LESSON 6: GEOMORPHOLOGY II

SECTION A: SLOPES

Key Concepts

In this lesson we will focus on summarising what you need to know about:

- Overview of South Africa's topography
- Types of slopes
- Slope elements
- Characteristics of slope elements
- Slope development over time and the concept of slope retreat

X-Planation

Overview of South Africa's Topography

SA's landscape has been shaped over a long time by movement below the surface of the Earth and by the movement of water across the surface of the Earth. Different layers of rocks have been laid down over millions of years and then shaped by erosion. Different strata and rock formations are eroded and the topography results from these processes.

What is a Slope?

The angle which any part of the Earth's surface makes with the horizontal

OR

Any geometric element of the Earth's surface.

Types of Slopes

Gentle Slope

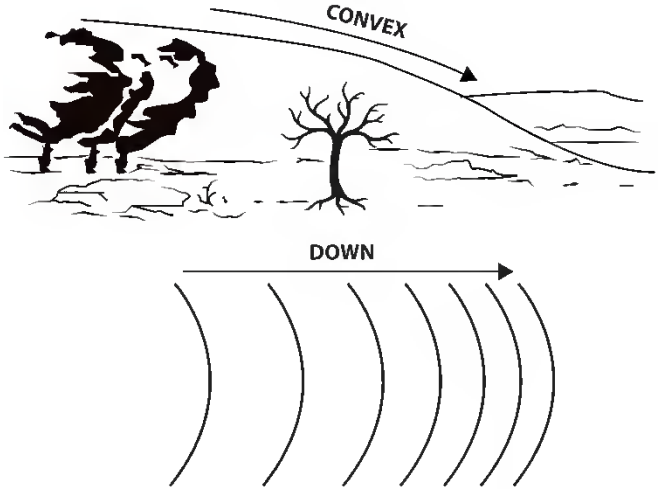
A slope with contour lines spread far apart from each other. This even spacing is maintained in both up and down slope.

Steep Slope

A slope represented with contour lines close to each other on a topographical map.

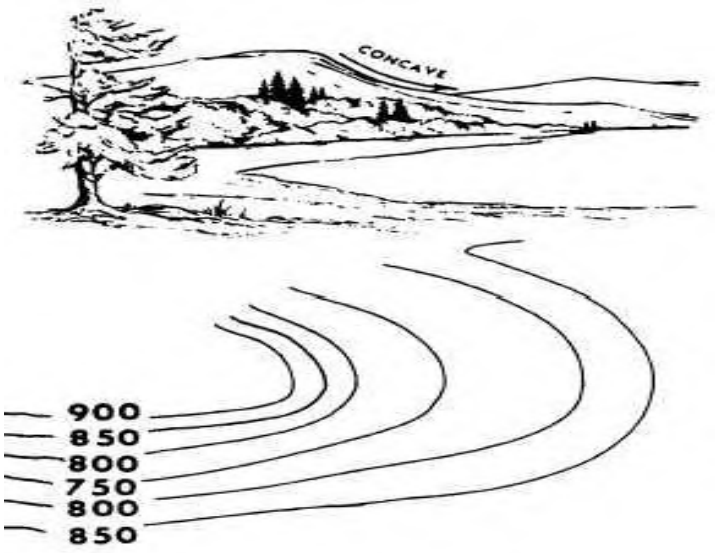
Convex Slope

A slope which becomes progressively steeper downhill. It can refer to an entire slope or part of one. On a map the contour lines will be spaced closer together with a decline in height above sea-level.



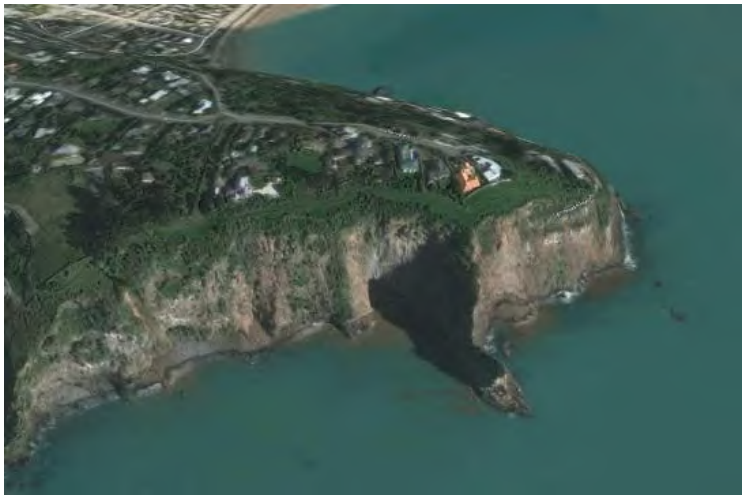
Concave Slope

A slope which becomes progressively steeper uphill. It can refer to an entire slope or part of one. On a map the Contour lines will be spaced closer with an increase in height above sea-level.



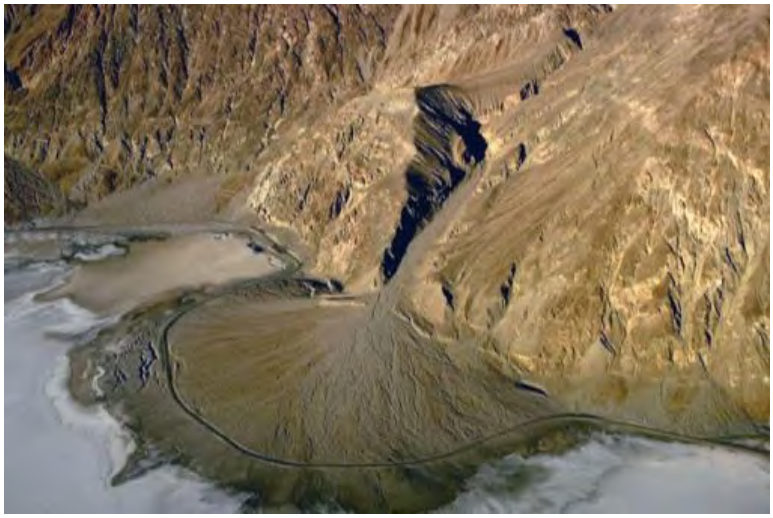
Tectonic Slopes

These are formed through internal forces that result in the folding, warping and faulting of rock masses or layers. Anticlines and synclines, are formed when layers of rock are folded; while horsts (block mountains) and graben (rift valleys) are formed when blocks of land rise or fall in relation to each other when faulting occurs.

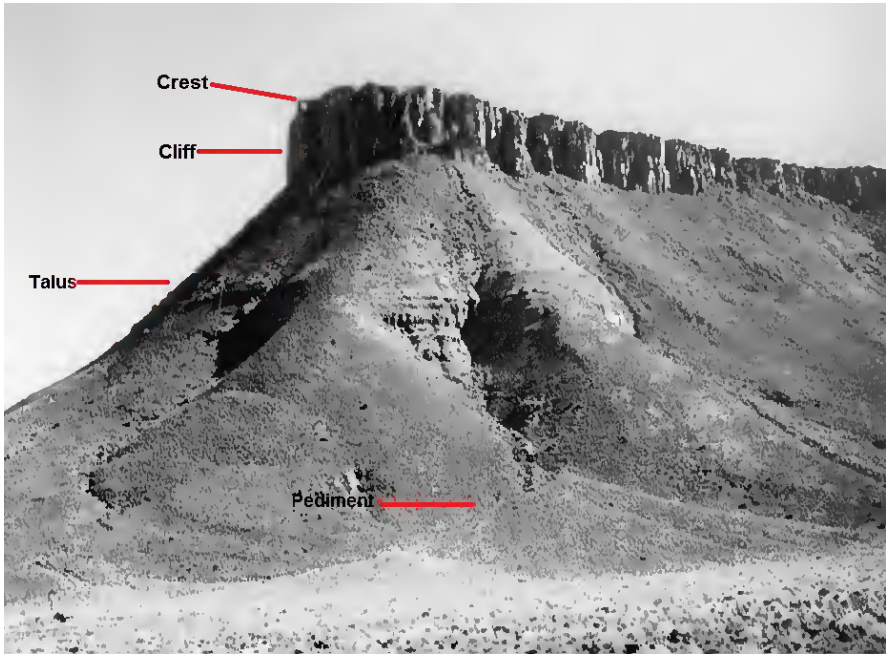


Depositional Slopes

Deposits of weather material build up to form inclined surfaces, mounds and hills when an agent of erosion (e.g. wind, water or ice) which has lost its energy of motion, lays down its load in a particular place. Examples are alluvial fans, alluvial cones, deltas and sand dunes.



Slope Elements



Crest

A small convex-shaped slope, with a thin covering of soil

Freeface / Scarp Cliff

A near vertical slope, more than 80° to the horizontal

Talus / Scree / Debris

A slope with a constant angle, and is formed of eroded material from crest and freeface

Knickpoint

The change in gradient at the base of the scree slope

Pediment

A low-angle concave slope

Characteristics of Slopes

Crest

- Edge of the hill
- Convex
- Thin layer of soil
- Weathered material removed

Freeface / Scarp Cliff

- > 80° to the horizon
- Layer hard resistant rock
- Loose material falls to bottom of cliff
- Cliff retreats parallel to itself

Talus / Scree / Debris

- Accumulates from crest and cliff face
- Uniform slope

Pediment

- Low angle, concave slope
- Slope is not uniform- steeper close to the talus slope
- Pediment increases as the slope increases backwards due to scarp recession

Slope Development over time and the Concept of Slope Retreat

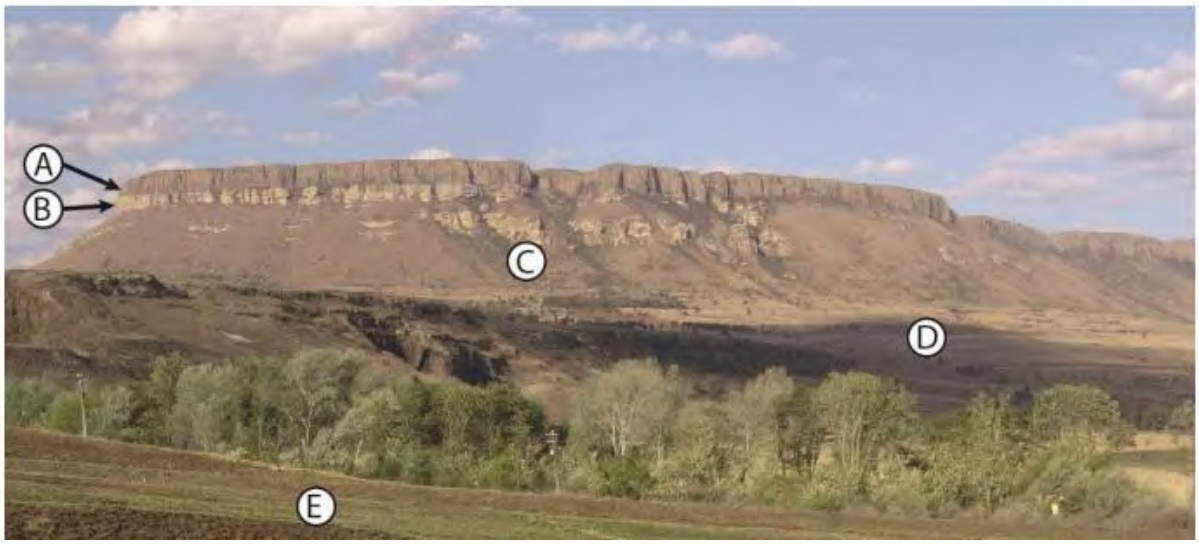
SLOPE DECLINE (W.M DAVIS, 1899)	
REGION OF STUDY	Theory based on slopes in what was to Davis a normal climate (north-western Europe and north-eastern USA)
CLIMATE	Humid climate
DESCRIPTION OF SLOPE	Steepest slopes at the beginning of the process with a progressively decreasing angle over time to give a convex upper slope and a concave lower slope
CHANGES OVER TIME	Assumed a rapid uplift of land with an immediate onset of denudation. The uplifted land would undergo a cycle of erosion where slopes were initially made steeper by vertical erosion by rivers but later became less steep (slope decline) until the land was almost flat (peneplain)
SLOPE REPLACEMENT (W. PENCK, 1924)	
REGION OF STUDY	Conclusions drawn from evidence of slopes in the Alps and Andes
CLIMATE	Tectonic areas
DESCRIPTION OF SLOPE	The maximum angle decreases as the gentler lower slopes erode back to replace the steeper ones giving a concave central part of to the slope
CHANGES OVER TIME	Assumed landscape started with a vertical rock slope with equal weathering overall. As scree (talus) collected at the foot of the cliff it gave a gentler slope which, as the scree grew, replaced the original one.

PARALLEL RETREAT (L.C KING, 1948, 1957)	
REGION OF STUDY	Based on slopes in South Africa
CLIMATE	Semi-arid landscapes. Also sea cliffs with wave-cut platforms
DESCRIPTION OF SLOPE	The maximum angle remains constant as do all slope facets apart from the lower one which increases in concavity
CHANGES OVER TIME	Assumed that slopes had two facets- a gently concave lower slope or pediment and a steeper upper slope (scarp). Weathering caused the parallel retreat of the scarp slope allowing the pediment to extend in size

X-ample Questions

Question 1

Refer to the FIGURE showing elements of a slope to answer the questions.



a.) Identify the slope elements labeled A, B, C, and D. (4 x 2) (8)
b.) Describe slope element B. (1 x 2) (2)
c.) Identify at least ONE factor that promotes fertile soil in area E . (1 x 2) (2)

SECTION B: MASS MOVEMENTS

Key Concepts

In this lesson we will focus on summarising what you need to know about:

- Concept of mass movements
- Causes of mass movements
- Kinds of mass movements
- The impact of mass movements on people and the environment
- Strategies to minimise the effects of mass movements

X-Planation

What is Mass Movement?

Mass movement is the down slope movement of earth materials under the influence of gravity.

The detachment and movement of earth materials occurs if the stress imposed is greater than the strength of the material to hold it in place.

Causes of Mass Movements

Mass wasting is caused by **gravity**. On a mass of material gravity exerts a force downward proportional to the amount of mass.

Because of the effect of **water** on slope stability, many mass wasting events are triggered or hastened by heavy or extended rainfall.

Kinds of Mass Movements

Soil Creep

Creep is the slow, continuous movement of soil or unconsolidated sediments over extended periods of time.

Often, the rate of creep is less than a centimeter per year and can only be detected over many years by looking for its effect on the landscape

Causes of Soil Creep

- Creep is caused by repeated freeze-thaw cycles that slowly inch material downslope (during freezing, particles are elevated perpendicular to the slope, but during thaws they fall straight down to a new position lower on the slope).
- Creep can also be caused by a buildup of pore water that allows material to begin to flow under the influence of gravity.

Effects of Soil Creep

- Creep causes fence posts, utility poles, walls, and other structures to lean over time. Eventually the lean topples the structures and they must be rebuilt.
- In some cases, creep can be slowed or prevented by installing drainage pipes in soils that drain them and keep pore pressures low.

Solifluction

- It is the down slope movement of soil over a permanently frozen subsurface. Solifluction is common on slopes underlain by permafrost (permanently frozen sub – soil).
- During the summer when the upper permafrost is activated, the waterlogged soil mass slowly moves down slope to form solifluction lobes or terraces.

Landslides

- A landslide is a movement of rock or debris down a slope along one or more distinct surfaces. Landslides range in speed from 1 m/day to as much as 300 km/hr.

Rockfalls

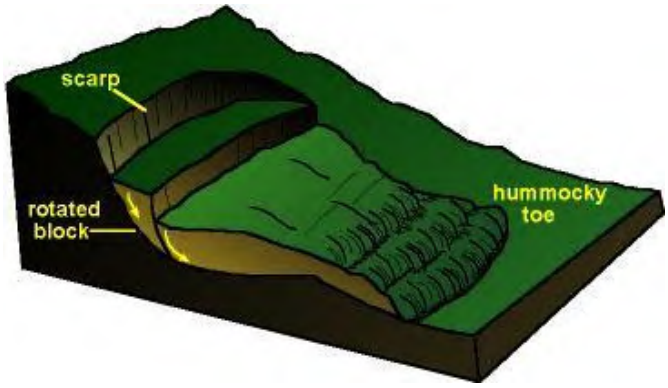
- Rockfall (free fall of rock) is an extremely rapid process and occurs without warning.
- Rockfall is typically the result of frost wedging.
- Frost wedging is a process where water enters cracks in rocks, freezes, expands, and breaks the rock apart.

Mudflows

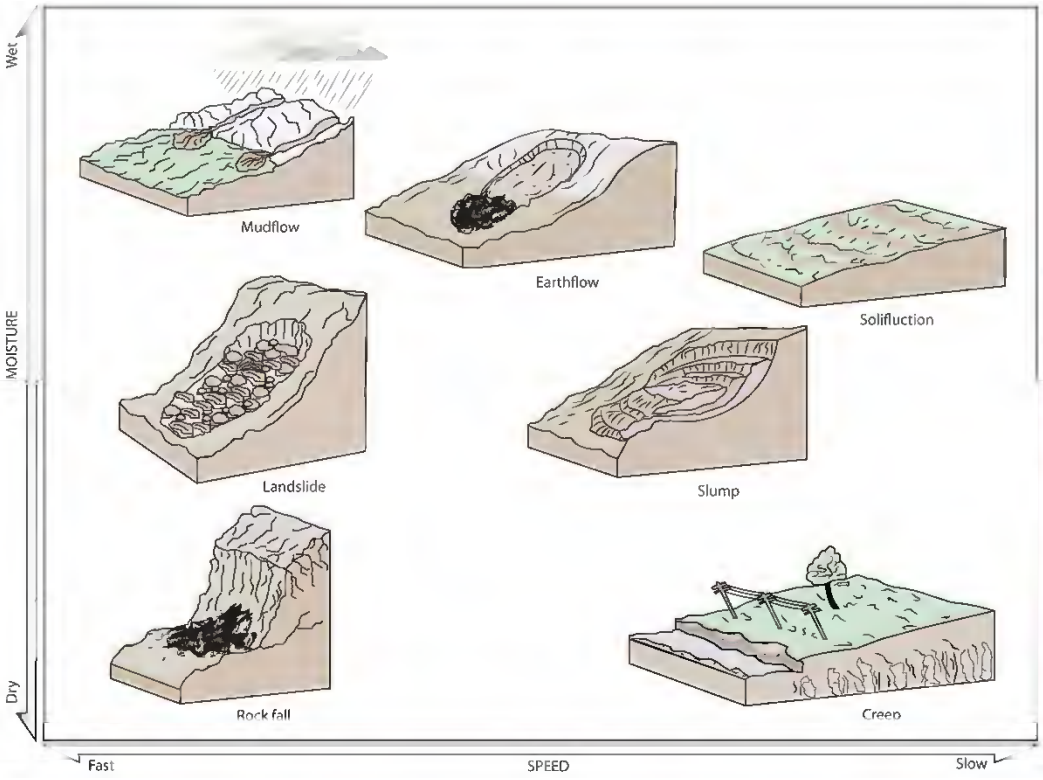
- Occur on moderate-to-steep slopes
- Movement is generally rapid
- Primarily fine-grained material (smaller than sand-sized particles)
- May begin as shallow soil slip (shallow slides in soil over rock that parallels the slope)
- Typically flows down slopes or follows drainage channels

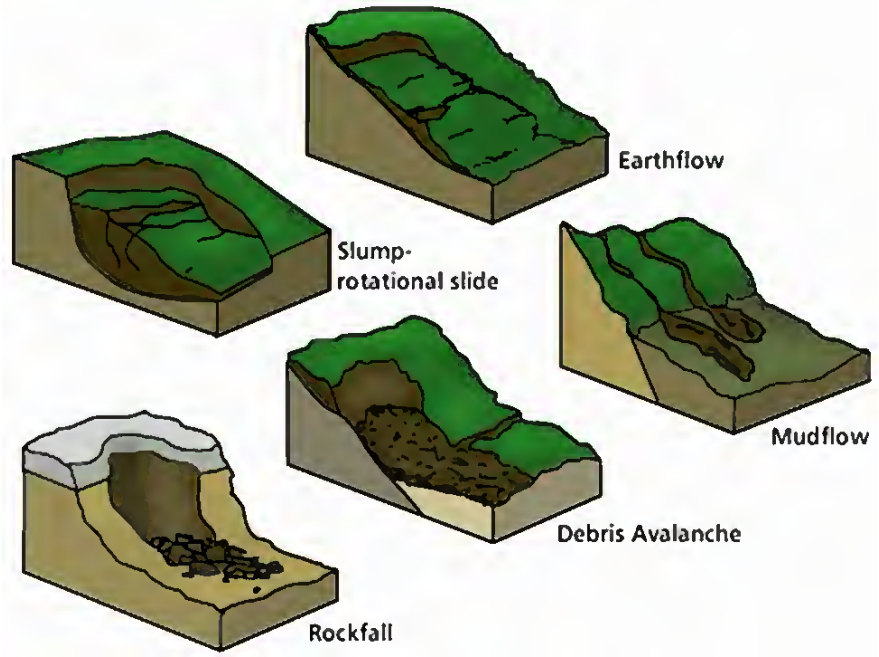
Slumps

- The sliding of material along a curved surface called a rotational slide or slump.
- A common cause of slumping is erosion at the base of a slope. For example, coastal storm waves erode cliff bases, removing supporting material.
- The slump block rotates downward, producing a scarp (cliff) at the top of the slope.



Effects of Mass Movement





Human Impact on Landslides

Excavation into a slope (for a road or construction site) creates a flat area at the base of a slope. However, it also over steepens the slope. Removing the basal support can result in slope failure.

Harvesting timber can also have an impact. Removing slope-supporting material (trees and brush), as well as creating roads, affects the landscape. If the surficial (and sometimes subsurface) geology is unstable, mass wasting often occurs.

Urbanization also has an effect on slope stability. **Grading hillsides** (cutting benches for building homes on) greatly increases landslide potential.

Construction of homes on unstable slopes has similar effects. Changing the slope face, the additional weight (homes and fill material), plus the added water (homeowners' sprinkler systems and septic tanks) make a formerly stable slope unstable. Add a heavy rainy season and you have lots of landslides!

Strategies to Minimise the Effect of Mass Movements

Minimizing landslide hazards requires three steps:

1. Identification of landslide potential areas,
2. Prevention of landslides, and
3. Corrective measures when a landslide occurs.

Identification of Landslide Potential Areas

Identification is accomplished by

- studying aerial photographs to determine sites of previous landslides or slope failures, and
- field investigations of potentially unstable slopes.

Potential mass-wasting areas can be identified by steep slopes, bedding planes inclined toward valley floors, hummocky topography (irregular, lumpy-looking surface) covered by younger trees, water seeps, and areas where landslides have previously occurred. The information is then used to generate a hazard map depicting the various landslide-prone areas.

Prevention of Landslides

Controlling drainage and reducing the slope angle reduces landslide potential. Concrete interceptor drains can be constructed to contain runoff and prevent infiltration. Steep slopes can be graded into gentler slopes. A series of "stair-steps" can be created on very steep slopes.

Engineering methods can be used to help prevent slope failure. Retaining walls, rock bolts, and "shotcrete" (coating of concrete-rock mixture on slope surface and crevices to prevent water entry) are used to inhibit slope failure. Wire cables and wire fences minimize the danger of rockfall.

Corrective Measures

Correction of some landslides is possible. This is accomplished by installing a drainage system, which reduces water pressure in the slope, thereby preventing further movement.

The key to preventing damage from landslides is to identify and avoid developing landslide prone areas such as steep, unstable hillsides. However, if some of these areas must be developed then building codes should require extensive efforts to insure slope stabilization:

- vegetation of unstable slopes
- installation of drainage and runoff channeling structures
- benching and regrading of slopes to lessen their steepness
- stabilization structures such as retaining walls, deeply sunk pylons, and backfilled supports

Good slope engineering is expensive and the temptation to cut corners is great. However, landslide damage is far more expensive and estimates have shown that for every rand spent on slope stabilization, between 10 and 2000 rand are saved over the long term.

X-ample Questions

Question 1

Refer to the FIGURE showing an element of mass movement.

a.) Identify the type of mass movement shown in the diagram. (1 x 2) (2)
b.) Describe how this type of mass movement occurs. (2 x 2) (4)
c.) Identify at least TWO impacts on human that this type of mass movement would have. (2 x 2) (4)

X-ercise Questions

Question 1

(Adapted from Gr 11 Exemplar, DBE, Paper 1, Question 1.5)

Read the article in FIGURE 1 and answer the questions that follow.

FIGURE 1: LANDSLIDES

The 2010 Uganda landslide occurred in the district of Bududa in eastern Uganda on 1 March 2010. The landslide was triggered by heavy rain between 12:00 and 19:00 that day. At least 100 people are believed to have been killed.

The landslide struck villages on the slopes of Mount Elgon, including Nameti, Kubewo, and Nankobe. Eighty-five homes were destroyed in Nameti alone. Many areas in the affected villages were buried by the landslides, including houses, markets and a church. Many roads were also blocked. Officials and aid workers were worried that further landslides could occur, as heavy rain continued to fall in the region.

[Source: Wikipedia.org]

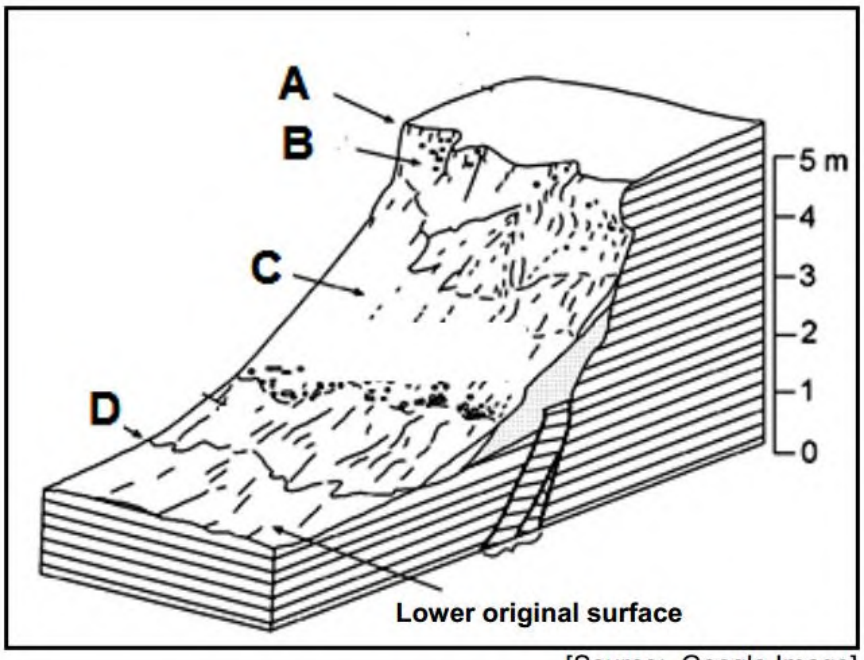
1.1	Define the term landslide.	(1 x 2) (2)
1.2	Where do landslides generally occur?	(1 x 2) (2)
1.3	State TWO causes of landslides.	(2 x 2) (4)
1.4	Describe THREE impacts of landslides on people and the environment.	(3 x 2) (6)
1.5	Write a short paragraph in which you explain strategies that can be used to prevent, or minimise, the effect of mass movements.	(6 x 2) (12)

Question 2

(Adapted from Gr 11 Exemplar, DBE, Paper 1, Question 2.6)

Refer to FIGURE 2 shows the typical slope elements/forms associated with a slope.

FIGURE 2: SLOPE ELEMENTS/FORMS



[Source: Google Image]

2.1 Identify the slope elements/forms labelled A, B, C and D. (4 x 2) (8)

2.2 Give ONE characteristic of each of the slope elements/forms labelled A and C. (2 x 2) (4)

2.3 Explain why slope element/form D is useful to farmers. (2 x 2) (4)

Solutions to X-ercise Questions

Question 1

(Adapted from Gr 11 Exemplar, DBE, Paper 1, Question 1.5)

1.1 Landslide refers to a sudden movement of a block of the land surface

1.2 On hill slopes

1.3 Heavy rainfall
Earthquakes
Removal of part of slope due to construction

1.4 A landslide may fall across a river, damming the water
A new lake can form

The above could cause flooding
Can cause great destruction across a wide area of habitable land
Destruction of vegetation
Houses destroyed
Farmland/crops destroyed
People killed/buried alive

1.5 Using wire to hold the rock in place
Building gabians at the base of the slope
Spraying concrete on the side of the slope to stabilize the rock slope
Drilling bolts into the side of the hill slope
Covering slopes with nets
Avoid development along unstable slopes
Using early signs to detect land movements and instability of slopes
Completing environmental impact study before development on steep slopes
Closing roads to ensure the safety of people when slopes become unstable
Artificial rockfalls to stabilise slopes
Building roofs over roads along steep slopes

Question 2

(Adapted from Gr 11 Exemplar, DBE, Paper 1, Question 2.6)

2.1 **A** - crest/waxing slope
B - cliff/free fase/scarp
C - talus/scree/debris/constant slope
D - pediment

2.2 **A** convex
soil creep
top of slope
C consist of weathered material
angle of approximately 35°
slope remains constant

2.3 Gentle slope
Covered with soil layer