecast the weather.
- A satellite image (Figure 45) shows what is happening in the upper atmosphere.
- For example, cloud patterns indicate movement in air masses.
- Synoptic weather maps (like Figure A in Activity 3 below) depict mainly large-scale weather elements on the Earth's surface, like cold and warm fronts.
- The word 'synoptic' means 'view at a common point', which is time.
- To avoid confusion due to different time zones, meteorologists create a common point in time by using Universal Time Coordinate (UTC) or Zulu time (Z).

- When the matching satellite image and synoptic weather map are read and analysed together, you develop a better understanding of weather processes and weather systems active at that particular time in the photographed and mapped areas.
- The colours available on Figure 45 provide a near real image of land and water areas, and give an indication of vegetation as well as the temperature of clouds.



Term 1:

Topic 1: Climate and weather

Unit 2: Tropical cyclones

Key terms

Vortex	A rotating, whirling movement of air.
Active quadrant	In the Southern Hemisphere, the forward left-hand quadrant of the westward moving tropical cyclone.
Latent heat	The amount of heat energy needed to convert water into water vapour; the energy released when water vapour condenses.
Dissipate	Lose energy; fade away.
Natural hazards	Natural events or processes that affect people's lives adversely, causing injury or loss of life, economic damage or environmental degradation.
Eye	The area of subsiding air in the centre of a tropical cyclone.
Storm surge	A rapid rise in sea level caused by the movement of a tropical cyclone over the area.
Tropical cyclone	A severe tropical low pressure storm, characterised by devastating winds and rainfall.

- A tropical cyclone is a severe storm with torrential rain and excessively strong winds of over 119 km/h.
- The storms form between 5°–30° north and south of the equator in the tropical regions of the world.
- As they need heat and moisture for their formation, these tropical cyclones develop over ocean areas in the summer months and in early autumn.
- Warm moist air rises in this low pressure area and begins to spin because of the Earth's rotation.
- As the warm moist air rises, it expands, cools and the water vapour present in it condenses to form huge cumulonimbus clouds that rotate and form a vortex around a central area called the eye.
- Air is continually sucked into this vortex of gigantic clouds; it then spirals upwards.
- As the water vapour condenses, heat is given off, making the air rise faster.
- Once they are spinning, these storm systems move from east to west towards land surfaces.
- When they move over land, tropical cyclones cause devastation over large areas.

1. What are the general characteristics of tropical cyclones? (SFA & Via)

- Tropical cyclones are classified according to their intensity:
 - They are named alphabetically every summer season.
 - Their pressure may drop below 920 hPa in a severe storm.
 - They can range from 200-500 km in diameter.
 - The average diameter of the eye is 25 km.
 - Tropical cyclone winds can reach up to 200-300 km/h.
 - Their average life span is 7-14 days.

- As low-pressure areas, their rotation is clockwise in the Southern Hemisphere and anti-clockwise in the Northern Hemisphere.
- The source of energy in tropical cyclones is the large amount of latent heat released as rising warm, moist tropical air condenses.
- They are accompanied by heavy rain, storm surges and high winds.

Table 2.2: Classification of tropical storms – the Saffir-Simpson scale

	Scale	Predicted damage	Predicted pressure (hPa)	Wind speed (km/h)
Tropical storm				55–119
Hurricane	1	Minimal	>980	120–149
Hurricane	2	Moderate	965–979	150–179
Hurricane	3	Extensive	945–964	180–209
Hurricane	4	Extreme	920–944	210–249
Hurricane	5	Catastrophic	<920	>250

2. Where do tropical cyclones form? (SFA, skets Via)

- Tropical cyclones form in the low pressure area between 5°–30° north and south of the equator.
- These equatorial areas in the tropical regions have the necessary heat required for uplift of air.
- They form over ocean areas and move from east to west towards land surfaces: they are driven by the tropical easterly winds that blow in this region.
- Tropical cyclones do not form at the equator because of the absence of the Coriolis force which is needed for air to rotate and spin.
- They are given different names in different areas of the world.

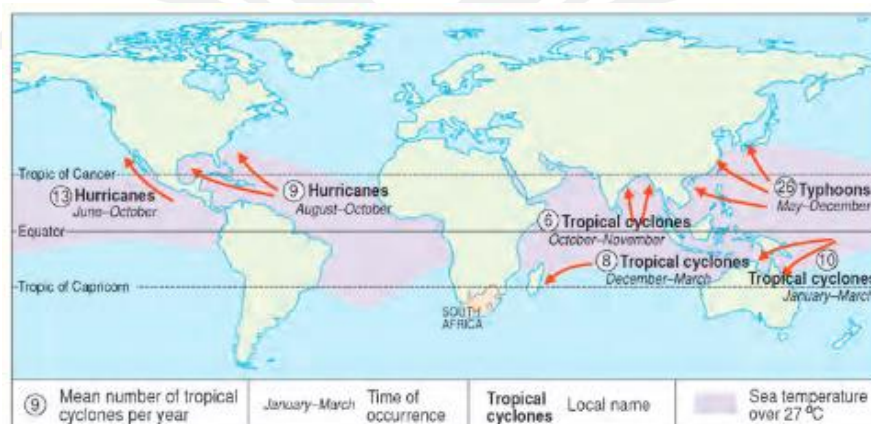


FIGURE 49 Tropical cyclones: global location and mean frequency

3. What are the factors necessary for tropical cyclones to form?

Factor or condition	Influence on formation process
Sea temperature of at least 26 °C	Heat is needed for convection.
High humidity	Latent heat is released during condensation.
Unstable air	Atmospheric instability makes convection possible,
Little surface friction	Ocean surface allows unhindered movement of air.
Light variable winds	Strong directional winds inhibit the development of a vortex, because they reduce both the temperature of surface water and the production of water vapour.
Air pressure must be low with closed isobars	An air pressure of less than 950 hPa at the centre of the cyclonic system enhances convergence and rise of air.
Divergence of air at upper levels	This stimulates circulation and the formation of the vortices.

4. What are their stages of development?

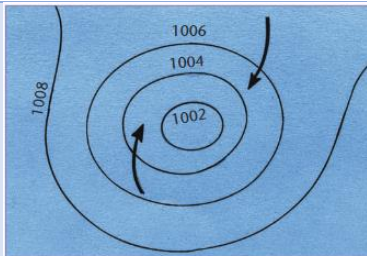


Figure 2.14a): The formative stage. This diagram shows the formative stage of a tropical cyclone. A plan view shows how the system appears on a synoptic chart. It is a view from above.

Formative stage

- There is convergence of air towards a low pressure centre to create a vortex.
- Air pressure is about 1 002 hPa and winds reach speeds of up to 60 km/h.

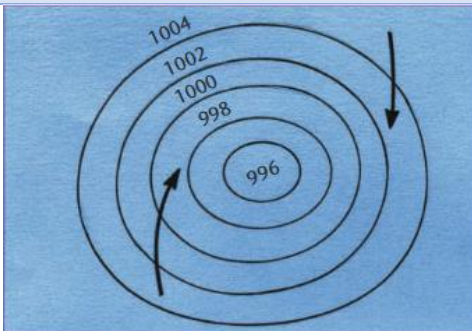


Figure 2.14b): The immature stage

Immature stage

- The intensity of the storm increases as air continues to converge and rise at the low pressure centre.
- In the upper atmosphere divergence takes place.
- Pressure continues to drop to about 990 hPa and wind speed increases to about 120 km/h.
- The low pressure centre forms an eye and huge cumulonimbus clouds swirl around the eye creating a vortex.

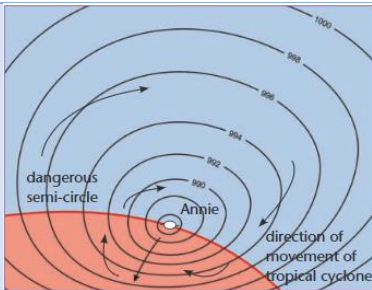


Figure 2.14c): The mature stage

Mature stage

- The storm has reached its maximum intensity.
- Pressure drops to a low of about 950 hPa and wind speeds exceed 180 km/h.
- The eye is fully developed and is a clear, cloudless centre of the cyclone due to cooler, subsiding air.
- The vortex is well developed and the cyclone may reach up to 600 km in diameter.
- There is torrential rain, thunder and lightning associated with a tropical cyclone.

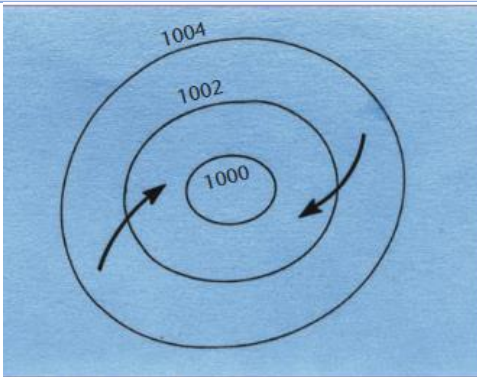


Figure 2.14c): The decaying stage

Decaying (degeneration) stage

- Dissipation occurs when the tropical cyclone cools down when entering the temperate latitudes.
- Cooler air flows into the cyclone increasing the pressure.
- It may also dissipate when the storm moves inland because there is no longer a supply of moisture and surface friction slows it down.

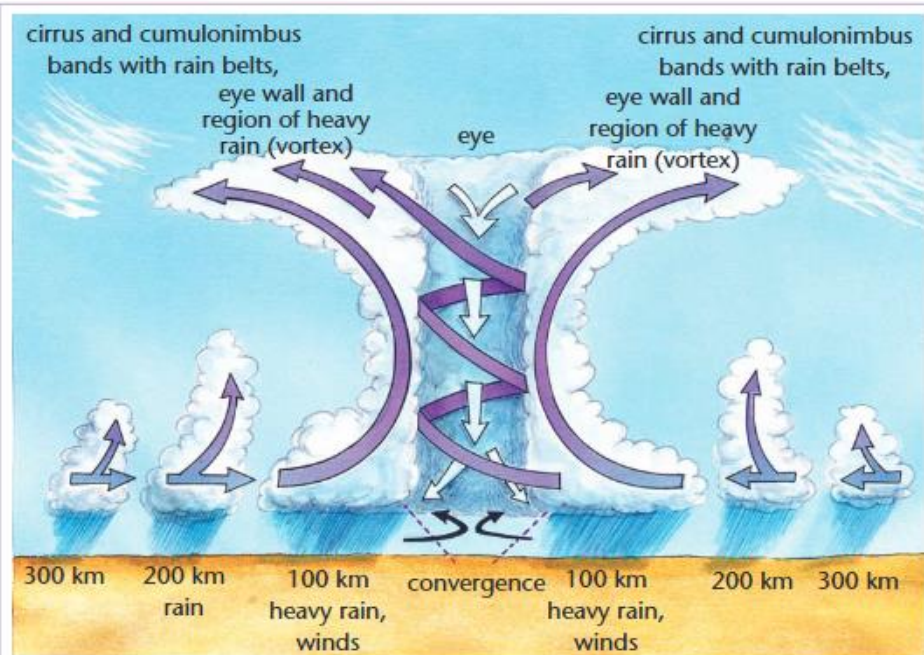


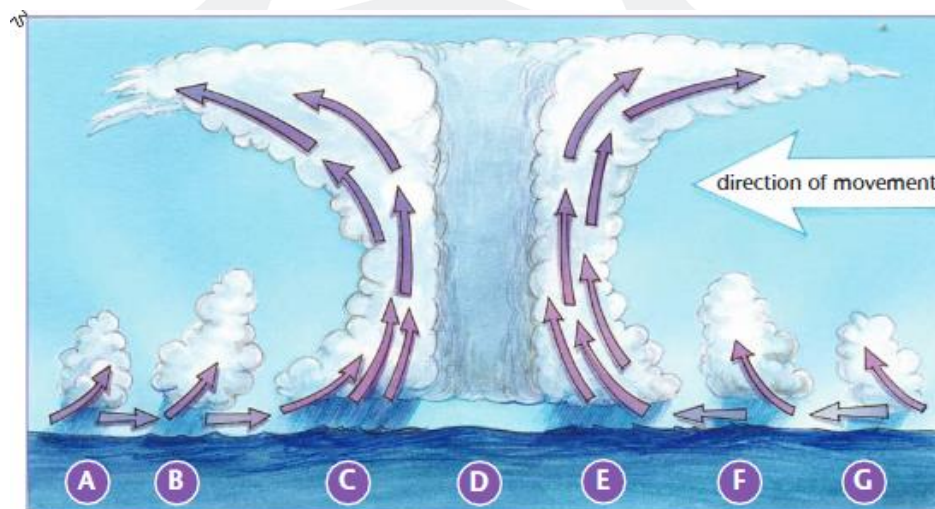
Figure 2.15: A cross-section of a tropical cyclone. A cross-section shows a side view of a tropical cyclone from one vortex, through the eye to the other vortex.

- Meteorologists classify tropical cyclones as follows:

Tropical depression	System of clouds and thunderstorms with defined circulation and sustained winds of 61 km/h or less.
Tropical storm	Organised system of heavy thunderstorms with a defined circulation and sustained winds of 61-117 km/h.
Tropical cyclone	Intense tropical weather system with a definite circulation and sustained winds of 118 km/h or higher.

5. What are the associated weather patterns?

- Tropical cyclones cause devastation and destruction when they reach land.
- They damage property and the environment, and they can cause loss of life.
- Countries that experience these systems regularly during the summer months prepare for these cyclones by issuing warnings and by having efficient emergency relief operations at hand to deal with the after-effects.
- The weather changes during the three main stages in the cyclone –
 - the first vortex,
 - the eye and
 - the second vortex.



- A – Scattered clouds, winds strengthen, rain begins
- B – Clouds build up, high seas, gale-force winds, heavier rain
- C – Vortex, torrential rain, thunderstorms, hurricane force winds
- D – Eye, calm, clear, subsiding air, very high swells on sea
- E – Vortex, torrential rain, thunderstorms, hurricane force winds
- F – Gale-force winds, heavy rain
- G – Rain and wind lessen

Figure 2.16: The weather associated with the passage of a tropical cyclone

- The eye of the cyclone is the centre of the storm where the lowest pressure is found.
- It is characterised by a period of calm where temperatures rise and the wind and rain stop.
- This is caused by air descending at the centre of the cyclone.
- Most damage is done in the vortex areas of the storm.

- Winds and rain are strongest in the vortex areas, and are characterised by rising, rotating air around the central eye.
- The worst weather occurs in the dangerous semi-circle.
- This is caused by the combination of intense wind in the storm, as well as the force of air associated with the speed of the whole system as it moves.
- In the southern hemisphere, this section is the left front quadrant of the system.
- **The reasons why tropical cyclones cause so much damage**

High wind speeds	• These can exceed 160 km/h and may even reach 250 km/h. • These powerful winds can: - Uproot trees - Blow off parts of buildings - Break signposts - Blow electricity, telephone and power lines down - Destroy crops in rural areas and wipe out shack houses in developing areas.
Flooding	• Caused by intense rainfall. • This flooding can: - Cause rivers to break their banks - Destroy homes, property and farm areas - Damage ecosystems and the environment - Cut off villages from transport networks.
Storm surges	• Affect coastal areas because the intense low pressure and high winds cause sea waves that are 5-6 m higher than normal. • These storm waves move onto coastal areas where they flood beaches. • They can also destroy homes and the infrastructure of the area. • Many coastal areas, such as Bangladesh, are densely populated, low-lying coastal regions. • As a result, large numbers of people lose their lives and their livelihood from storm surges.
Landslides and soil erosion	• Occur when the increased rainfall washes away buildings and soil on steep slopes. • This material is deposited in lower-lying areas where it blocks transport routes and destroys houses and farms in the valley areas.

6. Reading and interpreting satellite images and synoptic weather maps of tropical cyclones

- Satellite information is important for tracking and determining the intensity trends of tropical cyclones.
- When a cyclone is still well offshore, forecasters use satellite imagery to track the storm's movement and development continuously.
- The imagery provides information about the top of the storm, and a detailed analysis can be made of the nature of the tropical cyclone if other data sets are overlaid on the image.
- In Figure 51 the wind flags and arrows indicate the wind speed and wind direction respectively.
- They also indicate the direction in which the wind converges into the system.
- The strongest winds are the flags with small triangles (at least 50 knots).
- Below the image you will see a bar using different colours to also indicate wind speed.
- On the left side in white you have speeds from 0–5 knots.
- On the right end of the bar in purple you have wind speeds of higher than 50 knots.
- The highest wind speeds clearly are around the eye.

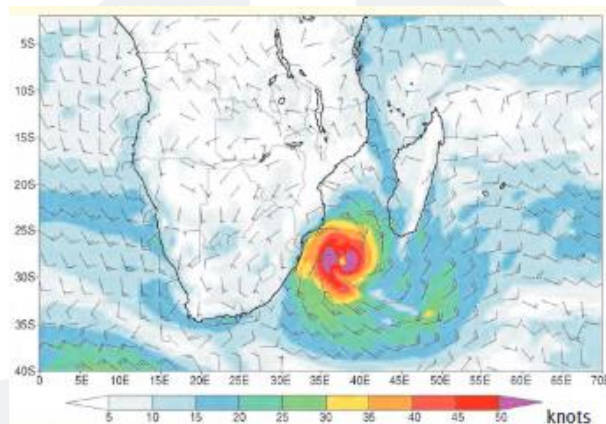


FIGURE 51 Tropical cyclone Funso on 25 January 2012

6.1. How do you recognise tropical cyclones on synoptic maps?

- Characteristics of a tropical cyclone on synoptic maps are:
 - a low-pressure cell with circular isobar patterns between 5° and 30° north and south of the equator (Figure 53)
 - symbol for tropical cyclone in the eye (centre of low pressure)
 - name of the tropical cyclone written next to system
 - the date of the map in late summer or early autumn.

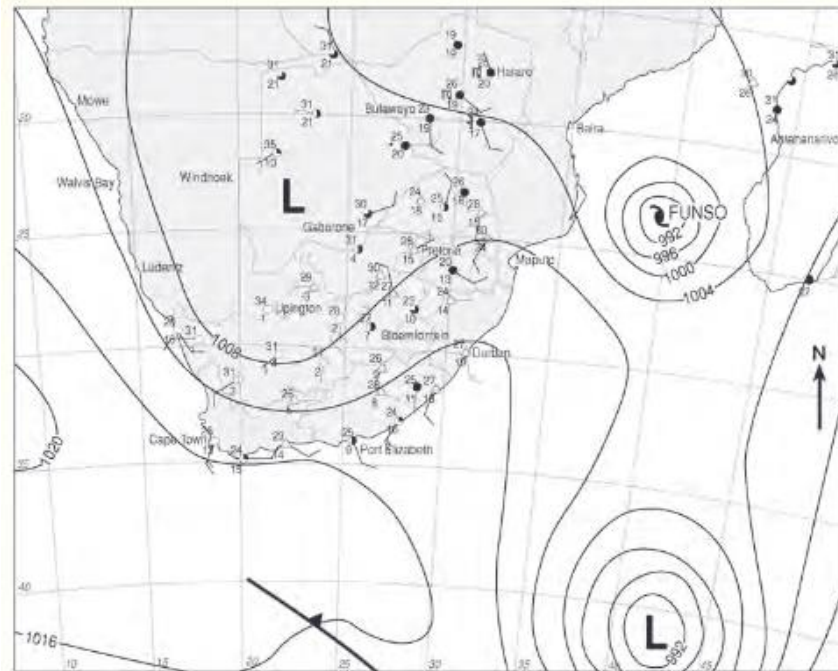
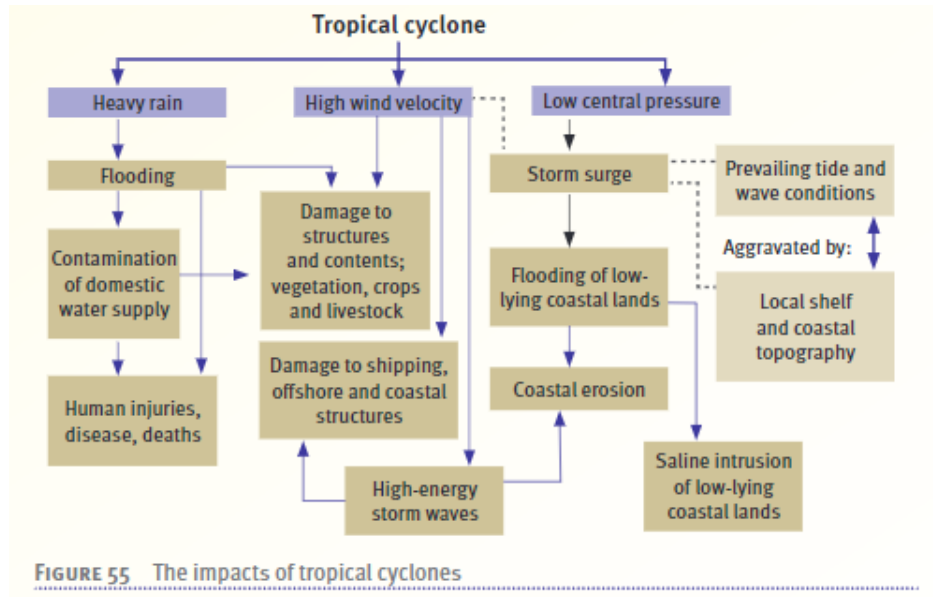


FIGURE 53 Synoptic weather map of 25 January 2012

7. What are the impacts of tropical cyclones on human activities and the environment?

- Tropical cyclones are the most destructive natural hazards in terms of frequency and number of deaths.
- Not only people, but also the natural and constructed environments are affected.
- Tropical cyclones are not something that can be controlled by people.
- They are a major threat, especially to coastal areas along the eastern side of continents and in densely populated low-lying delta areas.
- Three factors are the main cause of the destruction:
 - heavy rain,
 - high wind velocity and
 - the low pressure.
- Each factor has resulting impacts, which are illustrated in the flow diagram in Figure 55.



8. What are the strategies to help prepare for and manage the effects of tropical cyclones?

- Warnings about impending tropical cyclones are normally communicated by the local weather office or disaster risk management centre.

8.1. What precautions should be taken?

- Across the world advice in the event of a tropical cyclone is communicated in the form of posters and literature.
- During the 2012 tropical cyclone season the South African Weather Service (SAWS) issued the following precautions on the radio, TV and Internet.
 - Avoid crossing strongly-flowing or flooded rivers at causeways or drifts.
 - Dwellings very close to rivers or within floodplains should be evacuated in good time.
 - Farmers should move pumps away from rivers.
 - Small to medium-sized boats and fishing craft should return to port.

Small fishing boats should be moved well above the normal high-water mark and firmly secured, as storm surge can be expected to raise local sea levels.

Term 1:

Topic 1: Climate and weather

Unit 3: Subtropical anticyclones and associated weather conditions

Key terms

Trough	An outward bulge in a low-pressure system towards a high-pressure system, shown on synoptic maps by the circle-like patterns of the isobars.
Offshore	Wind from the land moving towards the sea.
Onshore	Wind from the sea moving towards the land.
Altitude	Height above sea level.
Anticyclone	An area of high pressure where air is sinking.
Berg wind	In South Africa a hot, dry descending wind from the mountain areas to the coastal areas.
Escarpment	The steep area of land separating the high lying areas of South Africa from the coastal regions.
Inversion	An area where temperatures increase, instead of decrease (as is normally the case) with an increase in altitude).
Moisture front	A meeting place of air with different moisture conditions.
Relief	The shape of the land.
Smog	A mixture of smoke and fog.
Stable	Conditions associated with sinking air in a high pressure area.
Subside	Sink

1. Location of the high-pressure cells that affect South Africa

- Over South Africa the subtropical high pressure belt is broken up into three high pressure cells that affect the climate of South Africa –
 - the South Atlantic high pressure cell,
 - the South Indian high pressure cell and
 - the Continental (or Kalahari) high pressure cell that forms over the interior of the land mass.

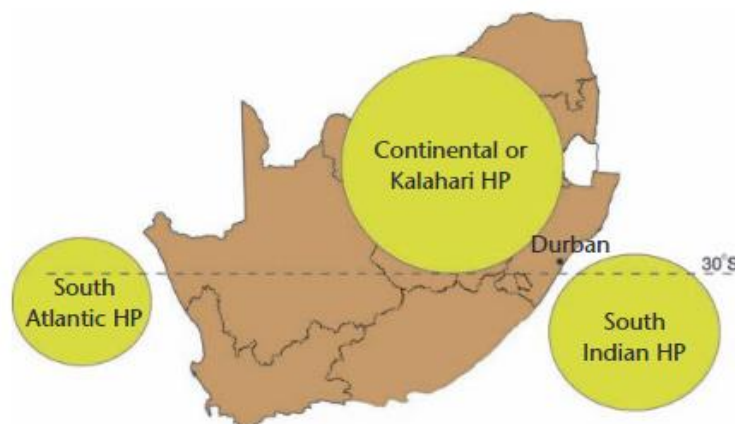


Figure 2.25: The three high pressure cells that affect South Africa's weather

1.1. Factors influencing the climate of South Africa

- Oceans surrounding the sub-continent
 - Oceans surrounding the subcontinent have a moderating influence on the weather and climate.
 - The cold Benguela current brings cooler, dry air into the west coast.
 - Along the east and south coast, the warmer Mozambique and Agulhas currents bring warm, moist air over the adjacent coastal regions.
- The plateau
 - The high altitude of the plateau lowers temperatures.
 - With the steep escarpment 'along the coast' preventing moist air coming into the interior, drier conditions are caused in the interior.
- The subtropical anticyclones
 - South Africa is situated in the subtropical high-pressure zone where air sinks and results in higher temperatures and dry, cloudless weather.

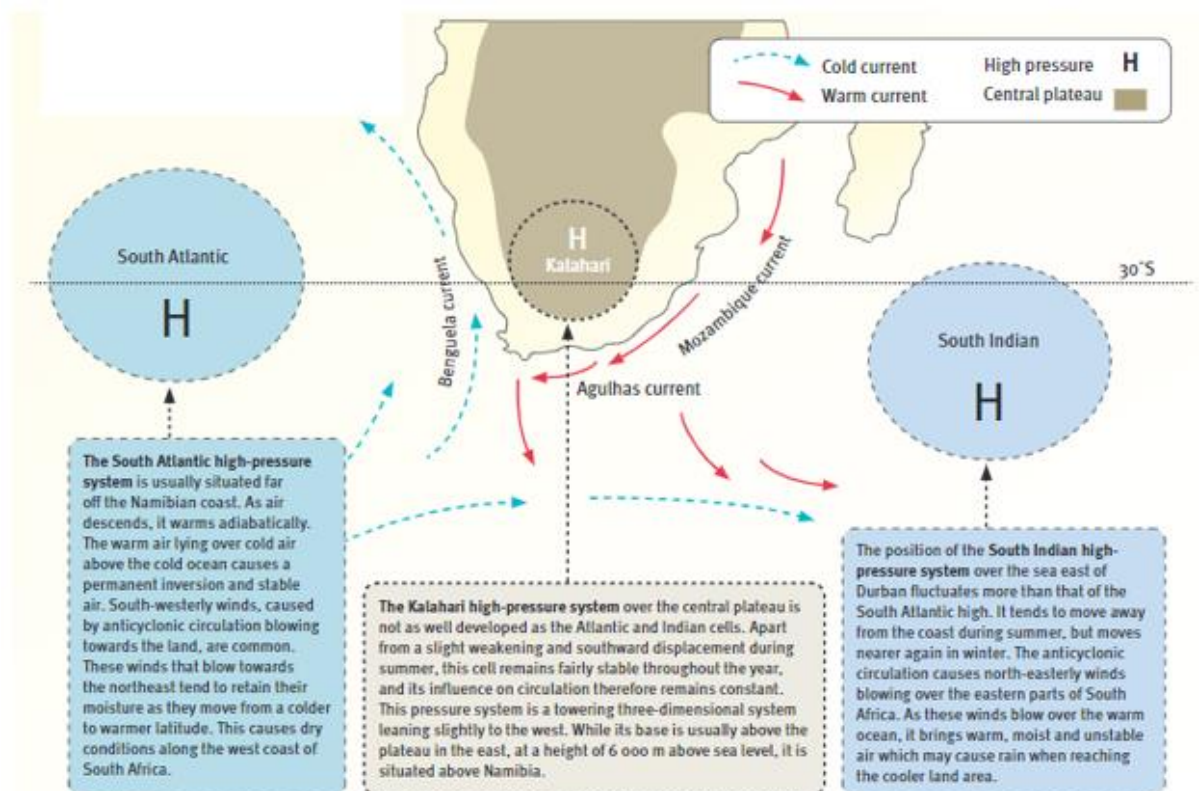
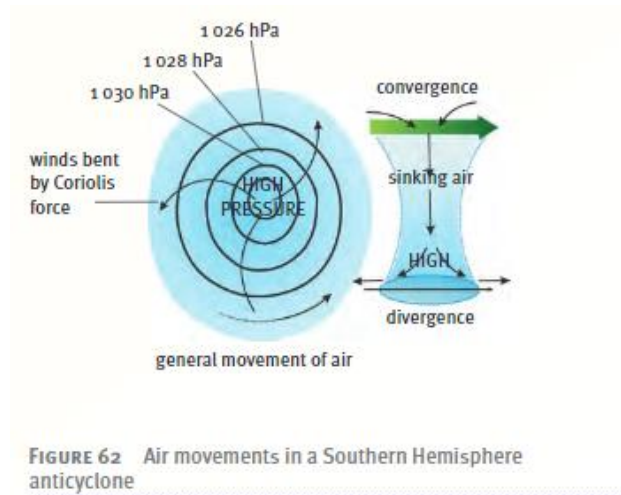


FIGURE 61 Main influences or determinants of South Africa's climate

2. What are the characteristics of these high-pressure cells?

- The high-pressure cells are weather systems characterised by:
 - Descending air
 - Air that comes from the dier upper atmosphere
 - Descending air warming at around 1 °C/100 m
 - Fair, sunny and dry weather conditions
 - A continual state of change, for example, their size.
 - Moving northwards in winter and southwards in summer.

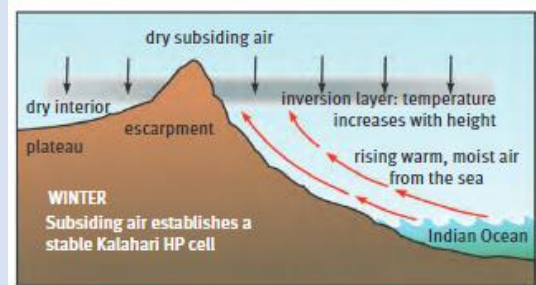


3. How does the anticyclonic air circulation around South Africa influence the weather and climate?

- The Kalahari high-pressure cell over the interior is associated with fine weather, but it impacts our weather differently in winter and summer.

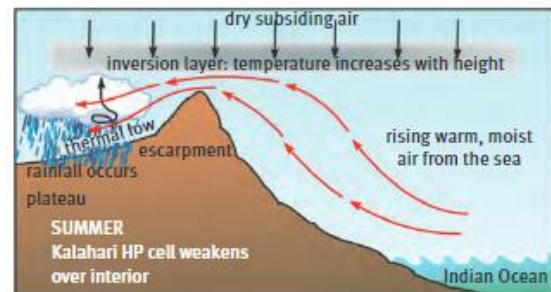
Winter:

- Subsiding air in the Kalahari cell heats lower layers and most moisture evaporates, causing a dry interior.
- Because of the cold plateau with no rising air, an inversion layer is formed.
- This is often lower than the escarpment and prevents moist air moving in from the Indian Ocean.
- Frost is common on the plateau due to cloudless nights and quick cooling of the Earth's surface.



Summer:

- The sinking air of the Kalahari high-pressure cell is weaker.
- The plateau is hot and air rises, causing thermal lows.
- The inversion layer is now higher, above the escarpment.
- Warm, moist air can flow in from the ocean, causing extensive rainfall in the eastern part of the country.
- In the western half of the country, subsidence of air (sometimes as hot berg winds) causes little or no rain.



4. What are the travelling disturbances associated with anticyclonic air circulation in South Africa?

- The shifting of the anticyclonic air circulation in high-pressure cells over and around South Africa during the year, as well as the air movement between them, creates travelling disturbances.
- These disturbances create weather phenomena that significantly impact the weather of specific regions.
- Some of these phenomena occur more frequently in summer and others more often during winter months.

4.1. Disturbances occurring mostly in summer

4.1.1. Line thunderstorms and moisture fronts

- Line thunderstorms are caused by large-scale convergence along the trough line or moisture front on the boundary between the cooler dry air from the Atlantic Ocean and the warmer moist air from the Indian Ocean (Figure 64).
- The sequence of weather processes at the moisture front is similar to the developments along a cold front.
- The colder and denser air from the Atlantic Ocean moves in beneath the warmer less dense air from the Indian Ocean, forcing it upwards.
- This causes condensation and cumulonimbus cloud formation.
- The effect of the uplift is strongest along a line east of the moisture front and parallel to it.
- This is where thunderstorms and heavy rain develop.
- Sometimes this line extends almost from coast to coast.
- The storms move eastwards, along with the moisture front.

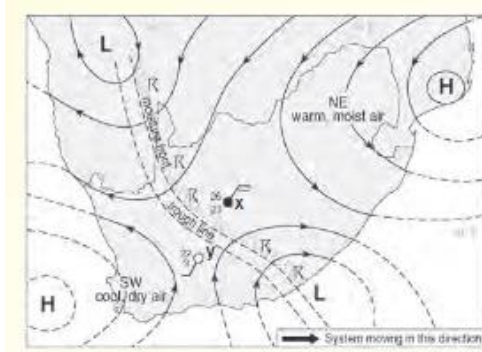


FIGURE 64 Line thunderstorms along the eastern side of the moisture front

4.2. Disturbances associated with winter conditions

4.2.1. Coastal low-pressure system

- A coastal low-pressure system is a weak low pressure cell, about 100km wide, in the lower layers of the atmosphere (Figure 65).
- Coastal lows occur when the wind blows from the land to the sea.
- This results in warm, often strong, offshore berg winds in front of the low and cool onshore flow behind it.
- This often causes fog. Coastal lows form off the west coast, move around the south-western Cape and then along the east coast, finally disappearing near Mozambique.
- Coastal lows often precede an approaching mid-latitude cyclone.
- Areas over which they move may experience instability, partly cloudy conditions and possible drizzle, due to the rising air.
- Coastal lows pass Port Elizabeth about five times a month.

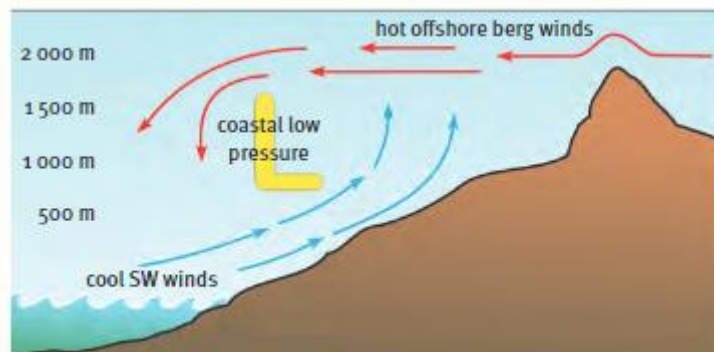


FIGURE 65 The origin of coastal low pressures

4.2.2. Berg winds

- Berg winds are warm, dry offshore winds, descending from the high-lying areas and blowing towards the sea.
- Berg winds occur mainly in winter, but they can also cause very dry and hot days during other seasons.
- The air pressure over the interior usually is high, due to the position of the Kalahari high-pressure cell.
- Along the coast lower air pressures can be due to a passing coastal low or mid-latitude cyclone (Figure 66).
- The difference in air pressure causes a strong pressure gradient, and winds blow from the high pressure on the plateau to the lower-lying coastal regions.
- Berg winds warm up adiabatically at approximately $1^{\circ}\text{C}/100\text{ m}$ descent.
- Coastal towns can experience dry air of over 30°C in winter.

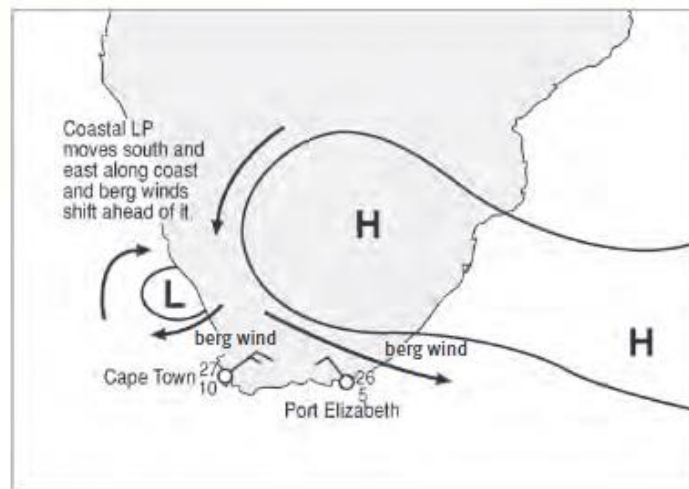


FIGURE 66 The berg wind phenomenon

5. Satellite images and synoptic weather maps linked to subtropical anticyclonic conditions

5.1. Summer conditions

- The typical summer weather patterns are closely linked to the basic pattern of atmospheric pressure and the summer circulation.
 - The westerly wind belt and its depressions move well south of the continent (Figure 67).
 - Temperatures generally are high.
 - The South Indian high is situated eastwards and anti-clockwise circulation transports moisture on its way to the continent.
 - Uplift along the escarpment can cause clouds and precipitation.
 - Moist air moves westwards with an inversion layer at higher levels.
 - The South Atlantic high is closer to the west coast and brings in dry air.
 - A moisture front forms where the different air masses from the Indian and Atlantic oceans meet (east of the low-pressure trough).

- Thunderstorms develop along the moisture front (see weather at Windhoek on Figure 67) and west of the low-pressure trough on the satellite image (Figure 68).
- Note position of tropical cyclone Dando on both Figures 67 and 68.
- Summer heating causes a heat low to develop in the west or northwest, causing clockwise wind circulation.
- Coastal lows may develop on the west coast, causing fog and drizzle along the south coast.

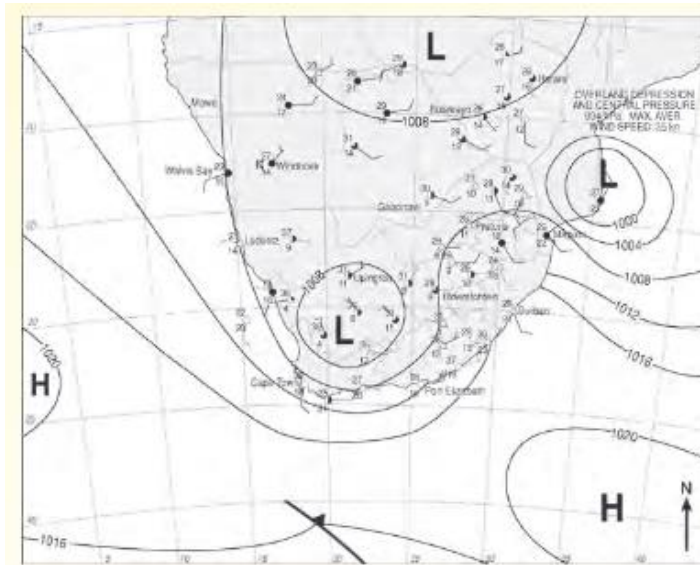


FIGURE 67 Synoptic weather map (16 January 2012) typical of summer conditions

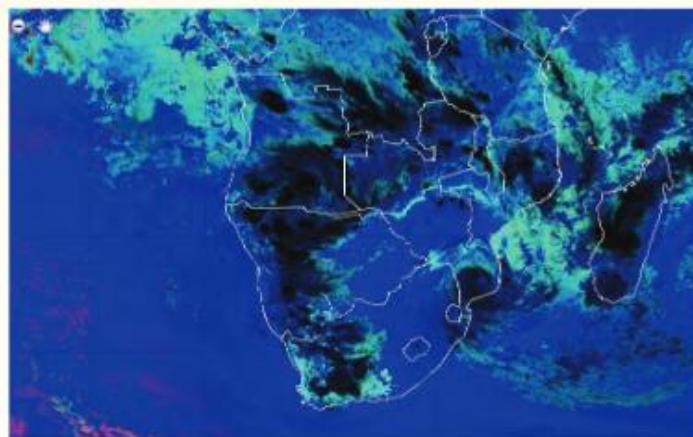


FIGURE 68 Satellite image for 16 January 2012

5.2. Winter conditions

- The synoptic weather map in Figure 69 illustrates weather patterns typical of winter conditions.
- Compare this with Figure 67.
 - All pressure belts and circulation shift northwards.
 - Westerlies and cold fronts are closer to the continent.
 - Temperatures are generally lower than shown on Figure 67.
 - Absence of a heat low over the interior can cause the Atlantic and Indian highs to be linked overland.
 - The Kalahari anticyclone is prevalent over the interior. It prevents warm, moist air from moving into the interior. This results in dry conditions with little cloud cover.
 - Air flows from the high over the interior to the lower pressure along the coast, causing berg winds. These winds heat up adiabatically as they flow down the escarpment.
 - Coastal lows may form. Offshore winds and clear skies will occur ahead of them and onshore winds with cloudy skies behind them.

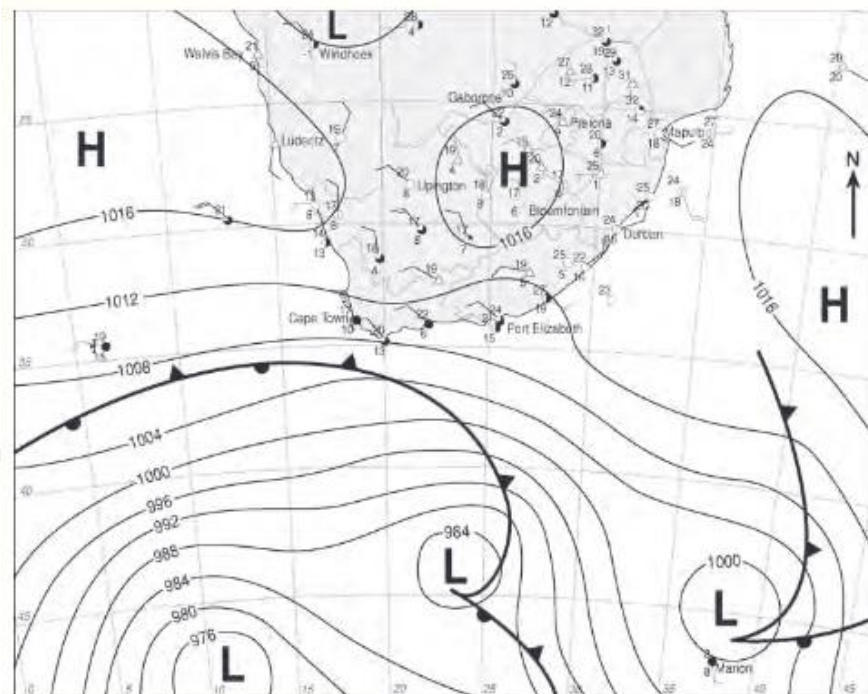


FIGURE 69 Synoptic weather map (16 May 2005) typical of winter conditions

Term 1:
Topic 1: Climate and weather
Unit 4: Valley climates
Key terms

Insolation	Energy from the Sun reaching the Earth's surface.
Thermal belt	The zone where warmer air is trapped between colder air masses, usually along the middle section of a valley slope.
Smog	A mixture of smoke and fog, seen as the hazy smoke layer over an urban area, in which smoke particles act as nuclei for condensation.
Impact assessment	Study of how any change may affect the environment and the communities living in it.
Anabatic wind	An upslope wind in a valley during the day.
Aspect	The direction in which a slope faces.
Katabatic wind	A downslope wind in a valley at night.
Mountain wind	The movement of air down the length of a valley during the night.
Radiation fog	Early morning low cloud formed as a result of temperature inversion.
Valley wind	The movement of air up the length of a valley during the day.

1. What are micro-climates?

- A micro-climate, or local climate, refers to the climate of a small area such as a valley or an urban area.
- These localised climates are normally influenced by the characteristics of the specific locality.
- Therefore, they differ from nearby areas with different characteristics.
- While people adapt to these micro-climates, they also modify them.

2. How is the micro-climate in valleys influenced by the effect of the slope?

- The micro-climate of an enclosed valley is called a valley climate.
- The location and direction of the hill slopes of the valley in relation to the Sun's rays are called the slope aspect.
- This has an important effect on the valley climate.
- Temperature differences also depend on the angle of the slope, for example, in regions of high latitude, where the Sun's rays strike the Earth's surface at a low angle.
- Furthermore, slopes facing the equator (in middle and high latitudes) are warmer than slopes facing away from it (Figure 70).
- In Figure 70 two surfaces are heated more intensely than others: KL and MN.
- The level part, JK, receives less insolation than KL and MN.
- Figure 70 also illustrates the shadow zone where there is no direct warming by the Sun.
- In the Southern Hemisphere (as in the example) the Sun's rays therefore strike the surface from the north at a fairly low angle.
- North-facing slopes are warmer than south-facing slopes.

- South-facing slopes are likely to be in the shadow for a longer period of the day, especially in winter.
- Vegetation in valleys can have a zonal distribution, based on the position of the Sun's incoming rays.
- People are also influenced by aspect.
- In southern Africa groups of dwellings are often located high up on the slopes rather than low down in the valleys, and on the warmer north-facing slopes rather than on the south-facing sides.
- In modern cities in the Southern Hemisphere, residential plots on warmer north-facing slopes are more popular than those on south-facing slopes, which are colder in winter.

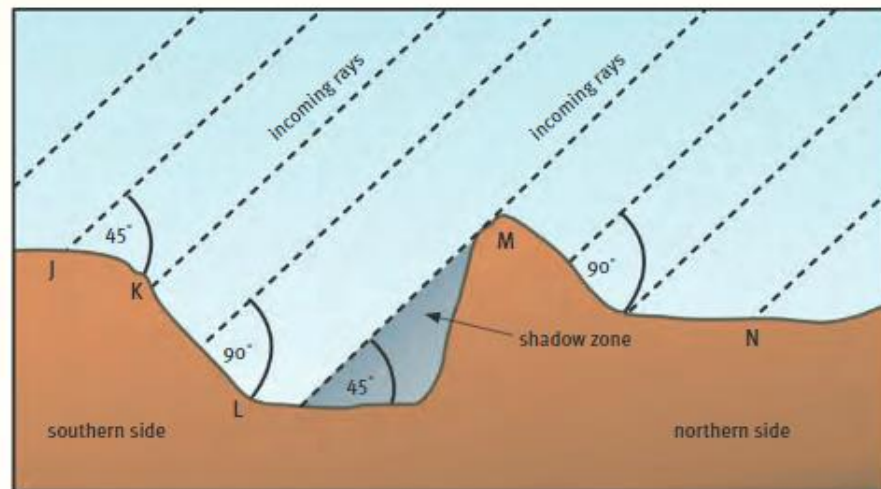


FIGURE 70 The relationship between slopes and the Sun's rays in the Southern Hemisphere



3. What weather phenomena are associated with the micro-climate in valleys?

3.1. Anabatic and katabatic winds

- When there is little or no influence by regional weather systems, valleys produce their own winds due to unequal heating of the valley slopes during the day and night.

Anabatic winds

- Anabatic winds move up the slope of a valley.
- They occur during the day due to the upper slopes of a valley heating up quickly.
- This causes a lower pressure to develop, resulting in air from the bottom of the valley moving upslope to the lower pressure.

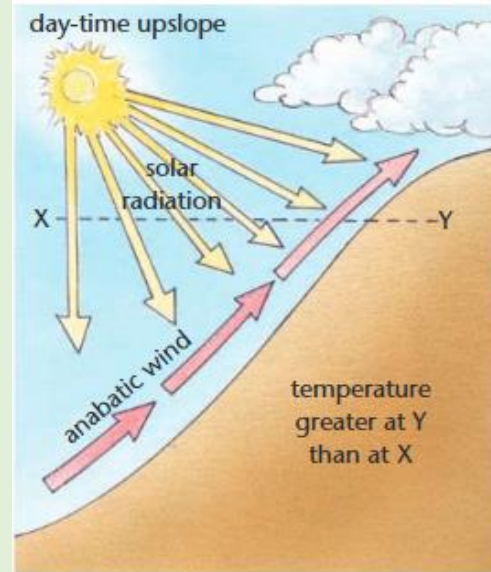


Figure 2.35a): Anabatic winds

Katabatic winds

- A katabatic wind moves down the slope of a valley during the night.
- Air in contact with the slope of a valley is colder than over the centre of the valley due to loss of heat through longwave radiation.
- This air moves down the slope under the influence of gravity.

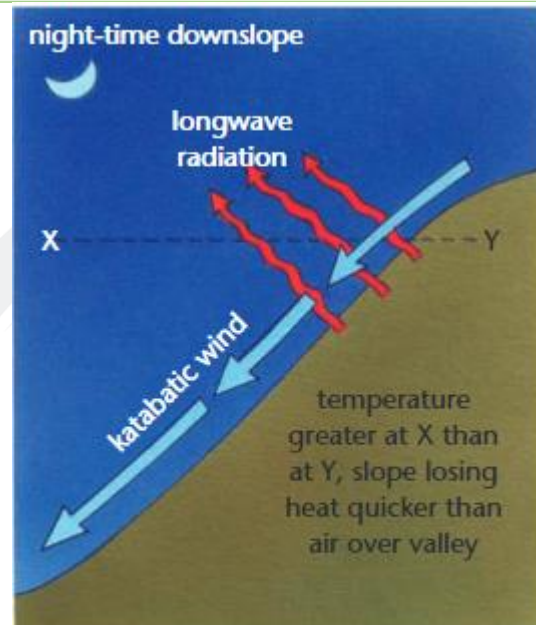


Figure 2.35b): Katabatic winds

Valley winds

- A valley wind blows during the day.
- A low pressure develops in the upper areas of the valley at A due to more intense heating.
- Air moves up the length of the valley from B to A.

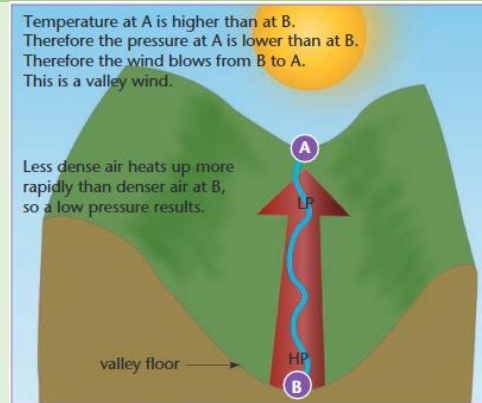


Figure 2.35c): Valley winds

Mountain winds

- A mountain wind blows during the night.
- There is greater heat loss at B, causing the pressure to be lower at B than at A.
- This causes air to move down the length of the valley from A to B from higher to lower pressure.

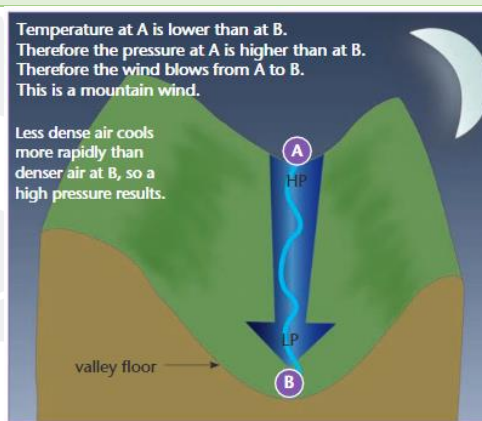
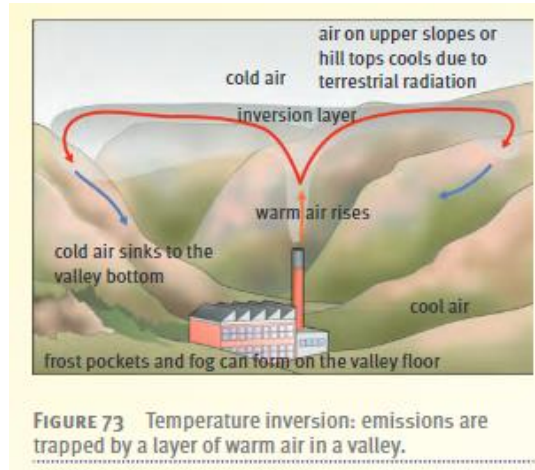


Figure 2.35d): Mountain winds

3.2. Inversions

- Air is less dense higher up the slopes of a valley than on the lower slopes.
- On the upper slopes this results in higher levels of insolation during the day and more radiation at night.
- On calm, cloudless winter nights with no strong winds to mix the air, the upper slopes of the valley cool rapidly due to terrestrial radiation.
- The air becomes denser and flows down the slopes to collect in valleys, depressions or hollows.
- While cold air now displaces warm air on the valley floor, warmer air rises to replace the cold air that moved away from the high-lying areas.
- In this way a layer of warm air is trapped between two layers of cold air.
- This forms a temperature inversion layer (Figure 73) and temperature increases with altitude in the valley.



3.3. Frost pockets

- Frost is widespread in South Africa and can cause extensive damage during winter.
- Cold air moves down the slopes and collects in the lowest part of the valley.
- When temperatures there drop below freezing point and dew point temperature is reached, water vapour condenses directly into ice crystals, forming frost.
- The slopes at the top of the valley have relatively little frost or are frost-free.
- When frost forms on the valley floor where cold air collects it is called a frost pocket, which may have a significantly shorter growing season than the surrounding region.
- Many farmers take this into consideration when planting a variety of crops on the same slope.
- Those that are frost-resistant are planted at the foot of the slopes, while those that are sensitive to frost are planted higher up the slope.

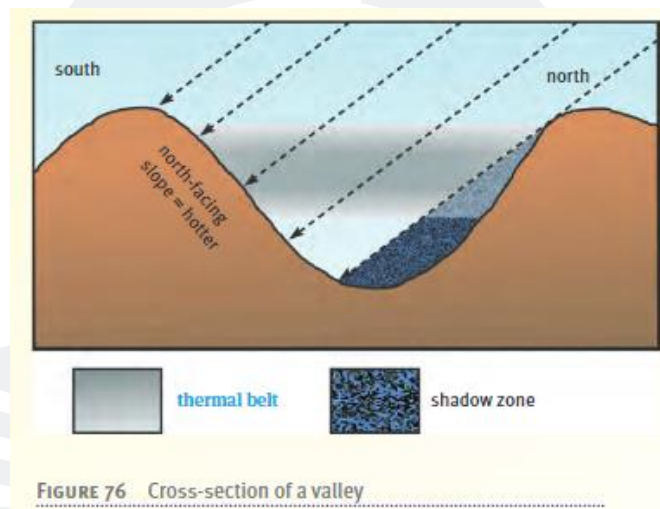
3.4. Radiation fog

- Radiation fog, typically found in valleys, is formed when nights are cold, clear and cloudless.
- Under such conditions the Earth's surface and the layer of the atmosphere in contact with it cool rapidly.
- If the cooling process occurs over a greater vertical distance than needed for the formation of dew and dew point temperature is reached, condensation occurs and many minute droplets are formed.
- These droplets are so small that they are suspended in the air.
- As this fog is formed as a result of radiation from the Earth's surface, it is called radiation fog.
- Fog on the valley floor disappears rapidly during the course of the morning after insolation starts, when the Earth radiates heat into the atmosphere.

4. How do local climates impact human activities?

4.1. Influence on settlement

- Aspect influences settlement patterns.
- People in South Africa normally prefer the warmer north-facing slopes rather than colder and shadier south-facing slopes.
- Settlements are more likely to be developed mid-slope in the warm thermal belt (Figure 76).
- This is the warmer air layer that is trapped above the colder valley floor and beneath the colder mountain tops.
- Night-time temperatures will also be higher in the thermal belt.
- In rural areas many groups of dwellings are located high up on the slopes rather than low down in the valleys.
- This is because cold air may sink to the bottom of a valley. In densely settled narrow valleys, where industry is concentrated, air pollution can become particularly dangerous when pollution and smog are trapped by an inversion.
- A pollution plume usually can be seen over the affected area.



4.2. Influence on farming

- Aspect affects farming.
- For example, in South Africa vineyards are planted on the warmer north-facing slopes.
- Trees, shrubs and shade-loving plants will thrive on the wetter, cooler south-facing slopes.
- Vegetation in valleys tends to have a zonal distribution, based on different temperatures in a valley.
- Deciduous farmers plant their trees in the bottom of valleys as they require a genetically determined amount of cold weather (chill hours) to set fruit.
- In the Elgin valley, apple and pear trees are planted in the cold lower part of the valley, while peach trees, which are more sensitive to cold, are invariably planted higher up the slopes.
- Citrus trees that are subtropical in origin and cannot tolerate severe frosts are planted against slopes to avoid frost pockets damaging the crop immediately before harvest.
- Citrus production in South Africa is consequently confined to areas with mild and almost frost-free winters where temperatures seldom drop below -2°C and almost never below -3°C .

5. Indigenous knowledge and climate change**5.1. What is indigenous or traditional knowledge?**

- Indigenous knowledge is the knowledge and know-how that traditional societies have accumulated down many generations.
- This is renewed by each new generation and guides them in their interactions with their surrounding environment.
- The ability of traditional societies to adapt to environmental change is based on their understanding of the land.
- Communities adapt and respond in unique ways to ongoing environmental and climate change.

5.2. Why should indigenous knowledge be valued?

- Today, many indigenous societies are vulnerable to the impact of climate change, for example through floods and drought, because their livelihoods are based on local resources.
- The decisions, policies and actions undertaken by mainstream society to support indigenous societies are often inadequate, ill-adapted and even inappropriate.
- This is because of inadequate understanding of the specific vulnerabilities of local communities, their concerns and their ability to adapt.
- When we appreciate indigenous knowledge it helps us to understand how traditional communities adapt to change.

5.3. Can indigenous knowledge contribute to climate science?

- Indigenous observations and interpretations of meteorological phenomena have guided activities of local communities for millennia.
- The indigenous understanding of climate is useful, especially in the fields of impact assessment, and natural disaster preparedness and response.
- As indigenous knowledge focuses on elements of significance for local livelihoods, security and well-being, taking this knowledge into account is essential for planning adaptation to climate change.

Term 1:

Topic 1: Climate and weather

Unit 5: Urban climates

Key terms

Hygroscopic nuclei	Particles that attract water and promote condensation.
Turbulent	Swirling.
Evapotranspiration	The release of water vapour from open water bodies and plants.
Isotherms	Lines on maps joining places of equal temperature.
Vector-borne disease	Disease spread by blood-sucking insects or arachnids.
Particulates	Tiny pieces of solid matter or liquid that pollute the air.
Fallout	The pollutant that settle on the land under the influence of gravity.
Inversion	When temperatures increase with height because a layer of warm air lies over a layer of colder air.
Isotherms	Lines on a map joining all places with the same temperature.
Pollutant	Substances causing pollution.
Pollution	Doing something that makes elements in the natural environment dirty and not safe for use.
Pollution dome	A dome-shaped area of pollution that is trapped by an upper air inversion.
Urban heat island	An area of higher temperature in a city area surrounded by lower temperatures.
Washout	The pollutant particles deposited on the ground because of rain.

1. What are the differences between rural and urban climates?

- Major urban areas (cities) alter the weather and have their own urban climates.
- Increasing urbanisation and the growth of large cities have a dramatic effect on micro-climate.
- As urban areas expand, our activities like the construction of factories, motor ways, office blocks and residential areas destroy the existing micro-climate and create another.
- This will continue to happen as urbanisation increases.
- Climates in major urban areas usually differ markedly from the rural climates of surrounding areas.
- Urban micro-climates are normally warmer than those of rural areas in both winter and summer.
- The micro-climates in valleys are caused mainly by topographical features, but micro-climates associated with urban areas are strongly linked to land-surface characteristics.
- For example, extensively paved areas both absorb and radiate heat more strongly than vegetated areas.

2. What are the reasons for these differences?

- Key factors that cause these changes are:
 - The different building materials used in cities.
 - The taller structures in an urban area.
 - The lack of vegetative cover in an urban area
 - The greater number and variety of human activities in cities.
- Each urban area will have local differences in their urban climate.

Criterion	Urban versus rural climate conditions	Reason for difference
Annual mean Temperature winter Minimum	0,5 °C to 2 °C higher 1 °C to 3 °C higher	Urban areas are built with artificial surfaces such as tar, concrete and brick, all of which retain heat.
Cloudiness Fog in winter Fog in summer	5-10% more 100% more 30% more	Urban activities give off more pollutants that create more condensation surfaces on which water vapour can condense to form clouds.
Precipitation Amount of snowfall	5-10% more 5% less	More clouds cause more rainfall. The warmer conditions in winter will lead to less snow falling.
Relative humidity – the amount of moisture in the air	2-3% less	There are fewer moisture sources in a city, such as trees and dams. Storm water drains remove surface water after it rains.
Dust and pollutant particles	10 times more	Building and factory activities add more dust and soot to the air over a city.
Radiation amount	15-20% less	The increased amount of pollution in a city reduces the amount of solar energy that reaches the Earth's surface

- The difference in temperature between urban and rural areas depends on:
 - The size of the city or the area covered by the city
 - Number and types of industries in the urban area
 - Local factors such as relief and altitude
 - Distance from large water surfaces like the sea or lakes
 - Time of the day and the season of the year
 - Percentage of open space in the city
- The effects of various factors on the micro-climate in and around an urban area are illustrated in Figures 83 and 84.
- Figure 83 plots the change in temperature across the built-up areas of the city of Christchurch and the surrounding rural areas in New Zealand.
- The isotherms indicate how temperature changes along the line X–Y.
- Compare this with the accompanying graph and note the following.
 - Temperatures increase as you move into the centre of the city.

- The highest temperatures are experienced in the central business district (CBD) and the lowest in the surrounding rural areas.
- Areas with vegetation, like the park, and water surfaces like the harbour, experience lower temperatures than constructed areas with artificial surfaces.

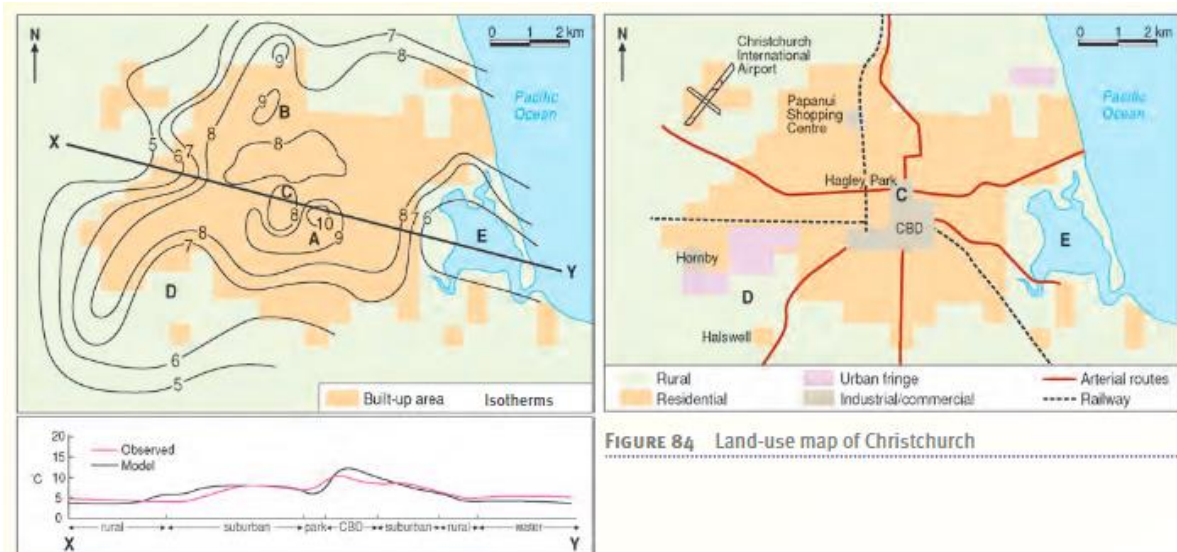
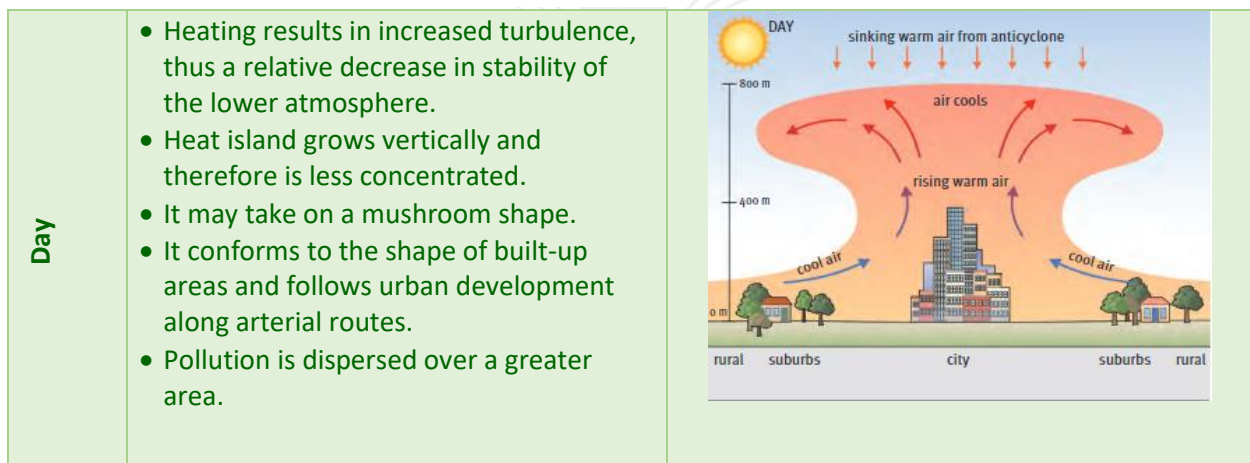


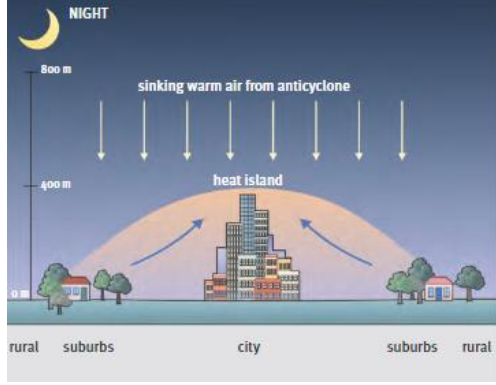
FIGURE 83 Temperatures in and around Christchurch, New Zealand

FIGURE 84 Land-use map of Christchurch

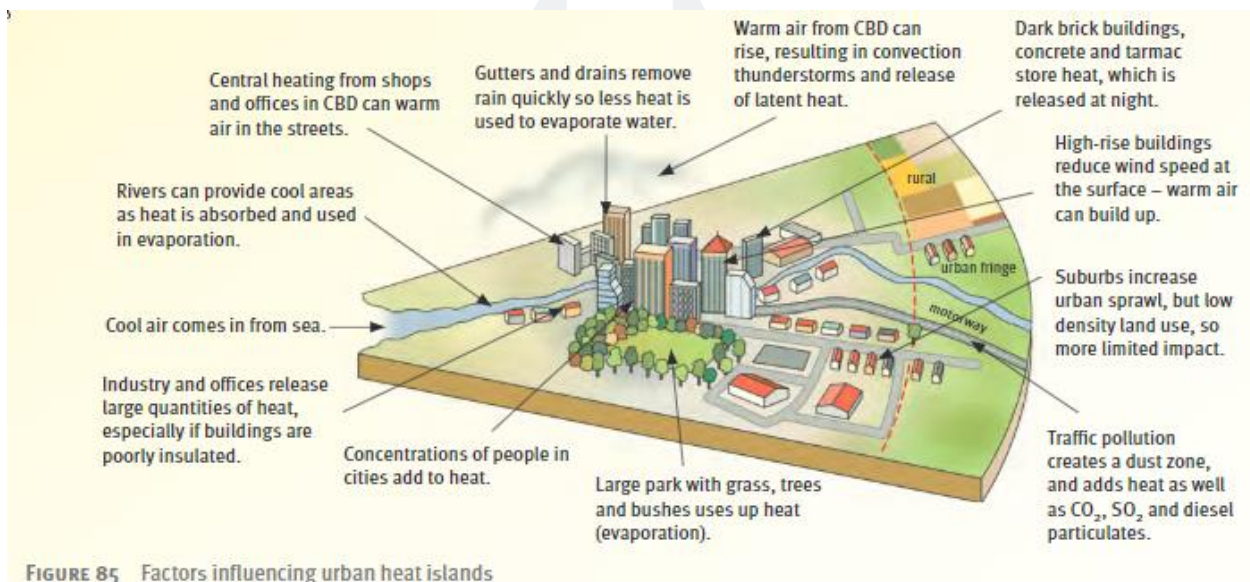
3. What is an urban heat island?

- An urban heat island is the name given to describe the characteristic warmth of both the atmosphere and surfaces in cities compared to their non-urbanised surroundings.
- For example, in Johannesburg, on winter nights temperatures in the central city area are at least 5°C higher than in the outer suburbs.
- Urban heat islands exist throughout the year, but their effect is more pronounced at night and in winter when temperatures are lower.
- This is also the situation when there is a prevailing anticyclonic subsidence of air, which is a common occurrence in southern Africa in winter.



Night	• With less heating, there is a decrease in turbulence, thus a relative increase in stability of the lower atmosphere. • The vertical dimension decreases and therefore the heat island is more concentrated. • The 'heat bubble' is now denser and shallower and takes on a dome shape due to the cooling of the air. • Pollution is concentrated in the dome.	
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3.1. What are the causes of urban heat islands?



3.2. What effects do urban islands have?

- Heat islands have a range of effects on both city dwellers and the environment.
- These include:
 - increased human discomfort, especially in summer
 - exacerbated heat stress and deaths during heat waves, especially in temperate areas
 - increased conditions suitable for the spread of vector-borne disease, caused by insects such as mosquitoes and fleas
 - reduced visibility due to smog, particularly in winter
 - increased energy use, especially in summer
 - increased air conditioner use leading to release of more heat and greenhouse gases, which degrade local air quality
 - increased urban smog due to higher urban temperatures in the daytime

- increased levels of urban ozone and air pollution
- increased costs because of greater water and energy use
- increased biological activity, for example, growing season length, which is positive
- reduced ice and snow, which is positive.

4. What is a pollution dome?

- A pollution dome is a mass of polluted air in and above a city or industrial complex.
- This air is prevented from rising by the presence of an inversion above it.

4.1. What causes a pollution dome?

- In calm, stable air over the city, the temperature will decrease with altitude but at a slow rate.
- Although convective mixing of air occurs, the formation of precipitation is inhibited due to higher temperatures in the inversion layer.
- With the pollution trapped beneath the inversion layer, a broad pollution dome can form over an urban area (Figure 86).
- If there is a wind, the pollution will be carried downwind to form a pollution plume.
- Particulates concentrated in the urban atmosphere serve as nuclei for the condensation of water.
- Studies show that precipitation is enhanced downwind of an urban area due to increased particulate content in air (Figure 86).
- The air above urban areas has up to 200 times more sulphur dioxide and 10 times more nitrogen oxide (which are the major components of acid rain) than rural areas.
- It also has 10 times more hydrocarbons and twice as much carbon dioxide (CO₂).

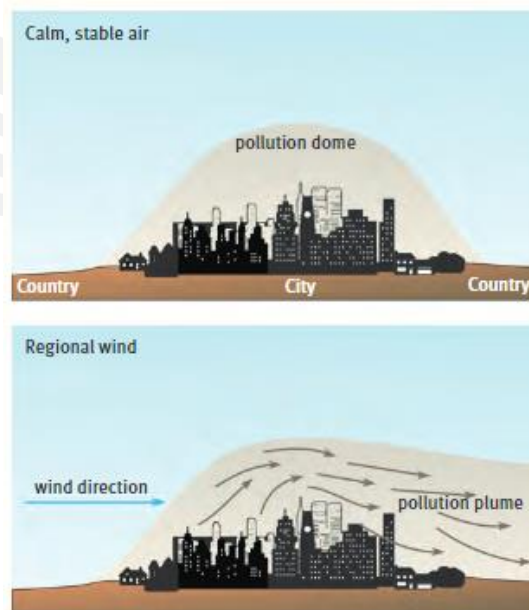


FIGURE 86 Pollution dome and plume

4.2. What are the effects of a pollution dome on people and the environment?

- Urban pollution has both seasonal and long-term effects on humans and the environment.
 - Lead poisoning may result from petrol fumes and old paint peeling off buildings.
 - Respiratory discomfort and asthmatic attacks may increase due to smoke emissions.
 - The pollutants tend to increase cloud cover and precipitation.
 - During winter more heat is generated and convection (the environment's cleaning process) is not as active because there is less solar radiation and more temperature inversion.
 - Insolation is reduced by pollution, especially in the morning when the Sun's oblique rays have to penetrate an even thicker layer of pollution.
 - The pollutants cause smog, which contributes to higher temperatures, reduces visibility and is harmful to humans and plant life (Figure 87).
 - The release of oil and coal combustion emissions in the air develops extremely corrosive acids, which fall back to the ground as acid rain. This pollutes rivers and lakes, causes damage to buildings and causes plants and fish to die.
 - Increased use of fossil-fuel-powered plants also increases emissions of greenhouse gases, such as carbon dioxide (CO_2), which contribute to global climate change.

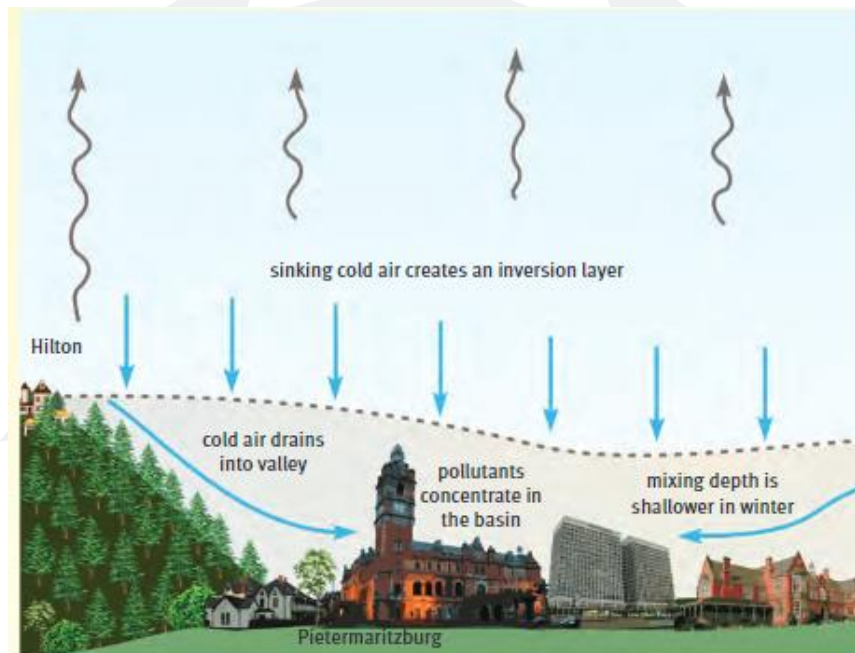


FIGURE 87 The formation of air pollution on a winter's morning in Pietermaritzburg

5. How can the heat island effect be reduced?

- The reduction of the urban heat island effect depends on a number of factors.
- Some of them are within and some outside of a community's control.
- Although prevailing weather patterns and topography are beyond the influence of local policy, decision makers can select energy-saving strategies that will create a healthier and more sustainable environment.
- Creating urban green spaces like parks and roof gardens, appropriate building design and public transport, can all contribute to reducing urban heat islands.



Term 1:

Topic 2: Geomorphology

Unit 1: Drainage systems in South Africa

Key terms

Aquiclude	A zone which does not allow water to move through it.
Aquifer	A zone where we find underground water.
Base flow	Groundwater that flows below the saturated water zone.
Confluence	The place where two rivers join.
Drainage basin	The area into which a river and its tributaries drain, and from where they get their water.
Episodic river	A non-perennial river which only flows for a short time after a period of rainfall.
Exotic river	A perennial river which flows through dry landscape but has its source in a well-watered area.
Groundwater	The water found under the ground in rocks and pore spaces.
Hydrograph	A graph showing the flow of a river over a period of time.
Interfluvium	The high-lying area between two river valleys.
Infiltration	The process of water seeping into the ground.
Lag time	The time between the peak rainfall and the peak river flow.
Mouth	Where the river ends, e.g. in the sea or in a lake.
Non-perennial river	A river which does not flow all year round.
Percolation	The movement of water through the ground.
Perennial river	A river which flows all year round.
Permeable	Something through which water can pass.
Porous	The spaces in rocks and soil through which water can pass.
River system	The main river and all its tributary rivers.
Run-off	The amount of water flowing in the rivers of a drainage basin.
Source	The place where the river begins, e.g. a spring in a high-lying area.
Throughflow	Groundwater that flows above the saturated water zone.
Tributary	A river which joins another larger river.
Water table	The upper level of the groundwater zone.
Watershed	The area of high land separating two drainage basins.

1. What are the characteristics of drainage basins?

- The drainage basin acts as a system with inputs, flow, storage and outputs.
- Water and sediment move through the system.
- The features of the system are dependent on a variety of physical and human factors.
- A drainage basin is the total area of land surface drained by a stream network.

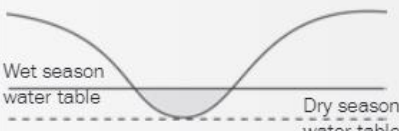
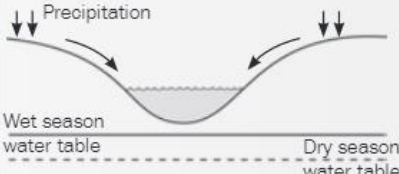


1.1. Features of drainage basins

Catchment area	Area over which rain falls and is caught by a drainage basin
River system	A main river with all its tributaries
Watershed	An area of high ground separating two drainage basins
Tributary	A river that joins another larger river
River mouth	Sea or lake where the river ends
Source	Where the river begins
Confluence	The place where two river join
Water table	The upper level of underground saturated rock
Surface run-off	The surface flow of water
Groundwater	Water found under the ground
Interfluvial	High-lying area or spurs between two river valleys
Infiltration	Movement of water through soil into the ground

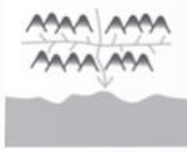
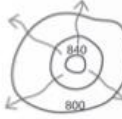
2. What are the different types of rivers?

- The type of river is influenced by the prevailing climate conditions.
- The climate determines the amount and season of precipitation as well as its form as rain or ice.
- Because of varied climate and rainfall patterns, four types of rivers exist.

Type of river flow	Examples of rivers	Sketch to show the water table levels
Permanent rivers: • receive water all year • the water table always lies above the bed of the river (base flow).	Tugela, Vaal, and Crocodile Rivers	
Periodic rivers: • have base flow that only contributes to the river runoff during the rainy season.	Most South African streams	
Episodic rivers: • never supplied with groundwater • will only flow after a heavy downpour, causing a flash flood for a day or so.	Swakop and Buffels Rivers	
Exotic rivers: • rise in high rainfall areas, but flow for most of their courses through arid regions. • groundwater does not contribute to the base flow in these arid areas.	Gariiep (Orange) and Nile Rivers	

3. What are drainage patterns?

- The shape of a drainage basin is determined by the type of land over which the river system flows.
- The differences in rock hardness and rock formations cause different drainage patterns or shapes.
- A drainage pattern refers to the arrangement of streams in a drainage basin.

Stream Pattern	Description of features	Requirements for pattern to develop
Dendritic 	- Pattern is tree shaped. - The tributaries join at an acute angle. - Distinct interfluvies are formed.	- Underlying rock types are uniformly resistant to erosion. - There is little variation in slope or gradient.
Trellis 	- Prominent ridges which lie parallel to each other. - The main river has cut through the ridges forming poorts or gaps. - The tributaries join the main streams at right angles. - The main streams are parallel	- Form in areas where there are alternating layers of hard and soft rock. - Layers are often inclined or folded. - Strong main stream which cuts across the landscape.
Rectangular 	- An angular pattern develops along exposed joints. - Surface water flows along the exposed joints. - Sharp angles in the stream pattern.	- Well-jointed rock outcrops, such as granite. - Joints exposed at the surface, which erode easily.
Radial 	- Streams radiate outwards from the central point (hilltop). - Looks like the spokes of a wheel.	A dome or cone shaped feature such as a volcano or isolated hill.
Centripetal 	- Streams flow towards a depression or lake. - Water does not usually flow out of the lake or water body.	- Drainage patterns like these occur where there are depressions or low-lying swampy areas. - The relief of the area determines the pattern.
Deranged 	- Haphazard pattern of drainage. - Numerous lakes, swamps or meander scars occur; oxbow lakes may form.	- Found in areas which are geologically young. - Surface rocks are unconsolidated and sediments have accumulated more recently.
Parallel 	- When rivers flow parallel to each other. - Usually a few stream all flowing in the same direction down the slope.	Uniformly resistant slopes which may be steep.

4. What is a drainage density?

- Drainage density refers to how many streams there are in a unit area of land.
- This also gives us a valuable way to compare river systems.
- Drainage density is based on this formula:

$$\text{Drainage Density} = \frac{\text{Total length of all the streams in a basin}}{\text{Total area of the drainage basin}}$$

- Drainage density can be described as high or low.
- The drainage density of an area depends on various factors.
- Regions with high rainfall should have a higher density.
- If a large proportion of the rainfall infiltrates into the ground, the surface run-off will be reduced.
- If the slope is gradual or covered with lots of vegetation a large proportion of the water will infiltrate.
- Streams form more easily in areas where softer rock is found.



FIGURE 103 High drainage density

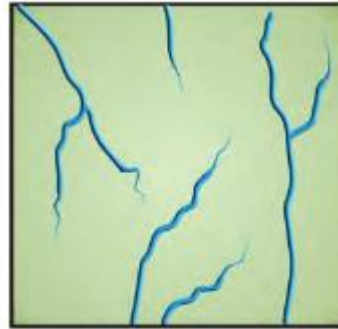


FIGURE 104 Low drainage density

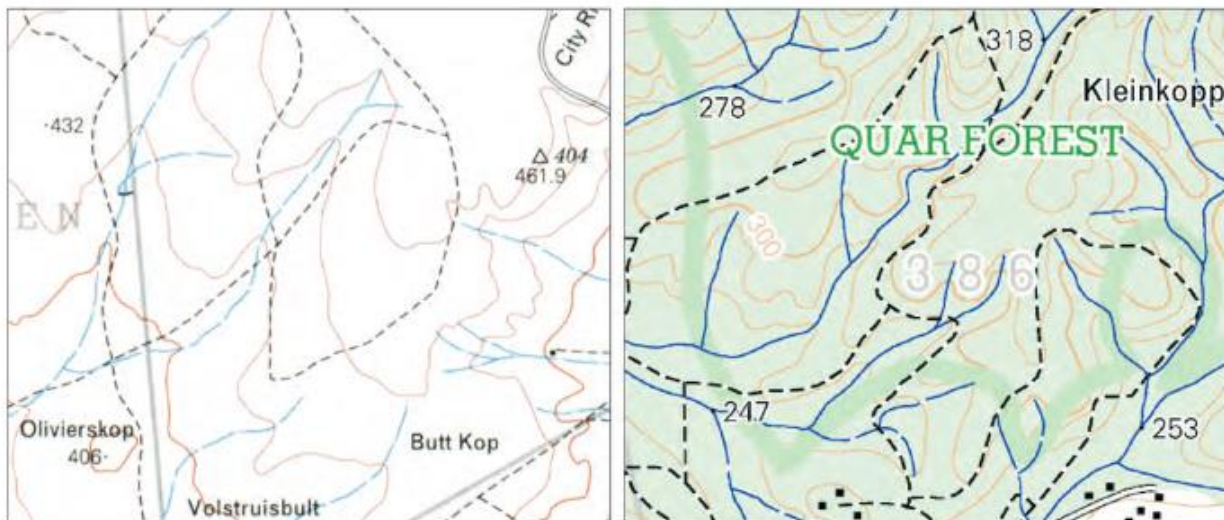


FIGURE 105 Topographic map extracts showing low (left) and high drainage density (right)

5. How do you identify stream order and density?

- Drainage basins can be described and compared by means of a ranking system, known as stream order (Figure 106).
- First-order streams are the lowest in the category and have no tributaries.
- When two first-order streams join, they become a second-order stream.
- When two second-order streams join, they become a third-order stream, etc.
- The largest order determines how the stream will be classified, according to a process of geo-adding.
- The following laws of stream orders show the relationship between stream order and factors such as gradient, number of streams, stream length and the size of the drainage basin.
 - There are more streams of a lower order than of higher order.
 - The lower the stream order, the steeper the gradient.
 - The lower the stream order, the shorter the length of the stream.
 - The lower the stream order, the smaller the drainage basin.

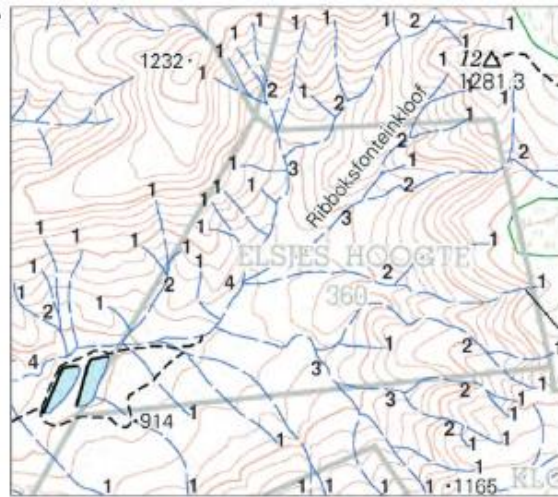
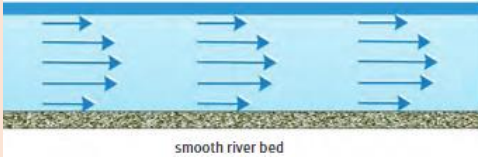


FIGURE 106 Topographic map with the stream order indicated by numbers

6. What is the nature of river discharge?

- River discharge is the volume of water that flows down a river.
- The stream flow can be either laminar, in which all water particles travel along similar parallel paths, or turbulent, in which individual particles take irregular paths.

Laminar flow



- Found where water flows over a level and even river bed.
- The water moves as parallel sheets.
- There is little friction, resulting in higher flow speeds.
- Although the speed is greater than turbulent flow, less erosion occurs because the lower layers of the water protect the channel.

Turbulent flow

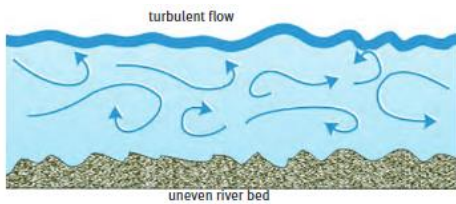


FIGURE 107 Laminar and turbulent flow

- Turbulent flow occurs where the river bed is uneven and steep.
- The water moves in a bubbling, turbulent manner and continually changes levels.
- Turbulent flow keeps sand particles in suspension for longer, causing erosion of the stream bottom.

Term 1:

Topic 2: Geomorphology

Unit 2: Fluvial processes

Key terms

Ungraded profile	When a river has many temporary bases of erosion along the longitudinal profile.
Rejuvenated	Made to look younger; a river showing renewed characteristics of an earlier (younger) stage.
Energetic stream	A fast-flowing stream with lots of energy.
Superimposed	One thing put on top of another.
Fluvial	Of a river, found in a river.
Base level	The lowest point to which a river can flow and erode – usually sea level.
Longitudinal profile	A 'slice' through the river, from source to mouth.
Transverse profile	A 'slice' across the river, from one bank to the other.
Vertical erosion	Downward erosion that makes a river channel or valley deeper; also called downcutting.
Lateral erosion	Sideways erosion that makes a river channel or valley wider.
Fluvial landform	A feature formed by the work of a river.
Erosion	The wearing away and removal of rock and soil.
Deposition	The process in which a river drops its sediment.
Waterfall	An interruption in the course of a river where its water suddenly plunges (falls) over a vertical cliff or rock face.
Rapids	A place in a river where water flows fast and unevenly over rocks.
Alluvium	A fine, mineral-rich soil deposited by rivers; also called silt.
Braided stream	A river with islands of sand deposits.
(natural) levee	A high bank of silt close to the river channel.
Delta	Low, flat land formed by silt deposits at a river's mouth.
Distributary	A branch of a river that flows away from the main stream.
Meander	A U-shaped bend in a river.
Oxbow lake	A curved lake formed from a meander that has been cut off from its river.
Floodplain	The wide, flat part of a valley over which a river spreads in times of flood.
Equilibrium	The state in which two opposing influences are balanced.
Graded river	A stable river with enough energy to transport its load, but no surplus energy for erosion; a river with a concave longitudinal profile.
Overgraded river	A river that erodes more than it deposits.
Undergraded river	A river that deposits more than it erodes.
Rejuvenation	The process in which a river gains new energy and eroding power.
Knickpoint	A point in a river's course that marks an old base level; the slope is gentle above and steep below.
(river) terrace	Step-like remain of old floodplain.
Incised meander	A meander that is cut deep into the landscape.
River capture / stream piracy	A more energetic river hijacks the flow of a less energetic river, usually by eroding through a watershed.

Captor stream	A river that captures another river/steals water from another river.
Captured stream	The captured or captive river.
Abstraction	The lowering of a watershed by erosion until the slope is the same on both sides.
Headward erosion	The erosion near a river's source; it lengthens the river.
Elbow of capture	The right-angled bend in a captured stream that shows the point of capture.
Wind gap	A dry valley between the elbow of capture and the misfit stream.
Misfit stream	A river much too small for its present valley.
Superimposed drainage pattern	A river course formed on top of a layer of sediment that has since been eroded away to expose a buried mountain range or ridge.
Antecedent drainage pattern	A river course formed before mountain uplift and maintained after uplift.

1. How does a river's transverse profile change along its length?

- A river flows from high to low ground, under the influence of gravity.
- Base level is the lowest level to which a river can flow.
- It is usually sea level.
- As a river flows from its source to its mouth, it changes its shape, becoming deeper and wider.

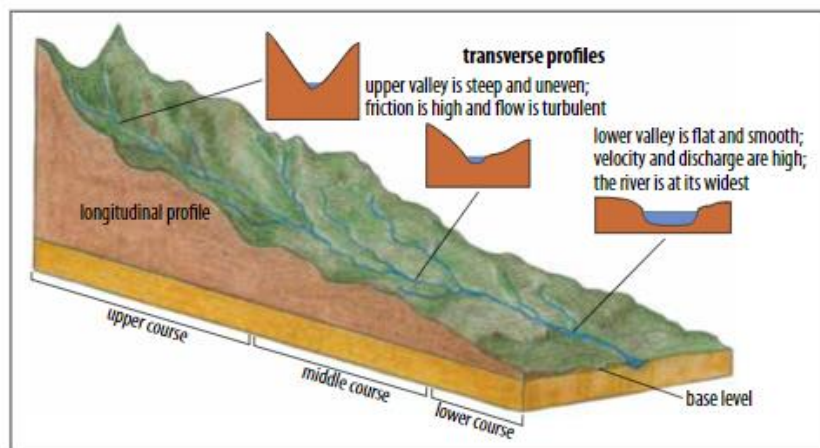


Figure 2.2.1 A typical course of a river

- Figure 2.2.1 shows the longitudinal profile of a river, as well as the transverse profiles for three points along its length.
- The longitudinal profile shows us the length of the river from source to mouth and its descending path towards the sea.
- The transverse profile shows the shape of the river channel, that is, its width and depth.
- Note the relationship between the two types of profile at different stages or points along the river:
 - In the upper course, the valley gradient is steep and the channel is narrow because vertical erosion dominates.

- In the middle course, the valley gradient slopes gently and the channel is wider because lateral erosion dominates.
- In the lower course, the valley gradient flattens out and the channel is at its widest and deepest.

2. What are fluvial landforms?

- Fluvial landforms are features formed by the action of rivers.
- The work of a river involves three main processes:

Erosion	● As water flows, it pummels, it scrapes and scours, and it dissolves rock minerals. ● The ability of a river to erode depends on its height above base level.
Transport	● A river picks up and carries the material downstream. ● Fine, light materials such as silt are carried along in the water. ● Pebbles and rocks are bounced and rolled along the riverbed.
Deposition	● When a river loses energy further downstream, it dumps or deposits its load. ● Heavier material is dropped first. ● Deposition is common in the lower course of a river.

2.1. Landforms produced by erosion

- Fluvial landforms produced by erosion include waterfalls and rapids.
- Although they are not confined to the upper course of a river, they are common where the river profile is steep.

Waterfalls	● Waterfall is a sudden, steep drop in a riverbed. ● Water runs or plunges down the drop. ● A waterfall usually forms where hard rocks meets softer rocks. ● The river erodes the softer rock more quickly, forming a steep step or cliff.
Rapids	● Rapids are fast-flowing, turbulent sections of river where there are steps in the riverbed. ● Rock obstacles change the river's flow from laminar to turbulent, and the churned up water is referred to as whitewater. ● Rapids form when a river flows over a bed of erosion-resistant rock and wears away weaker rock downstream, creating a steep slope.

2.2. Landforms produced by deposition

- Deposition is the process in which a river dumps its sediment.
- The fine, mineral-rich sediment deposited by rivers is called alluvium.
- Fluvial landforms produced by deposition include braided streams, natural levees and deltas.

Braided streams

- A braided stream is a river or a section of a river that branches into channels (braids) around deposits of sediment (bars).
- Braided streams are most common in the upper course of rivers, where the gradient is steep and the river is shallow.
- Braided streams form in river that have large supplies of sediment and sudden variations in discharge.

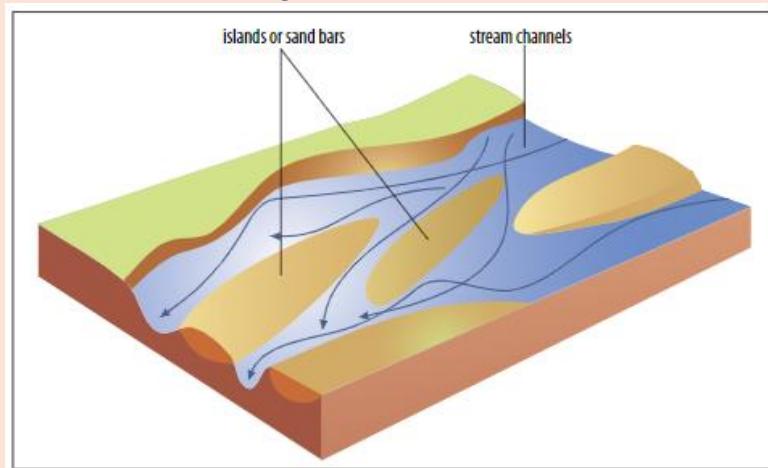


Figure 2.2.10 A braided stream

Natural levees

- Natural levees are banks of silt that build up along the sides of a river through repeated flooding.
- Levees raise the river bank above the level of the floodplain and provide natural protection against subsequent floods.
- They are most common in the lower course of a river.

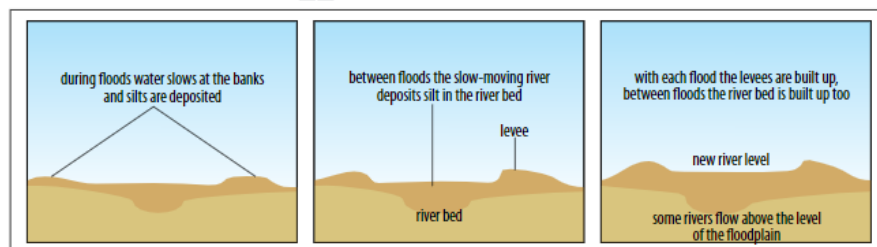


Figure 2.2.13 Natural levees and how they form

Deltas

- A delta is new land formed by the build-up of silt deposits at a river's mouth.
- The river usually branches around the deposits on its way to the sea; these branches are called distributaries.
- A delta forms only when the river deposits its sediment faster than the sea removes it.

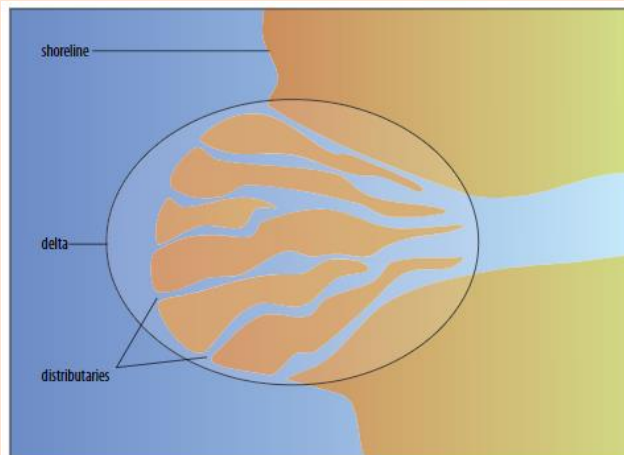


Figure 2.2.15 A delta

2.3. Landforms produced by erosion and deposition

- Some fluvial landforms are products of both erosion and deposition.
- These include meanders, oxbow lakes and floodplains.

Meanders and oxbow lakes

- Meanders are bends or loops in the middle course and lower course of a river.
- They are formed by erosion on one side of the river bank and deposition on the other as the river works to balance its energy, velocity, load and discharge.
- Over time, meanders become very tight loops – the meander widens and the neck narrows.
- Occasionally, the river cuts straight through a loop when its discharge is high.
- A meander that becomes separated from the river in this way is called an oxbow lake.
- Gradually,

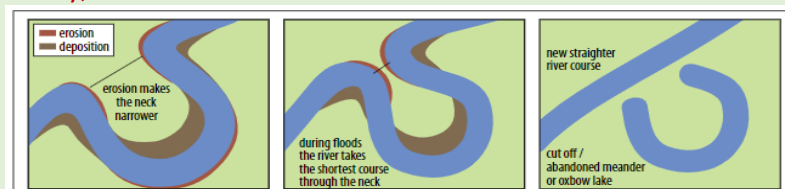


Figure 2.2.18 How meanders and oxbow lakes form

Floodplains

- A floodplain is the wide, flat area of land surrounding a river in its lower course.
- The valley in a floodplain has been widened by meander migration.
- Meanders move in two directions over time: downstream and sideways.
- Sideways migration due to lateral erosion widens the floodplain.
- The floodplain is built up by layers of sediment that are deposited each time a meander breaks its banks, or the river floods.
- The mineral-rich alluvium deposits make the floodplain very fertile.

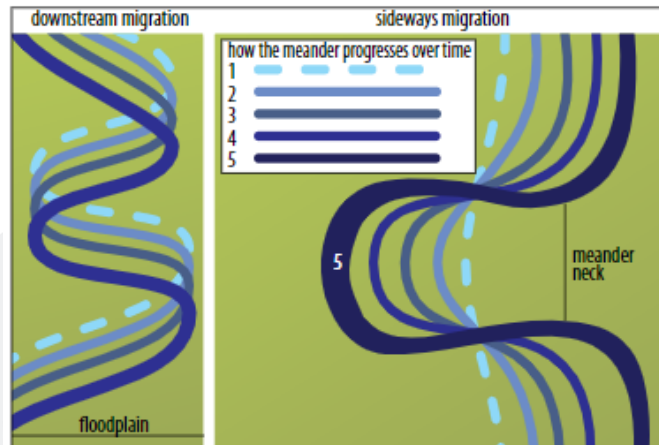


Figure 2.2.19 Meanders migrate downstream and sideways. Sideways migration widens the floodplain

3. What is a graded river?

- Near its source, a river's discharge is low, and the friction over the uneven riverbed is high.
- Here, the river needs a steep slope in order to flow and transport its load.
- However, near its mouth, a river's discharge is high and the friction of the riverbed is low.
- Here, it can flow on a gentle slope.
- Over time, a river erodes a slightly concave profile to achieve just the right combination of slope and discharge to transport its sediment.
- A river like this, in which the processes of erosion and deposition are in equilibrium, is called a graded river (see Figure 2.2.22).

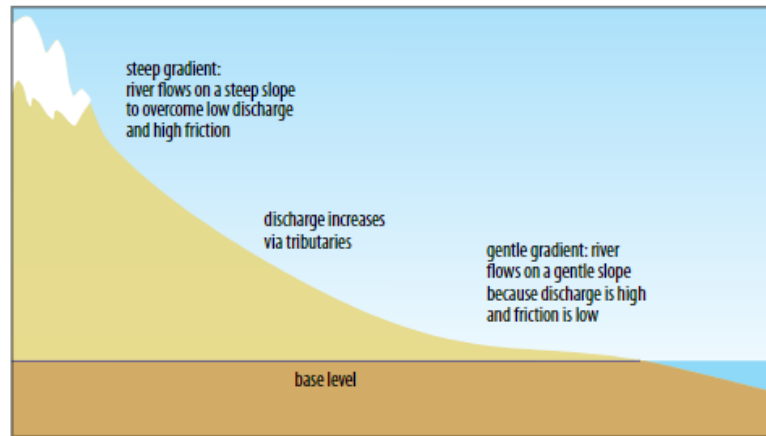


Figure 2.2.22 A graded river has a concave profile

- When a graded river experiences natural or human-made changes to its base level, gradient, discharge or sediment supply, it loses this balance of erosion and deposition.
- It becomes either an overgraded river, in which erosion dominates, or an undergraded river, in which deposition dominates.
- The river responds to changes in such a way as to achieve a new graded profile
- This tendency of a river to adjust its profile is called grading.

4. How does a river rejuvenate and which landforms are produced by rejuvenation?

- When a river undergoes rejuvenation, it regains energy and eroding power.
- There are two reasons a river might rejuvenate:
 - Its gradient increases when its base level drops, for example, by uplift of land or a drop in sea level.
 - Its volume increases, for example, by river capture or an increase in surface run-off.

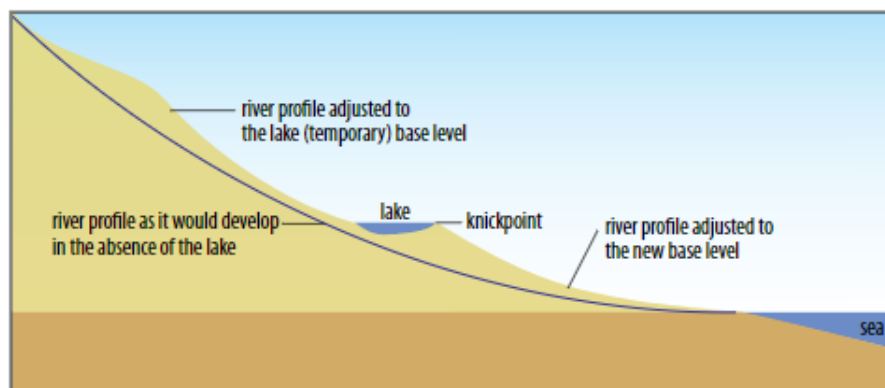


Figure 2.2.24 Longitudinal profile of a rejuvenated river

4.1. Features of rejuvenation

Knickpoint	• A sharp change in a river's slope due to a change in base level. • The knickpoint marks the old base level. • The gradient upstream of the knickpoint is gentle, while the gradient downstream is steep. • However, the steep gradient will gradually be eroded to form a graded profile.
Terraces	• Steps in the floodplain which form as a rejuvenated river erodes a new valley within the old one. • Each terrace consists of a flat surface (a tread) and a steep slope (a scarp).
Incised meanders	• Deep, steep-sided meanders formed by heavy vertical erosion of existing meanders. • Incised meanders form when a river cuts down faster than it can change its meandering course.

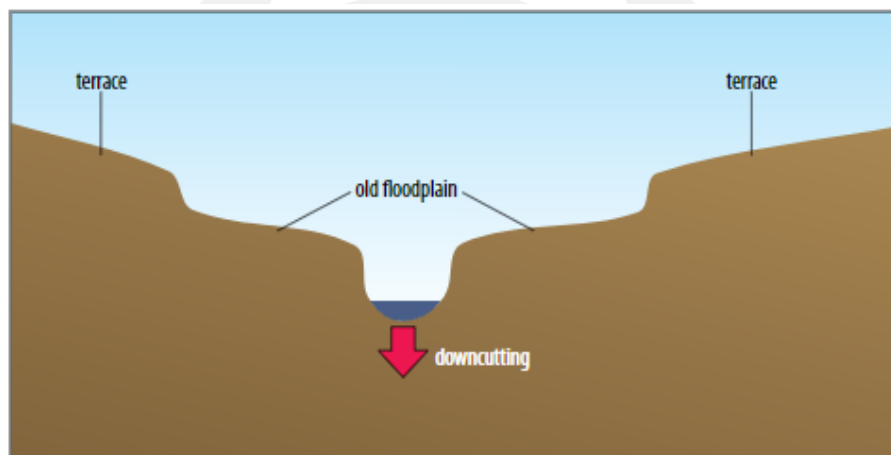


Figure 2.2.25 Transverse profile of a rejuvenated river, showing terraces

5. How does a river sometimes capture or diver the flow of another river?

- River capture (or stream piracy) takes place when a strongly eroding river (the captor stream) steals the water of a less energetic river (the captured stream).
- River capture by abstraction is the most common form of capture.
- Abstraction is the lowering and recession of a watershed.
- If the slope on one side of the watershed is steeper than on the other side, a river flowing down the steeper slope will erode back its side of the watershed faster.
- In this way, it can erode through the watershed and capture a slower-flowing river on the other side.

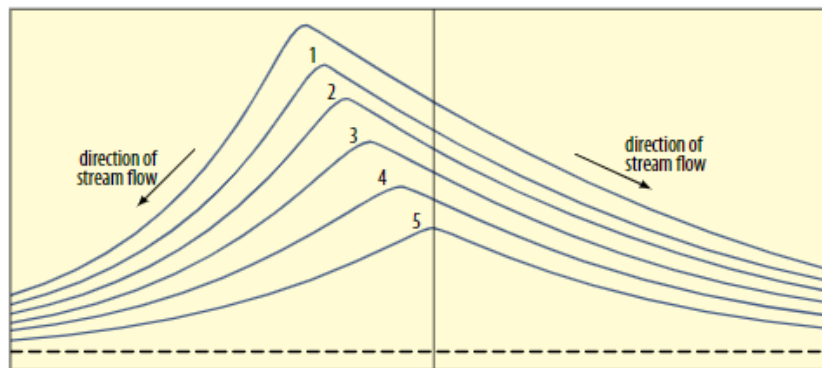


Figure 2.2.28 Abstraction: The stream on the left has captured the headwaters of the stream on the right

- Figure shows an aerial view of a watershed and the process of river capture.
- Notice the following on the left-hand side of the lower picture: a tributary of River 1 has eroded through the watershed by headward erosion and captured River 2.
- Headward erosion is erosion near a river's source, lengthening the stream.
- The characteristics of river capture are:

Elbow of capture	• A right-angle bend that marks the point of capture; there is often a waterfall just beyond this point.
Wind gap	• The abandoned river valley of the captured stream is left dry, with gravel deposits.
Misfit stream	• Because its headwaters have suffered capture and its size thereby reduced, the stream is too small and no longer matches the valley it once flowed through and which it helped to shape. • The captor stream, on the other hand, gains water and eroding power and becomes overgraded.

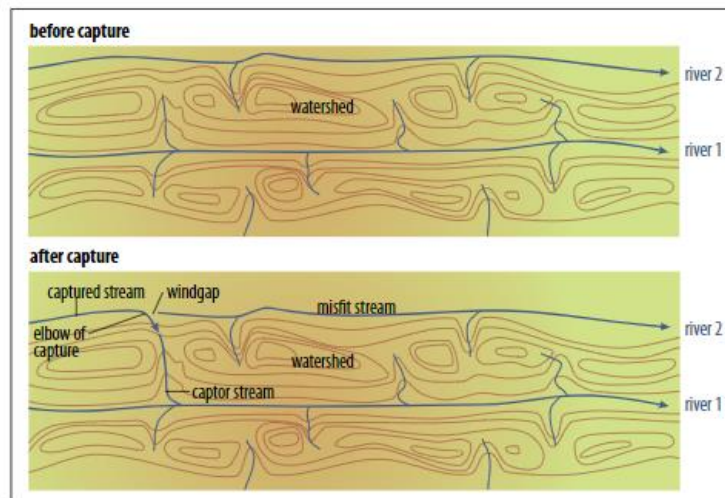


Figure 2.2.29 River capture

6. Superimposed and antecedent drainage patterns

- Sometimes the course of a river does not match the topography or lie of the land.
- Why do some rivers cut straight through mountains?
- There are at least two ways in which this can happen:
 - A river develops its course on top of a layer of sediment that has been eroded away to expose older rock formations, such as a buried mountain or ridge. The river nevertheless sticks to its course and cuts a gorge or canyon through the mountain. Such a river has a **superimposed drainage pattern**.
 - A river develops its course before an uplift event. If the river erodes faster than the rate of uplift, the river keeps its course, cutting through the mountain to form a gorge or canyon. Such a river has an **antecedent drainage pattern**. Antecedence is associated with river rejuvenation. Incised meanders are often a feature of antecedent drainage.

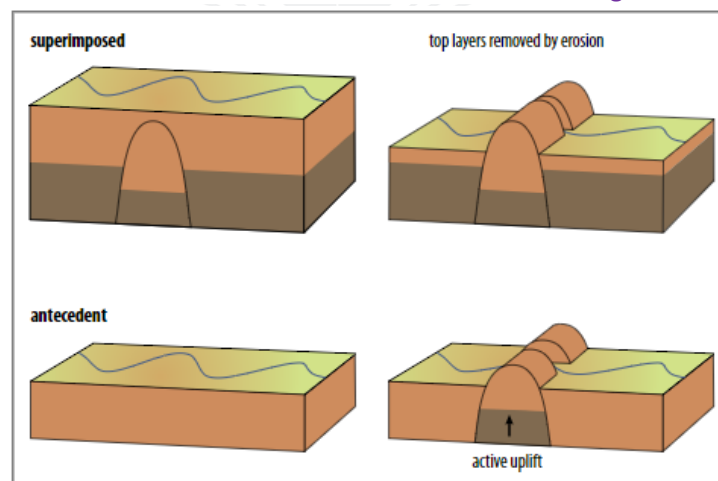


Figure 2.2.32 Superimposed and antecedent drainage patterns

Term 1:

Topic 2: Geomorphology

Unit 3: Catchment and river management

Key terms

Wetland	An area such as a swamp or marsh that is saturated with water because the water table is at the surface.
Habitat	The natural home of a living organism, such as an animal or plant.
Ecosystem	The relationships between a community of plants and animals and their environment.
Riparian zone	Area alongside a river.
Lag time	The period between maximum precipitation and peak discharge.

1. Importance of managing drainage basins and catchment areas

- Although about 70% of Earth's surface is covered by water, only 2% of Earth's water is fresh water suitable for human use.
- This fresh water supply comes from rivers, dams and groundwater sources.
- South Africa is regarded as a 'water-scarce' country, as it receives just over half the world average precipitation per year.
- Population growth, the expansion of agriculture and industry, and increasing urbanisation mean that more and more water is needed.
- Because drainage basins and catchment areas collect and store precipitation, they provide water that people need.

1.1. The importance of water sources and wetlands

- Fresh, clean water is important to people and the environment for the following reasons:
 - A supply of clean water, free from bacteria that cause water-borne diseases like cholera, is essential for human health.
 - People rely on rivers to provide water for many activities.
Without water there can be no agriculture, no industry, no business and no development.
People need the water from rivers for their homes.
Rivers and dams provide people with hydroelectricity.
 - Fresh water sources supply people with food.
 - Water sources are used for recreational activities, tourism, cultural activities and settlement.
 - Birds and wildlife depend on rivers and the vegetation in the riparian zone.
Wetlands are marshes and swamps that are found in some drainage basins and catchment areas.
- Wetlands are marshes and swamps that are found in some drainage basins and catchment areas.

- Wetlands are important as they trap and store water, regulate stream flow, and filter and purify the water that flows through them:
 - Wetlands remove harmful bacteria from the water and reduce the acidity of the water.
 - Wetlands also filter sand from the water and prevent silt from reaching rivers and dams, preventing them from silting up and reducing capacity.
 - Water flowing into a wetland slows down and spreads out.
The wetland plants hold back the water and the wetland acts as a sponge, storing the water and releasing it slowly downstream.
This reduces flood damage and ensures a steady supply of water all year.
 - Wetlands are important breeding areas and habitats for many organisms.

1.2. Why drainage basins and catchment areas need to be managed

- Rivers and their catchment areas need to be managed so that:
 - everyone can have access to water
 - river ecosystems remain healthy
 - flooding can be controlled
 - sustainable development can be maintained: this means that water sources are protected so that they are safeguarded for present and future generations
 - users of water sources do not harm rivers and make them unusable, for example when a large amount of waste flows into rivers, the river plants, animals and microbes are unable to break it down.
- Integrated Water Resource Management is the policy that groundwater, rivers and wetlands need to be managed together, as they are all linked within the water cycle.
- This management must include the land that surrounds the water sources and the human activities that have an impact on them.

2. Impact of people on drainage basins and catchment areas

- A drainage basin is a system of inputs, stores, flows and outputs.
- The drainage basin:
 - collects precipitation
 - allows for infiltration
 - stores and purifies rainwater in wetlands
 - channels runoff into streams, which join the main river that flows out of the basin.
- Human activities can affect the water that flows through the drainage basin, the water that is stored in the drainage basin, and the water that leaves the drainage basin.
- The following aspects of the drainage basin system are affected:
 - the volume and nature of the flow of water in the river channel
 - the land surfaces of the drainage basin over which water flows before it reaches the rivers
 - the quality of the water that is underground, that flows over the surface of the land, and that flows in the river.

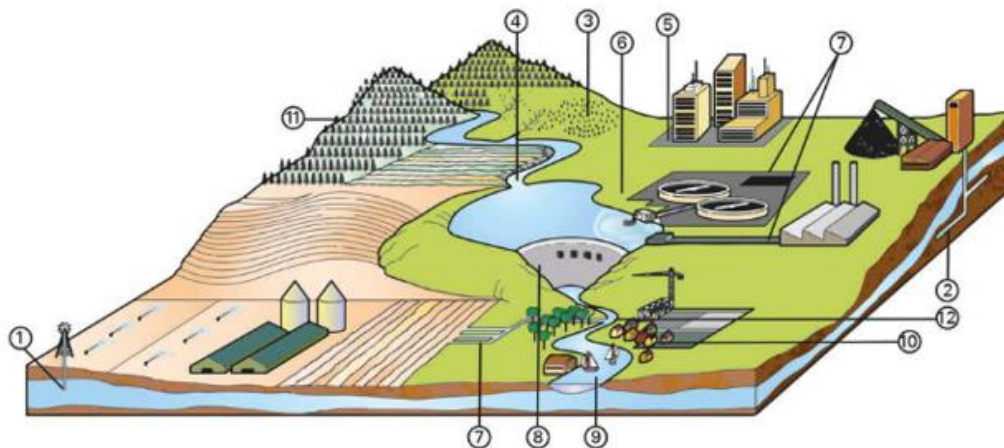


Figure 3.69 Impact of humans on the drainage basin system

1.	Boreholes remove water from the saturated groundwater zone, so less groundwater flows into the river.
2.	Groundwater can be polluted by human activities such as mining.
3.	Overgrazing and the clearing of vegetation in the catchment area of a river decreases the amount of infiltration and therefore decreases the supply of groundwater flowing into the river. The amount of water flowing over the land surface increases, so water containing a lot of silt enters the river.
4.	Runoff in agricultural areas contains high amounts of salt, nutrients and pesticides, which are harmful to aquatic life and the aquatic food chain, and can lead to an increase in algae in the water.
5.	Surfaces in urban areas are covered with concrete and tar, which is impermeable. Infiltration decreases and the amount of water flowing over the land surface increases. This, together with the removal of vegetation, causes a shorter lag time and higher flood peak, which can lead to flooding in urban areas.
6.	Many wetland areas have been converted to crops, commercial timber plantations of alien trees, waste disposal sites, pastures and dams. Often wetland areas are badly polluted by industry, sewage works, mines and agriculture.
7.	Removing water for irrigation, domestic use, industry and mines changes the flow of the river, reduces river habitats and affects the ecological processes of the river. The return water from these activities affects the quality of the water. Mismanaged sewage works can lead to excess sewage going into rivers.
8.	Water transfer schemes and the construction of dams result in unnatural flow patterns and disturb the river's ecology. The river deposits some of its load in the dam, but then has excess energy to erode the channel downstream of the dam. Although a dam reduces the damage to people and their homes caused by floods, it disrupts the life cycles of some species. Many people lose their homes when parts of a drainage basin are flooded to create a dam.
9.	Recreational activities in the riparian zone disrupt the ecology and result in litter and other forms of pollution.

10.	Settlement and construction within the riparian zone is often too close to the banks of the river or on the flood plain. This disrupts the natural flow of the river, and can cause the banks of the river to collapse.
11.	People introduce alien plant species, such as willows, blue gums and poplar trees that use an excessive amount of water, within the riparian zone. Alien fish compete with indigenous species, and there is a resultant loss of diversity in the river. Many of our rivers have been invaded by the alien water hyacinth plant.
12.	Flood control methods, such as turning river channels into canals, the construction of artificial embankments and cutting through meander loops, change the flow of the water and prevent natural flooding and the renewal of the flood plain's fertility.

3. Case study of one catchment management strategy in South Africa

3.1. Catchment and drainage basin management

- Catchment and drainage basin management is necessary to ensure healthy drainage basins, catchment areas, rivers and wetlands.

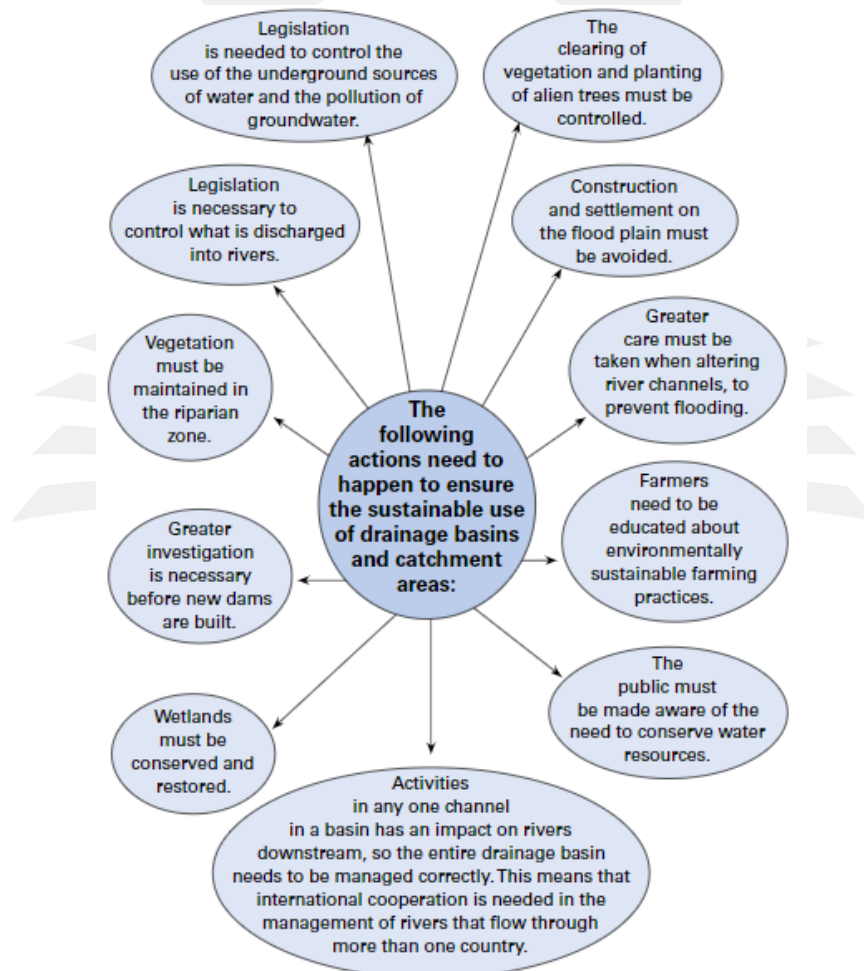


Figure 3.71 Catchment and drainage basin management

3.2. Catchment and drainage basin management in South Africa

- In South Africa, The Department of Water Affairs and Forestry (DWAF) is responsible for the sustainable use and health of our rivers.
- The National Water Act provides for the establishment of Catchment Management Agencies that work towards managing and developing catchments and integrating water management and land use.
- Other South African organisations and projects that operate to ensure the health and sustainability of our rivers include:
 - The Department of Environmental Affairs and Tourism (DEAT), which runs a wetlands conservation programme.
Wetlands are protected if they are Ramsar sites.
A Ramsar site is a wetland that has been identified as being internationally important.
 - The 'Working for Water' projects initiated by various Water Boards.
These projects involve employing local rural people to clear alien vegetation and rehabilitate wetlands.

3.3. Case study: the River Health Programme in South Africa

- The DWAF, together with the DEAT and the Water Research Commission, introduced the River Health Programme (RHP) in 1994.
- It collects information about rivers and their drainage basins, and writes reports on the present health of a river.
- Suggestions are made so that the desired health of a river (in relation to ecological considerations and sustainable development) can be achieved.
- The River Health Programme uses indicators and icons to report on a river.

Indicator	Icon	Description
Index of Habitat Integrity (IHI)		This assesses the diversity of habitats and the impact of disturbances, such as the removal of water and channel modification
Geomorphological Index (GI)		This assesses the channel condition due to the impacts of weirs and dams, and assesses channel stability in relation to erosion of banks and bed
Riparian Vegetation Index (RVI)		This indicates the status of vegetation around the river and indicates human influence, such as removal of vegetation
S. A. Scoring System (SASS) or aquatic invertebrate fauna		This assesses the changes in the structure and composition of aquatic invertebrates, as this indicates short-term changes in the quality of the water
Fish Assemblage Integrity Index (FAII)		This assesses the variety and quantity of fish in the river and indicates long-term changes in the river

Category of river health	Ecological perspective	Management perspective
Natural (N)	Very few changes to river habitats and organisms	Very few changes evident
Good (G)	Ecosystem essentially in a good state	Human-related disturbances have had little impact
Fair (F)	Sensitive species in danger	Socio-economic development has led to disturbance and poor water quality
Poor (P)	Loss of biodiversity, invasion by alien vegetation	Extensive resource exploitation

3.4. Case study: Buffalo River System and drainage system

- The Buffalo River System in the Eastern Cape was assessed by the RHP, and a State-of-the-Rivers Report was issued in 2004.

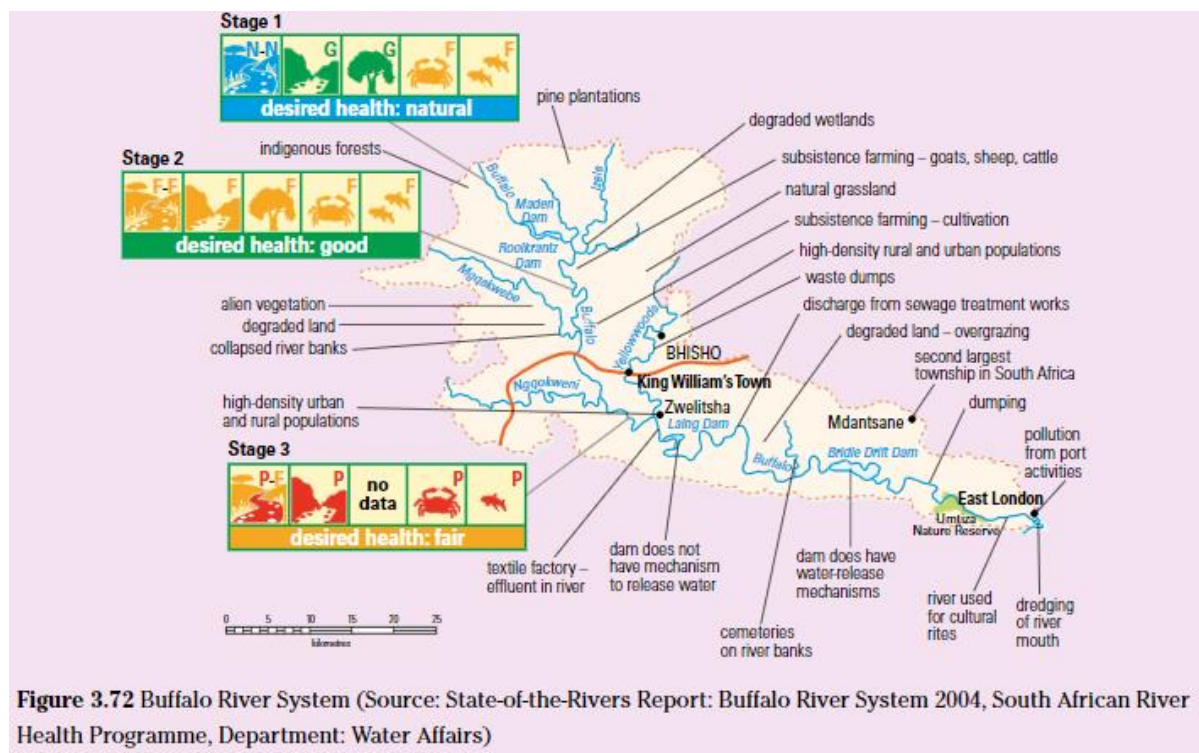


Figure 3.72 Buffalo River System (Source: State-of-the-Rivers Report: Buffalo River System 2004, South African River Health Programme, Department: Water Affairs)