Volcanic Hazards – Student Booklet

Science
Technology
Engineering and
Mathematics

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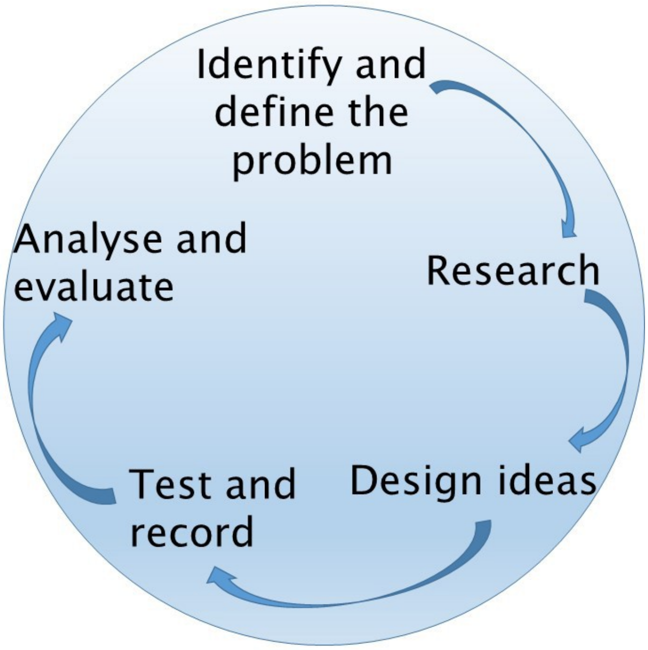
Volcanic Hazards – Student Booklet

The Challenge

Understanding the type and eruption history of a volcano is vital in understanding potential volcanic hazards. Volcanoes behave very differently depending on their type and location. The extent of the damage they cause will also depend on their proximity to populations. Your role is to investigate the behaviour of volcanoes and come up with an engineered solution which will help minimise the potential damage of a chosen volcano to local populations, explaining why it is a suitable solution for that area.



Background Information

Volcanoes are awesome yet powerful forces of nature, which were vital in the creation of Earth's current atmosphere and are important in the production of new, fertile soils, but they can also cause cataclysmic damage. In 1815 Mount Tambora, in Indonesia, erupted causing the 'year without a summer' as the large volume of ash and dust that entered the atmosphere filtered out a large portion of the Sun's rays.

Figure 1. Mount Tambora volcano on Indonesia's Sumbawa Island was the site of the world's largest historical eruption in April 1815. This NASA Landsat mosaic shows the 6-km-wide caldera truncating the 2,850-m-high summit of the massive volcano. Pyroclastic flows during the 1815 eruption reached the sea on all sides of the 60-km-wide volcanic peninsula, and the ejection of large amounts of tephra caused world-wide temperature declines in 1815 and 1816 (NASA, 2009).

An initiative supported by Woodside and ESWA

Over 71,000 deaths have been attributed to the eruption – the largest number of (human) deaths ever recorded to a volcanic eruption. Even with the best engineering solutions it would have been difficult to prevent death and injury from many of the hazards caused by the Mount Tambora volcano. Less violent eruptions can be easier to manage and predict, however.

In 1973 an eruption on the island of Heimaey caused a large lava flow that threatened to close off the harbour – the island's main income source by means of its fishing fleet. By pumping sea water onto the advancing lava flow, it was possible to cool the lava enough to halt its course and save the harbour. Other solutions to minimising the damage caused by volcanoes include creating man made channels to direct the flow of lava or landslides caused by eruptions.

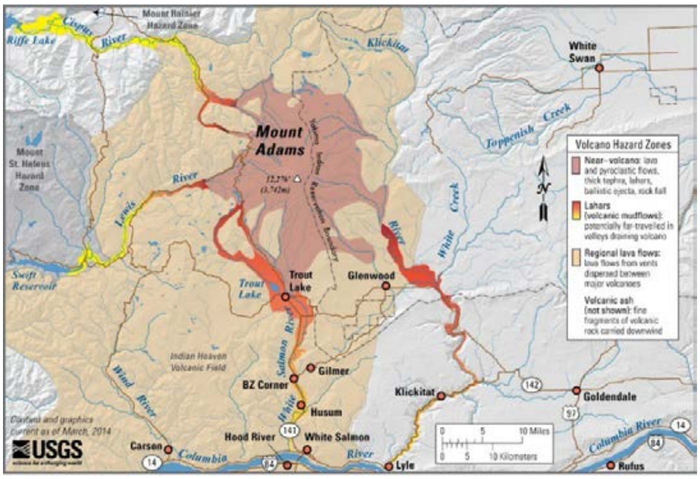


Figure 2. Mount Adams, Washington simplified hazards map showing potential impact area for ground-based hazards during a volcanic event (USGS, 2013).

A more simple solution can be creating a hazard map, using information known about the volcano and the topography of the region, to show areas that may be at risk and to not allow future building in these areas.

Volcanologists will investigate numerous factors to try to predict if, and when, a volcano may erupt again. The historic pattern of activity is a key indicator of when a volcano may erupt again, so by studying the frequency of previous eruptions it may be possible to forecast when one is due. Visible signs of a possible imminent eruption could include ground deformation – where it starts to swell due to rising lava – satellites are used to track this along with temperature changes. The swelling and ground movement can also cause small earthquakes which are tracked using seismometers. An increase or change in the type of gas being released is also an indicator that there is movement below ground and an eruption may be pending.

Background Research

1. How many people have been killed by volcanoes since 1900?

Suggested site: https://en.wikipedia.org/wiki/List_of_large_volcanic_eruptions_of_the_20th_century

2. Which countries have had the most fatalities caused by volcanoes since 1900?

Country	Fatalities	Date

Suggested site: https://en.wikipedia.org/wiki/List_of_large_volcanic_eruptions_of_the_20th_century.
Hint: Hover over the name of the volcano (eruption) to see more detail, including the country it is in.

3. Draw a shield and stratovolcano and add labels to compare their shapes. Attach these as a separate file or insert below.

Suggested site: http://ete.cet.edu/gcc/?/volcanoes_types/

4. Describe and explain the following volcanic hazards.

Hazard	What it is	How a volcano can cause it	Damage/risk it can cause
Lava flows			
Landslides			
Avalanches			
Lahars			
Earthquakes			
Volcanic (poisonous) gases			

Suggested sites: https://pubs.usgs.gov/fs/fs002-97/ and http://www.geo.mtu.edu/volcanoes/hazards/primer/

5. Explain how the following methods of monitoring volcanoes can help to predict the probability and timing of eruptions.

Method	How it helps make predictions
Gas sampling	
Groundwater monitoring	
Tiltmeters	
Infrared images	
Dating previous eruptions	

Suggested sites: https://volcanoes.usgs.gov/vhp/monitoring.html and https://volcanoes.usgs.gov/vhp/gas_water_methods.html and https://volcanoes.usgs.gov/vhp/tilt_strain.html and https://volcanoes.usgs.gov/vhp/thermal.html

6. What are the common causes of death by a volcano (give historic examples)?

Cause of death	Historic example

Suggested site: http://www.abc.net.au/science/articles/2001/01/17/234135.htm

Where in the World?

Objective

To use Geographical Information Systems (GIS) to find the relationship between eruption styles/types of volcanoes and their tectonic location.

This investigation can be completed using paper maps or Google maps. Choose the equipment list and method suited to you.

Option 1: Paper Maps

Equipment

- List of recent volcanic eruptions with information on their location (longitude and latitude) and the type of volcano that produced it
- Map of the world with longitude and latitude lines on it
- Sticky dots or different coloured pens
- Map of tectonic boundaries

Method

1. Locate the position of each volcanic eruption on the map using the latitude and longitude coordinates. (+ Latitude = North, - latitude = South. + longitude = East, - Longitude = West)
2. Place a sticky dot/draw a dot on the map where the volcanic eruption was, using a different colour dot to show if it was from a stratovolcano or a shield volcano.

Option 2: Google maps

Equipment

- Computer
- Access to Google maps
- Excel

Method

1. Create two spreadsheets in Excel (one for stratovolcanoes and another for shield volcanoes) with the following headings: Volcano name, Latitude, Longitude and Elevation (m) (elevation is optional).
2. Carry out an internet search to find a list of shield and stratovolcanoes that have erupted in recent history – your teacher may guide you to a particular site.
3. Enter the information into the correct spreadsheet, ensuring you have at least 25 of each type.
4. Save each spreadsheet as a CSV file.
5. Open Google maps and click on the menu tab. Then select "My Places."

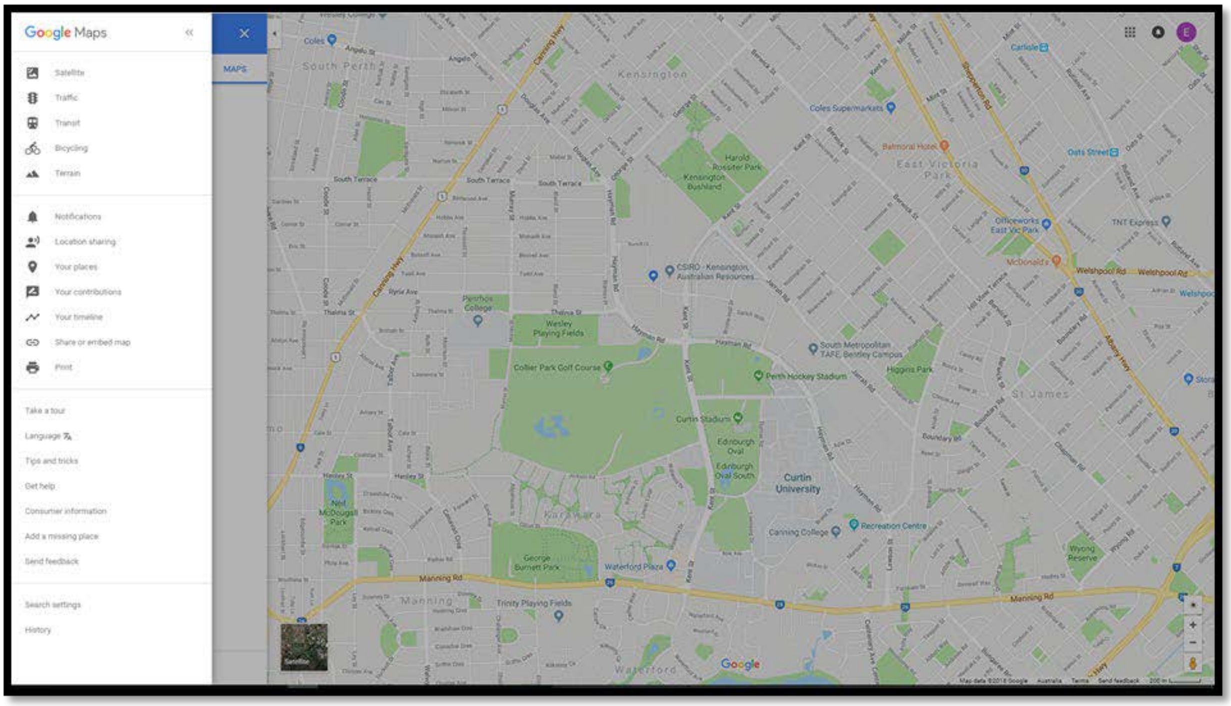


Figure 3. Screen shot of Google maps showing the menu bar.

6. Next select Maps -> create map.

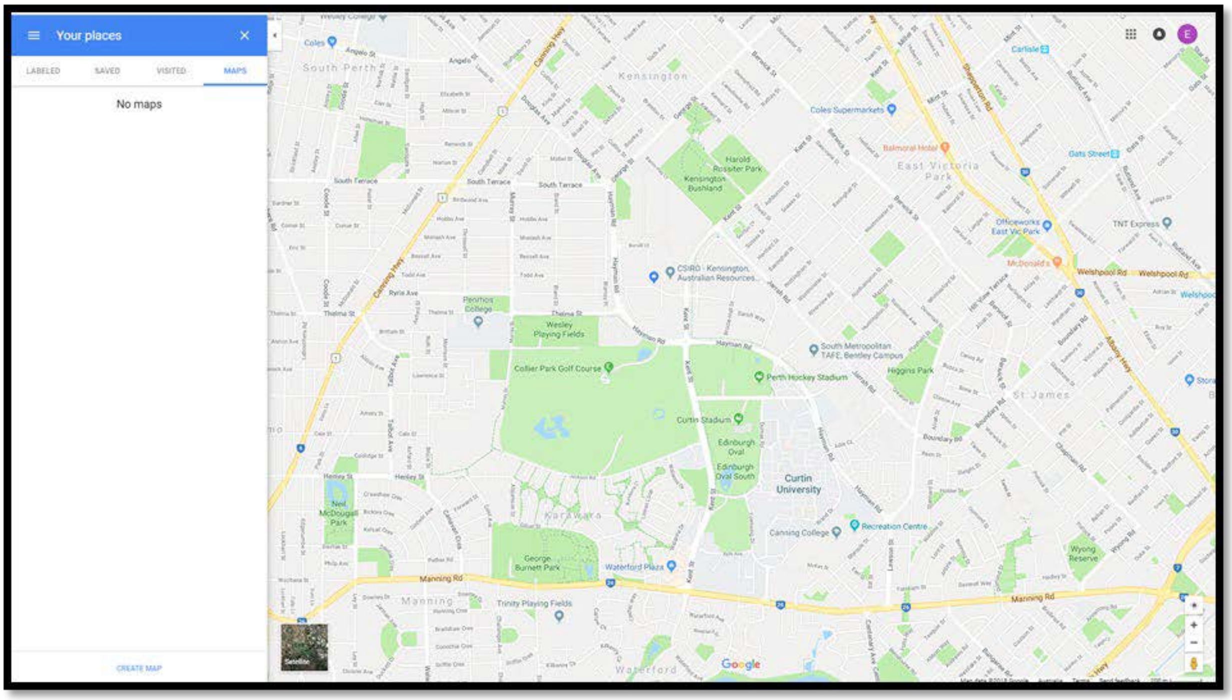


Figure 4. Screenshot of Google maps, select MAPS on the top bar, then CREATE MAP at the bottom of the menu bar.

7. Now you can either individually add each data point one at a time by selecting "add marker" tool (highlighted in yellow circle) OR you can import data directly from your spreadsheet by selecting "import".

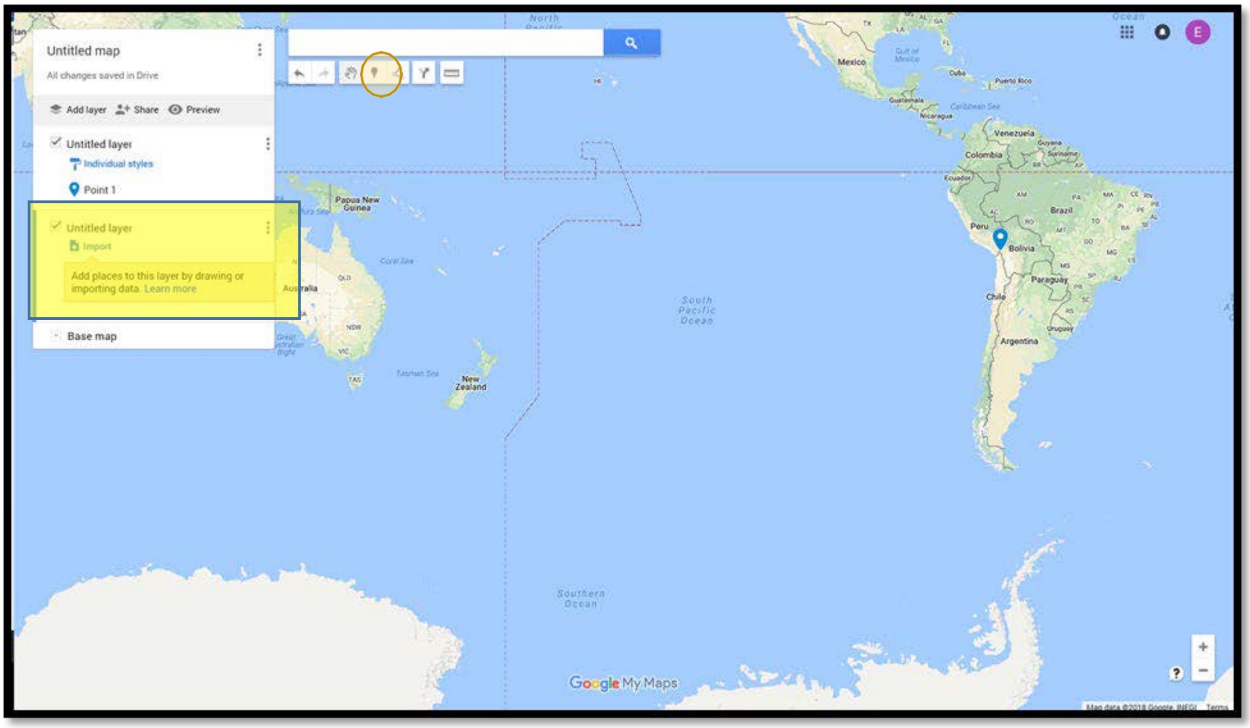


Figure 5. Screenshot highlighting where to select if you wish to add individual data points manually, or where to select if you wish to import a whole CSV file.

8. You can now edit your data points, by giving them different colours, to highlight the different volcano types.

Results and Analysis

1. Compare your map to a tectonic map. Is there any relationship between the location of shield volcanoes and tectonic boundaries?

2. Where are most shield volcanoes found?

3. Compare your map to a tectonic map. Where are most stratovolcanoes found, at convergent (destructive) or divergent (constructive) boundaries?

4. Draw and label a diagram to show a subduction zone (at a convergent boundary). Attach this as a separate file.
   Suggested site: https://www.volcanodiscovery.com/geology/subduction-zones.html

How Fast will it Flow?

This is a series of three investigations to help you to understand factors that impact the flow of lava. Your teacher may assign you to just one investigation or ask you to complete all three.

Investigation 1: Temperature and Lava Flow

Objective

To determine how temperature impacts lava flow.

Hypothesis

Complete the following:

The time taken for a liquid to flow a set distance will________________(increase/ decrease)

as its temperature increases, this is because

Equipment

- 200 mL glass/cup
- Teaspoon
- Cooking pan
- Honey (or another relatively thick liquid)
- Plastic plate, Perspex board, chopping board or other suitable flat surface
- Timer
- Marker pen
- Thermometer
- Wooden spoon
- Wooden block, thick book or other suitable prop
- Chux cloth, paper towel or other cleaning materials

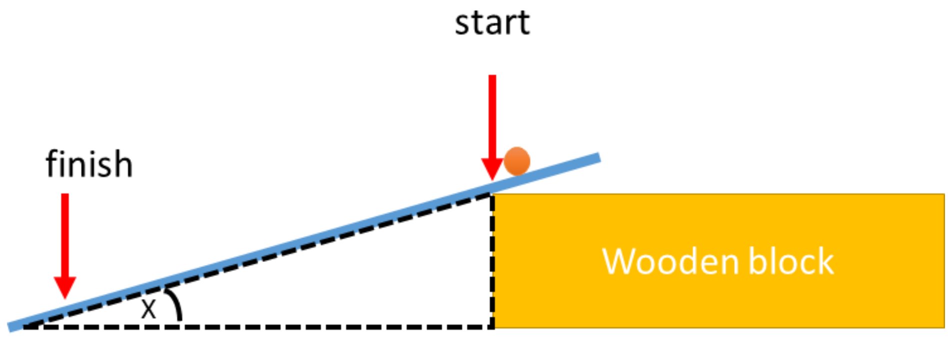


Figure 6. Side view of experimental set up. Measure how long it takes for a set volume of liquid (honey) to flow from the start to finish line, ensuring angle x is kept the same for each trial.

Method

1. Mark a start and finish line around 10 cm apart on your flat surface (paper plate/Perspex board/other).
2. Pour 100 mL of your thick liquid (honey/other) into a cup
3. Measure the temperature of the liquid and record it into your results table.
4. Set up your flat surface onto your prop (wooden block/thick book/other) as shown in figure 6.
5. Put a teaspoon of the liquid on the start line.
6. Time how long it takes for your liquid to reach the finish line, using the stopwatch.
7. Clean off your flat surface.
8. Slowly and gently start to heat the remaining liquid, using the wooden spoon to stir frequently, ensuring the liquid is the same temperature throughout.

Be very careful not to touch or get any warm liquid on you as it can burn!

9. Keep measuring the temperature (being careful that you are measuring the temperature of the liquid and not the pan). When the temperature has increased by 5°C take another teaspoon of liquid and place it on the start line.
10. Time how long it takes for it to reach the finish line.
11. Keep heating the liquid and repeat three more times, recording your results in the table.

Results and Analysis

Temperature (°C)	Time taken to reach finish line (s)
Original temperature= ___________	

+ 5	
+ 10	
+ 15	
+ 20	

1. Plot a scatter graph with temperature on the x-axis and time on the y-axis, adding a line of best fit (remember lines do not need to be straight, but should go through the most data points possible, and have the same number of data points on either side of it if they do not fit the line perfectly). See examples below:

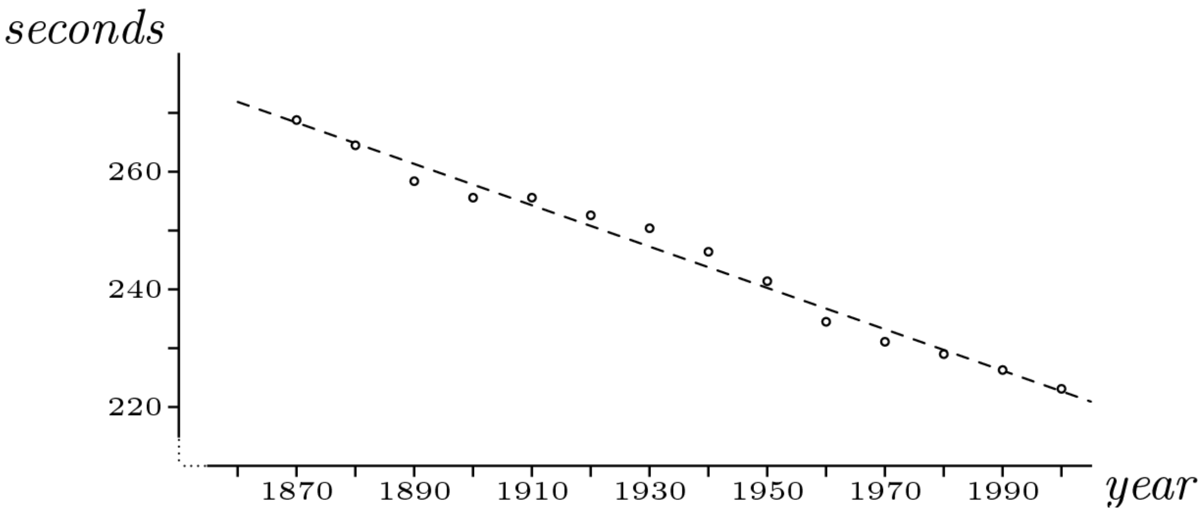


Figure 7. Scatter graph with line of best fit passing through as many data points as possible, and data being evenly spread either side.

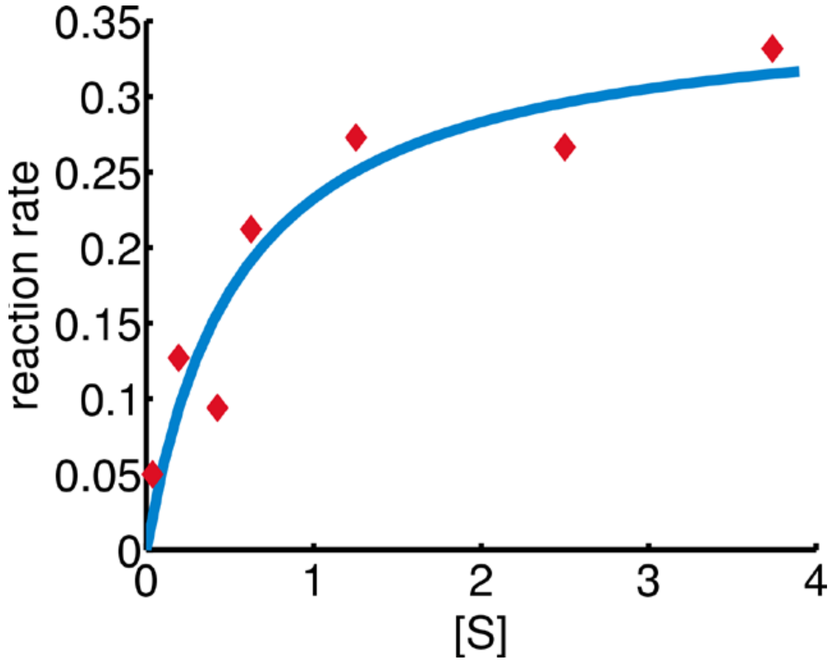


Figure 8. Line of best fit for curving data.

2. If your line of best fit is linear, find the gradient of your line by selecting any two points on that line. Subtract the first point's y-coordinate (y1) from the second point's y-coordinate (y2) and then subtract the first point's x-coordinate (x1) from the second points x-coordinate (x2). Divide the difference in y-coordinates by the difference in x-coordinates to get the gradient (m).

m (*gradient*) = (y1 – y2) / (x1 – x2)

y1	y2	x1	x2	m

3. What happens to the time taken for the liquid to flow between the two points as its temperature increases?

4. Was this what you predicted?

5. What could this mean in terms of lava flows and volcanic hazards?

Evaluation

1. Were there any potential sources of error in your investigation?

2. How could your improve this investigation?

Investigation 2: Angle of Slope and Lava Flow

Objective

To determine how the angle of a slope impacts lava flow.

Hypothesis

Complete the following:

The time taken for a liquid to flow will____________________________(increase/decrease)

as the angle of the slope increases, this is because

Equipment

- 200 mL glass/cup
- Teaspoon
- Ruler
- Honey (or another relatively thick liquid)
- Plastic plate, chopping board or other suitable flat surface
- Timer
- Marker pen
- A number of wooden blocks, thick books or other suitable props
- Chux cloth, paper towel or other cleaning materials

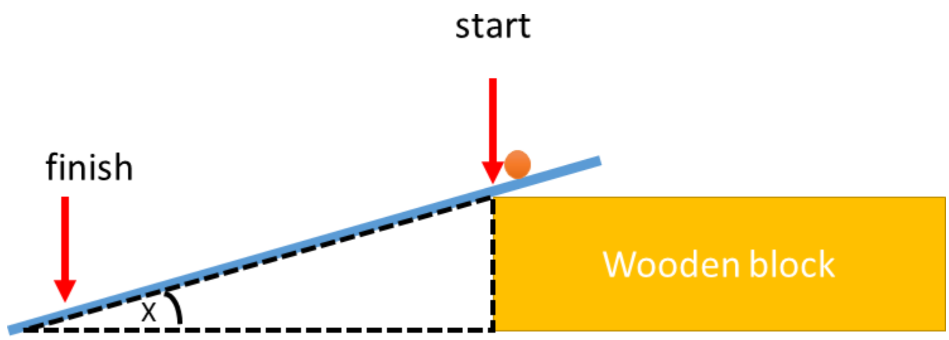


Figure 9. Side view of experimental set up. Measure how long it takes for a set volume of liquid (honey) to flow from the start to finish line, changing angle x for each trial.

Method

1. Mark a start and finish line around 10 cm apart on your flat surface (paper plate/ Perspex board/other).
2. Pour 100 mL of your thick liquid (honey/other) into a cup/glass.
3. Identify the opposite, hypotenuse and adjacent of the right angle triangle in figure 9. How will you measure the length of the adjacent for your experiment set-up?

   How will you find the length of the opposite for your experimental set up?

   How will you determine the angle, x, using trigonometry?

   How else could you find angle x?

4. Set up your flat surface onto one of your props (wooden block/thick book/other) as shown in figure 9.
5. Measure the length of adjacent, opposite and angle of slope and fill it into your table.
6. Put a teaspoon full of your liquid on the start line.
7. Time how long it takes for your liquid to reach the finish line and record it in your table.
8. Clean off your flat surface.
9. Repeat steps 5 to 8 three more times, adding one more prop each time to change the angle.

Results and Analysis

Length of adjacent (cm)	Length of opposite (cm)	Angle of slope (°)	Time taken to reach finish line (s)

1. Plot a scatter graph with angle of slope on the x-axis and time on the y-axis, adding a line of best fit (remember lines do not need to be straight, but should go through the most data points possible, and have the same number of data points on either side of it if they do not fit the line perfectly). See examples below:

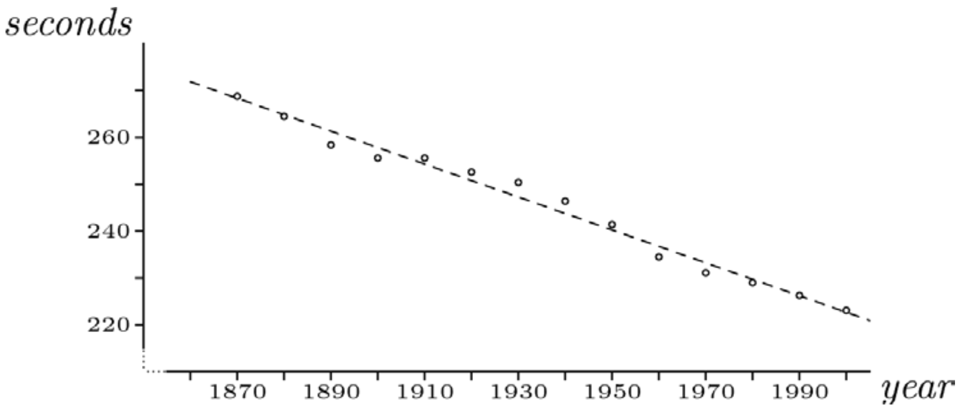


Figure 10. Scatter graph with line of best fit passing through as many data points as possible, and data being evenly spread either side.

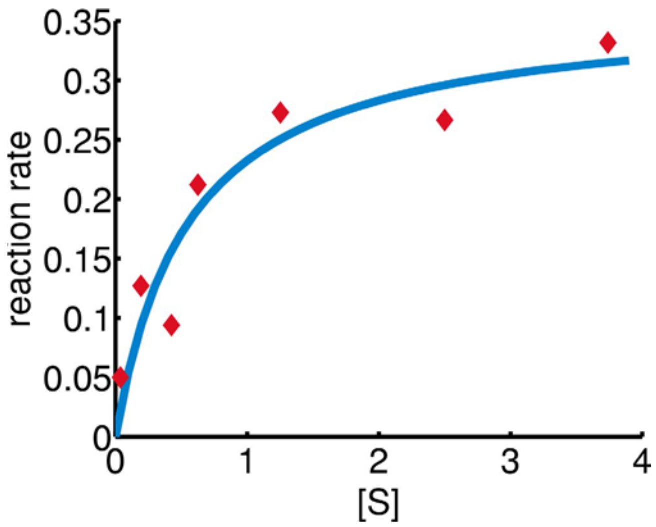


Figure 11. Line of best fit for curving data.

2. If your line of best fit is linear, find the gradient of your line by selecting any two points on that line. Subtract the first point's y-coordinate (y1) from the second point's y-coordinate (y2) and then subtract the first point's x-coordinate (x1) from the second points x-coordinate (x2). Divide the difference in y-coordinates by the difference in x-coordinates to get the gradient (m).

m (*gradient*) = (y1 – y2) / (x1 – x2)

y1	y2	x1	x2	m

3. What happens to the time taken for the liquid to flow between the two points as the angle of slope increases?

4. Was this what you predicted?

5. What could this mean in terms of lava flows and volcanic hazards?

Evaluation

1. Were there any potential sources of error in your investigation?

2. How could your improve this investigation?

Investigation 3: Viscosity and Lava Flow

Objective

To determine how the viscosity of a lava impacts its flow rate.

Background Research

1. What is viscosity a measure of in liquids?

2. Give three examples of highly viscous liquids compared to low viscosity liquids.

Highly viscous liquid	Low viscosity liquid

Hypothesis

Complete the following:

The time taken for a liquid to flow will______________________________(increase/decrease)

as the viscosity of that liquid increases, I think this because _

Equipment

- 200 mL cup/glass
- Teaspoon
- Ruler
- At least three different liquids with very different viscosities
- Plastic plate, chopping board or other suitable flat surface
- Timer
- Marker pen
- A wooden block, thick book or other suitable prop
- Chux cloth, paper towel or other cleaning materials

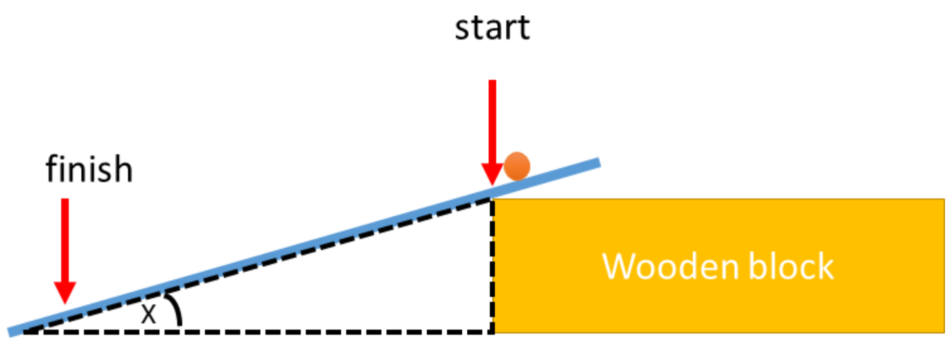


Figure 12. Side view of experimental set up. Measure how long it takes for a set volume of liquid to flow from the start to finish line, ensuring angle x is kept the same each trial.

Method

1. Mark a start and finish line around 10 cm apart on your flat surface (paper plate/Perspex board/other).
2. Collect samples of each of the liquids you will be testing.
3. Fill your liquids into your results table in order from lowest viscosity to highest viscosity.
4. Set up your flat surface as shown in figure 12.
5. Put a teaspoon full of your least viscous liquid on the start line.
6. Time how long it takes for it to reach the finish line, using the stopwatch, and record it in your table.
7. Clean off your flat surface.
8. Repeat steps 5 to 7 for each of the liquids you will be testing.

Results and Analysis

Liquid	Time taken to reach finish line (s)

1. Plot a histogram to show your results and attach this as a separate file.
2. What happens to the time taken for the liquid to flow between the two points as viscosity increases?
3. Was this what you predicted?
4. What could this mean in terms of lava flows and volcanic hazards?

Evaluation

1. Were there any potential sources of error in your investigation?
2. How could your improve this investigation?

VEI Scale

Objective

To create visual representations to make comparisons of the explosivity of historic eruptions, using the VEI scale.

Background Information

The Volcanic Explosivity Index (VEI) is a relative measure of the explosiveness of volcanic eruptions. It was devised by Chris Newhall of the United States Geological Survey and Stephen Self at the University of Hawaii in 1982.

Method and Results

1. Re-write the second column (ejecta volume) of the table below so that all volumes are given in m^3.

VEI	Ejecta volume	Description	Plume	Frequency	Example	Occurrences in last 10,000 years*
0	< 10,000 m^3	non-explosive	< 100 m	constant	Mauna Loa	many
1	> 10,000 m^3	gentle	100-1000 m	daily	Stromboli	many
2	> 1,000,000 m^3	explosive	1-5 km	weekly	Galeras (1993)	3477*
3	> 10,000,000 m^3	severe	3-15 km	yearly	Cordón Caulle (1921)	868
4	> 0.1 km^3	cataclysmic	10-25 km	? 10 yrs	Eyjafjallajökull (2010)	421
5	> 1 km^3	paroxysmal	> 25 km	? 50 yrs	Mount St. Helens (1980)	166
6	> 10 km^3	colossal	> 25 km	? 100 yrs	Krakatoa (1883)	51
7	> 100 km^3	super-colossal	> 25 km	? 1000 yrs	Tambora (1815)	5 (+2 suspected)
8	> 1,000 km^3	mega-colossal	> 25 km	? 10,000 yrs	Taupo (26,500 BP)	0

Figure 13. Volcanic Explosivity Index (Chegg Study, unknown).

VEI	**0**	**1**	**2**	**3**	
Ejecta Volume (m^3)					
	4	**5**	**6**	**7**	**8**
Ejecta Volume (m^3)					

Hint: 1 km^3 is equal to 1,000,000,000 m^3

2. Now convert all the volumes into scientific notation

VEI	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Ejecta Volume (m^3)									

3. From VEI 3 onwards, how much more ejecta is released for each increase in index (show your working)?

The atmosphere contains many layers and stretches far beyond what most people realise. Each layer carries out an important role which influences our daily lives. Below is a table of information regarding the layers of the atmosphere.

Layers of the Atmosphere		
Layer name	**Extent of height above Earth's surface (km)**	**Information**
Troposphere	14.5	This part of the atmosphere is the densest. Almost all weather is in this region.
Stratosphere	50	The ozone layer, which absorbs and scatters solar ultraviolet radiation, is in this layer.
Mesosphere	85	Meteors burn up in this layer
Thermosphere	600	Aurora and satellites occur in this layer.
Ionosphere	48 - 965	The ionosphere is an abundant layer of electrons and ionized atoms and molecules that stretches from about 48 kilometres above the surface to the edge of space at about 965 km, overlapping into the mesosphere and thermosphere.
Exosphere	10,000	This is the upper limit of our atmosphere.

Figure 14. Layers of our atmosphere (data from NASA (2018)).

4. Create a diagram to represent the first three layers of the atmosphere, ensure you have a clear scale and add any additional information you feel is important.

5. Add diagrams of volcanoes onto your diagram to show the maximum plume height for each index. You may want to research the example volcanoes given on the VEI scale so that you can also draw them to scale – or add pictures of them and further information, for example location and dates of historic eruptions.

6. Attach your diagram as a separate file or insert below.

Analysis

1. How much bigger on the VEI scale was the Krakatoa eruption in 1883 compared to the Galeras in 1993?

2. How much more ash (roughly) did the Krakatoa eruption in 1883 produce compared to the Galeras in 1993 (show your working)?

3. How much higher was the maximum plume height of the Tambora eruption of 1815 compared to the maximum plume height reached by Mauna Loa?

4. Which type of volcano typically has a higher VEI, stratovolcanoes or shield volcanoes?

5. Where are the more effusive and least explosive eruptions occurring, at convergent boundaries, divergent boundaries or at hot spots? Why do you think this is so?

Explosivity V Gas Content

Objective

To investigate if there is a relationship between the gas content of a liquid and explosivity, to relate this to volcanic eruptions.

Hypothesis

Complete the following:

As gas content of a liquid increases the explosivity will__________________________________
(increase/ decrease)
this is because

Equipment

- Large roll white paper/butchers paper
- 300 mL plastic bottle with a small hole in the top of the lid (this can be created by hammering a nail through it – !Caution while doing this!
- Effervescent powder, such as Alka-Seltzer (or crushed up Aspro Clear/similar tablets)
- Plastic tray/large container
- Ruler
- Timer
- Chux cloth or paper towel (for cleaning)

Optional

- Camera
- Food colouring

Method

1. Cover your working area and line your tray with paper (white or butchers). It is best if you can do this outside.
2. Fill the bottle full of water.
3. If you are using food colouring add a few drops just to give it some colour – this will make it easier to see how far your water has "erupted", however be very careful not to get it on clothes or carpets and clean up any mess straight away.
4. Put the tray in the centre of your table.
5. Very quickly empty half a sachet of effervescent powder into the bottle and screw the lid on – KEEP YOUR THUMB OVER THE HOLE IN THE LID FOR 30 seconds, this will allow the gas being evolved to build up pressure in the bottle.

6. Place the bottle in the centre of the tray, take your thumb off the hole and stand back.
7. The water should erupt out the hole in the bottle top.
8. When the "eruption" has finished, take photos from above to record the ejecta pattern and measure how far the water has reached (look for splatters on the desk and in the tray.) Record your results in the table below.
9. Clean up your working area.
10. Repeat the experiment adding more powder each time and recording your results. (If using dye we recommend that you change the colour of the dye for each repetition to make it clear which trial was which – you should ensure the area/paper is dry before each trial so it is clear which splatter comes from which trial).

Results and Analysis

Amount of powder	Maximum distance water was ejected (cm)

1. Which test resulted in water being ejected the longest distance?

2. Plot a scatter graph with amount of powder on the x-axis and maximum distance water was ejected on the y-axis and add a line of best fit (remember lines do not need to be straight, but should go through the most data points possible, and have the same number of data points on either side of it if they do not fit the line). Attach this as a separate file.

3. If your line of best fit is linear, find the gradient of your line by selecting any two points on that line. Subtract the first point's y-coordinate (y1) from the second point's y-coordinate (y2) and then subtract the first point's x-coordinate (x1) from the second points x-coordinate (x2). Divide the difference in y-coordinates by the difference in x-coordinates to get the gradient (m).

m (*gradient*) = (y1 – y2) / (x1 – x2)

y1	y2	x1	x2	m

4. What is the relationship between the volume of powder and eruption distance of the water?

5. What could this mean in terms of lava flows and volcanic hazards?

Evaluation

1. Were there any potential sources of error in your investigation?

2. How could your improve this investigation?

Probability of Eruption

Objective

To use historical data to determine the likelihood of a volcanic eruption of a particular size occurring.

Background Research

1. What is the Volcanic Explosivity Index (VEI)?

2. Use Wikipedia, or another website, to find out the frequency of volcanic eruptions in relation to their VEI.

VEI	Frequency
0	
1	
2	
3	
4	
5	
6	
7	
8	

Method and Results

1. Complete the table below to calculate the annual average occurrence for an eruption of each VEI, give the answer in scientific notation, correct to 3 significant figures.

VEI	Frequency	Annual average days of eruption
0	Daily	365
1	Daily	
2	Every 2 weeks	26 (52/26)
3	Every 3 months	
4	Every 18 months	
5	Every 12 years	
6	Every 75 years	
7	Every 750 years	0.001 (1/750)
8	Every 50,000 years	

2. What is the probability of an eruption with a VEI of >3 occurring today?

Volcanoes tend to have similar eruptions each time they erupt, due to their tectonic setting. We can predict the probability of a volcano erupting in a particular region if we know about its past.
You can use the database on the Smithsonian Institution Global Volcanism Program website: http://volcano.si.edu/ or another means to find the number of eruptions that have occurred in a particular country in the past.
Select a country that you know has been geologically active in the past 100 years (e.g. Iceland, Indonesia…) and download the dataset on that country – or research it and create a spreadsheet with the following headings:

- Date of eruption
- VEI
- Number of years from present day

3. Create a stem and leaf plot to display the VEI against number of years from present day for each eruption. Attach this as a separate file or insert below.

4. Calculate the mean and median VEI of the eruptions for that country.

Mean	Median

5. Create box and whisker plots to show the interquartile range of the VEI. Insert below.

6. Calculate the mean and median length of time between each eruption.

Mean	Median

7. What is the range in the length of time between each eruption?

Analysis

1. Can you give a rough prediction of when the next eruption may be due and what VEI magnitude it may have? Justify your answer.

Building a 3D Volcano

Objective

To use topographic maps to create a 3D model of an active volcano, to investigate probable routes of a lava/lahar flow and create a basic hazard map.

Equipment

- 2 x topographic maps of a volcano
- Scissors
- Clay/ playdough(how to make playdough: https://www.youtube.com/watch?v=oAIAm6BF0fs)
- Teaspoon
- Glass/cup
- Food colouring
- Tray/plate
- Camera or phone to record video (optional)

Method

1. First decide which volcano you would like to make a scale model of – a volcano where a large population lives near may be more interesting when considering the hazard map.
2. Find a topographic map of the volcano which is clear and has enough contour lines so that your model will not look flat. If the contour lines are very packed together you may wish to use larger intervals, rather than each individual contour.

For clay

1. Print out two copies of your topographic map.
2. Roll out some clay/dough to the size of your map, so it is 1 cm thick.
3. Cut your clay to the same shape as your volcano, following your lowest contour line – this is your base layer of your model. Place this to the side.
4. Now cut some more clay (still 1 cm thick) along the next elevation contour line on your map.
5. This is the second layer of your model – place this on top of your base, ensuring that it is orientated in the same direction (use your clean copy to check).
6. Continue working your way up the volcano – cutting out along the contour lines sequentially and placing them on top of the layers below, ensuring your clay thickness for each layer is 1 cm.
7. When you have completed all layers, you can use some excess clay to smooth the volcano out, making it more realistic – ensure you do not add too much though as you will change the shape of the volcano dramatically.
8. Allow your clay volcano to dry out in a kiln or on a sunny window sill.

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Identifying where the lava/lahar might flow.

1. Place your model volcano in a tray/on a plate
2. Fill up a measuring jug with 50 mL water
3. Add some food colouring (optional, but recommended)
4. Very carefully release a teaspoon of water onto the top of your volcano to represent a lava/pyroclastic flow. (Optional: use your phone/camera to create a video record of this event).
5. Note where the water went and repeat this 2 more times to check if the lava/ lahar follows the same route every time.

Results and Analysis

1. Did the water flow the same way on each trial?

2. On the second copy of your topographic map shade the route the water followed, highlighting "at risk" areas. Attach this as a separate file or insert below. *If possible use Google maps to look in detail at the area surrounding your volcano.*

3. Were there any houses or infrastructure in the way? Highlight/circle these on your map.

Evaluation

1. What improvements would you make to:
   a) The model
   b) The experiment
   to make it a more realistic test?

An initiative supported by Woodside and ESWA

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Designing a Diversion

Objective
To design an engineered solution for a chosen volcano which will help minimise the potential damage to local populations, explaining why it is a suitable solution for that area.

Background Research
1. Choose an active volcano/area near a volcano that you think would most benefit from volcanic hazard mitigation. Research more about the area such as:
    - The Gross Domestic Product (GDP) of the country
    - The population intensity
    - How frequently eruptions occur in the location
    - The maximum and average magnitude of eruptions in the location (VEI)
    - What type of volcano it is
    - The tectonic setting
    - The risk of lahars/landslides/avalanches/lava flows in the location if there is an eruption

2. Use the internet to find out more about current or historic ideas which have been designed to minimise the potential damage to populations living near volcanoes, to complete and add to the table below. Consider their strengths and weaknesses ***in relation to your chosen location*** by **critically analysing factors, including social, ethical and sustainability considerations.**

Case study / idea	**How it work(s)/(ed)**	**Strengths**	**Weaknesses**
Edfell, Iceland Cooling lava using water			
Suggested website	https://pubs.usgs.gov/of/1997/of97-724/methods.html or https://www.bbc.com/news/magazine-29136747		
Sakurajima Concrete lahar channels			
Suggested website	http://www.photovolcanica.com/VolcanoInfo/Sakurajima/Sakurajima.html Scroll down to 'Erosion Control/Lahar Defenses – The Sabo Systems		
Mauna Loa Use of explosives			
Suggested website	https://www.bbc.com/news/magazine-29136747		

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Case study / idea	**How it work(s)/(ed)**	**Strengths**	**Weaknesses**
Mount Etna Rock and ash barriers			
Suggested website	https://www.bbc.com/news/magazine-29136747		
Mount Etna Diverting the flow pathway			
Suggested website	https://www.bbc.com/news/magazine-29136747		
Early warning hazard system			
Suggested website	https://volcanoes.usgs.gov/vhp/notifications.html		

Method

1. Brainstorm your own ideas to minimise the damage from an eruption of your chosen volcano, comparing the pros and cons of them – add diagrams (use CAD if possible.)

Design	**Pros**	**Cons**

Design	Pros	Cons

If you are considering an idea such as creating earth barriers or lahar channels you may wish to make a model of your volcano in 3D and then cut out channels to test where they will be most effective.

2. If you plan to make a model of your hazard mitigation solution complete the following sections to write a project plan of how you will make your chosen design, ensuring you have completed the risk assessment table. Show this to your teacher and make any necessary changes before making your model.

   Equipment:

   Method:

Risk assessment:

Hazard	Risk	Prevention
e.g. chopping wood	Could cut fingers/hand	Use equipment with care and under supervision. Keep focused. Use the right equipment.

Evaluation

1. What were the strengths and weaknesses of your design?

Strengths	Weaknesses

2. What improvements could you make to your design? Explain why these suggestions would improve the design. Add a labelled diagram of your modified design below – highlighting the modifications.