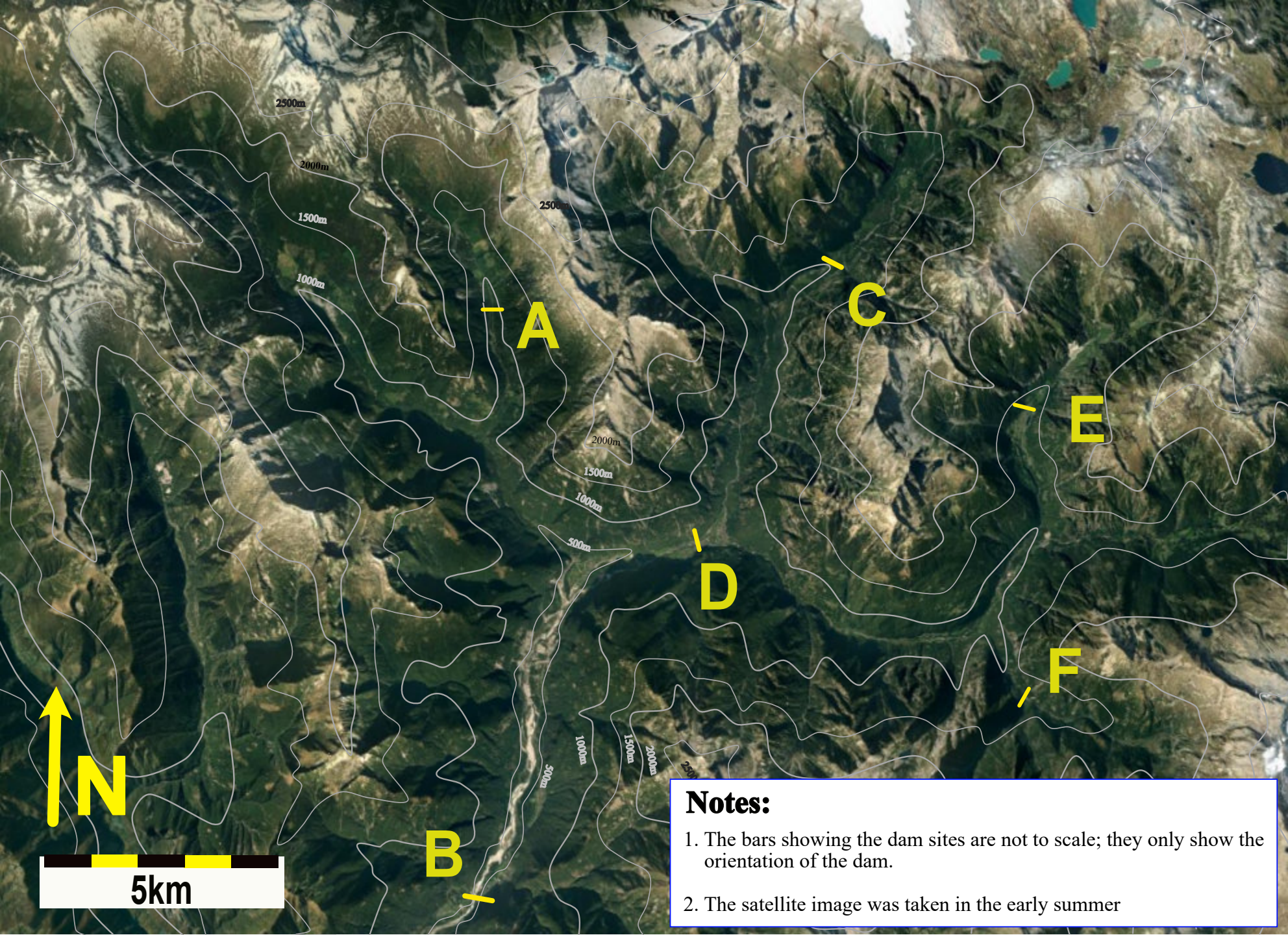
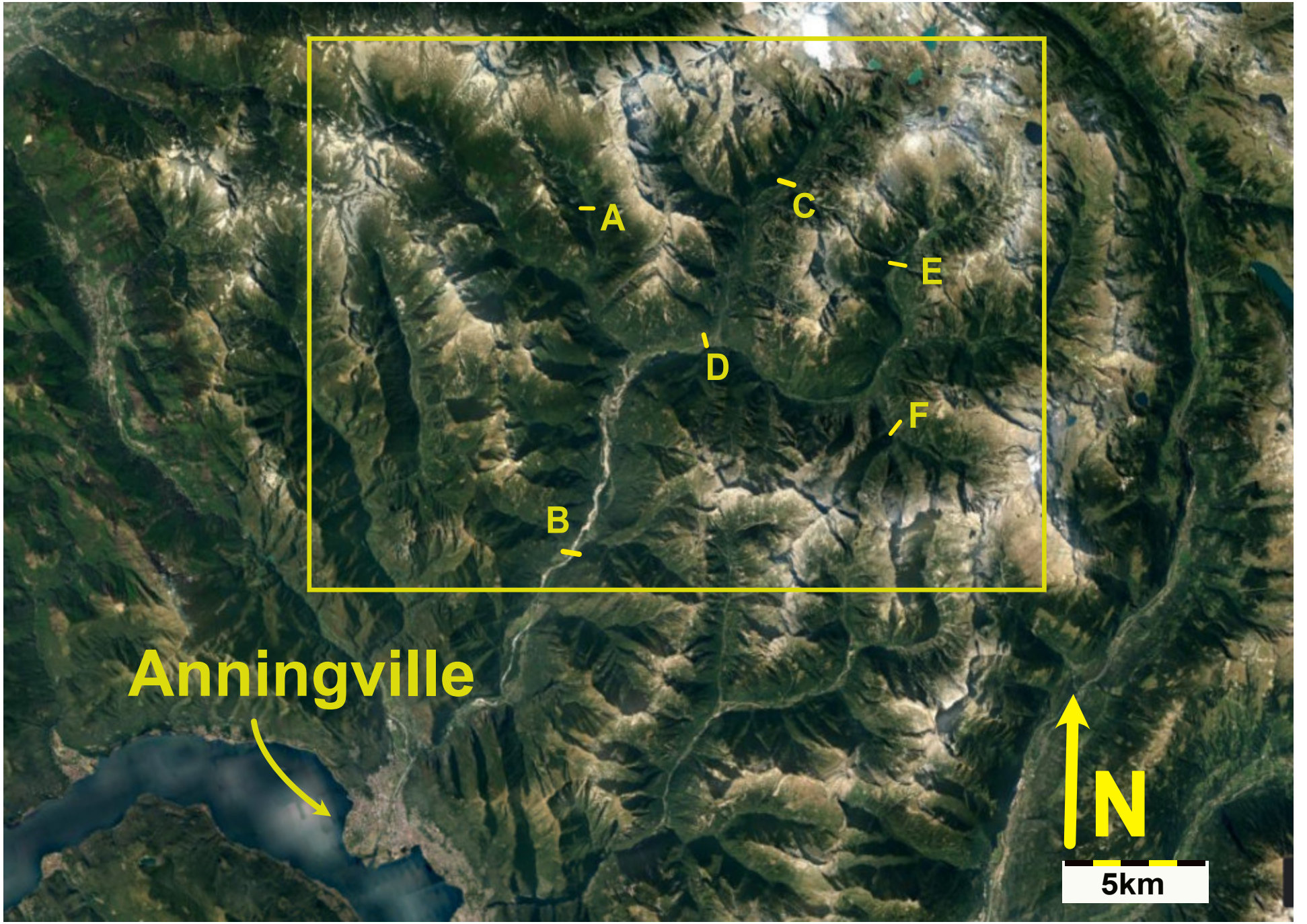
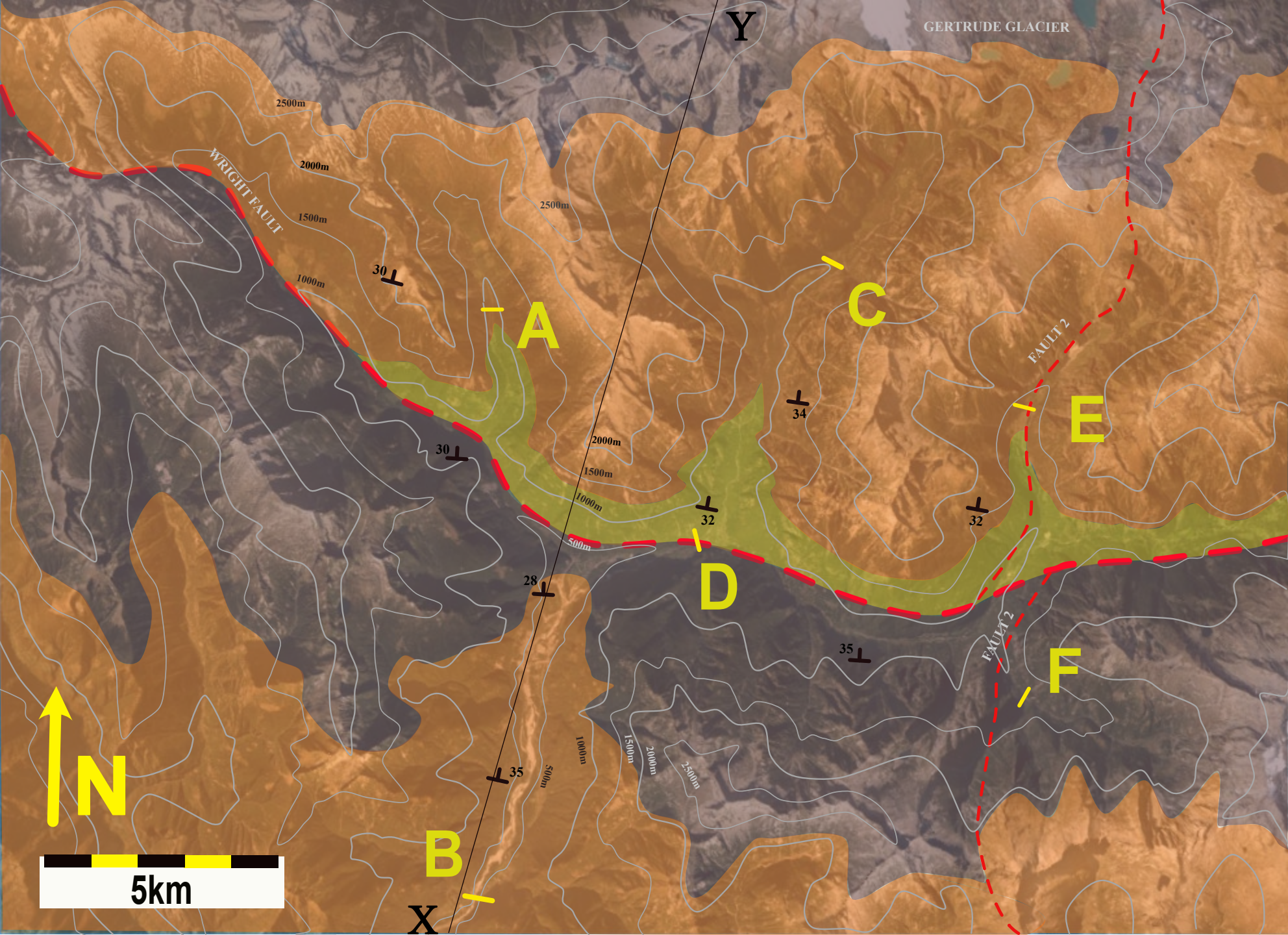


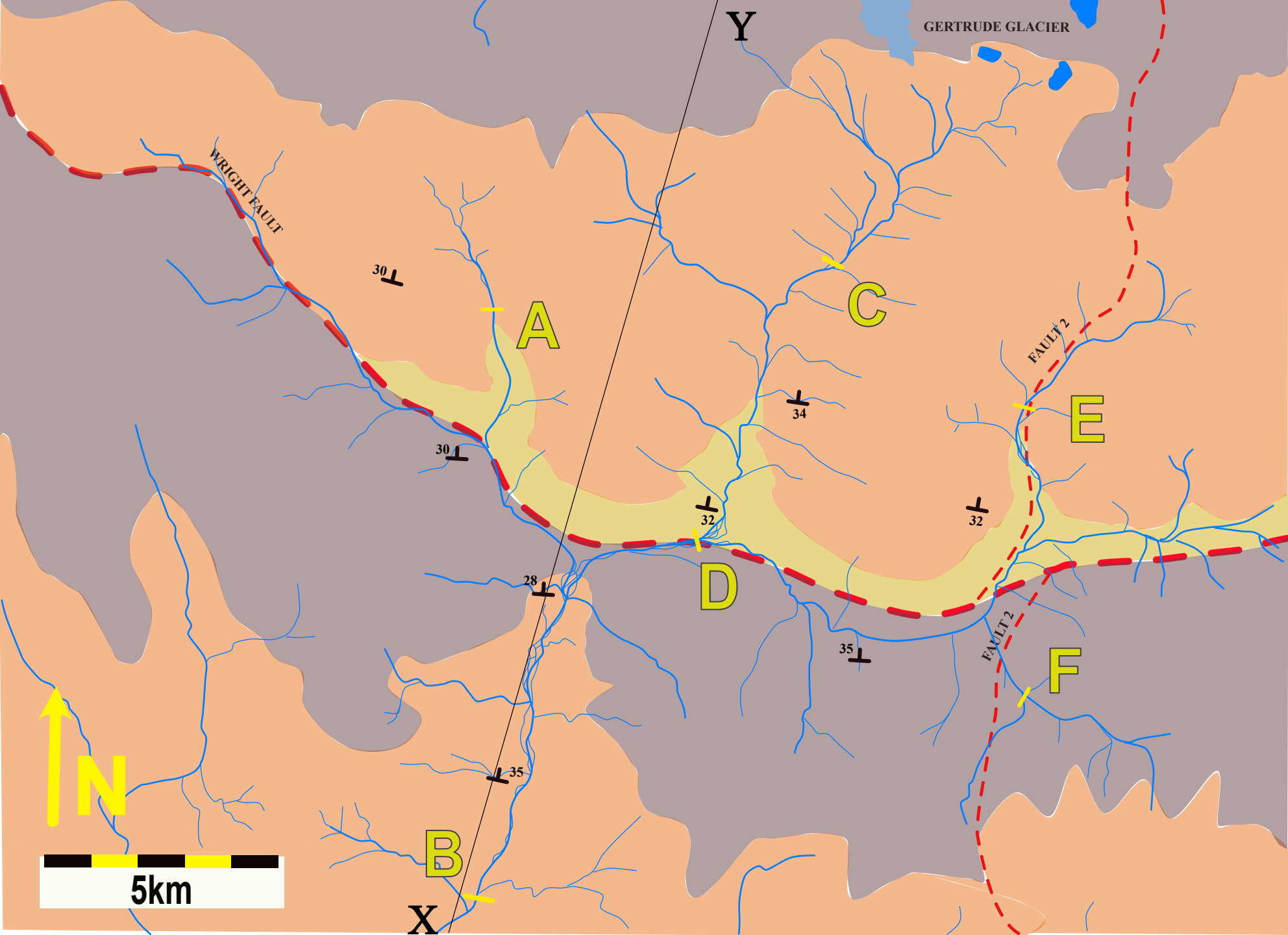
Notes:

1. The bars showing the dam sites are not to scale; they only show the orientation of the dam.

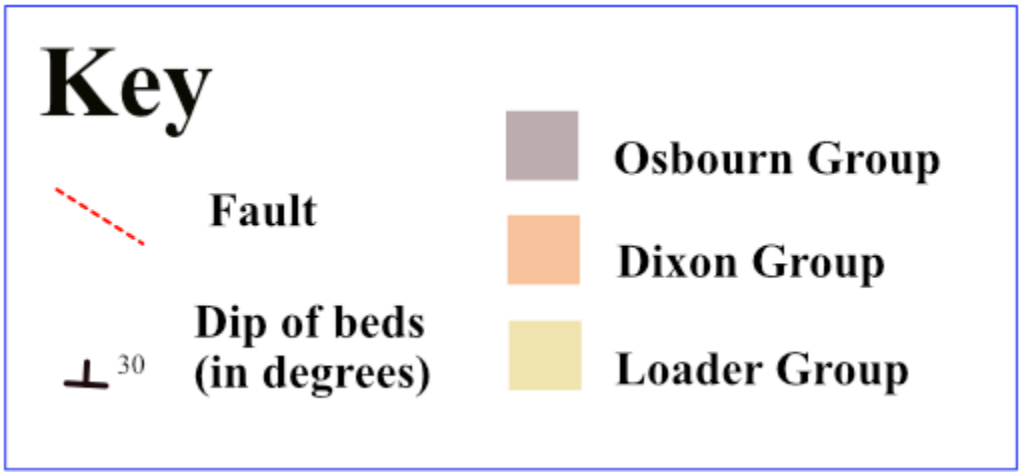
2. The satellite image was taken in the early summer


A
B
C
D
E
F
Anningville
N
5km


Y
GERTRUDE GLACIER
2500m
2000m
1500m
1000m
WRIGHT FAULT
30
A
C
FAULT 2
34
E
30
2000m
1500m
1000m
32
32
500m
28
D
35
FAULT 2
F
N
1000m
1500m
2000m
2500m
35
500m
B
5km
X


Y
GERTRUDE GLACIER
WRIGHT FAULT
30
A
C
FAULT 2
34
E
30
32
32
28
D
35
FAULT 2
F
N
35
B
5km
X

GEOLOGICAL MAP KEY AND NOTES



Osbourn group	Metamorphic. Bedded series of dark grey metamorphosed sandstone. Crystalline texture, impermeable. Composed mostly of quartz.
Dixon group	Metamorphic. Bedded series of pale brown-beige metamorphosed sandstone. Crystalline texture, impermeable. Composed mostly of quartz.
Loader group	Metamorphic. Bedded series of pale grey-white metamorphosed limestone. Crystalline texture. Composed of calcium carbonate ($CaCO_3$)

The Wright fault is considered inactive; its most recent movement was 20 000 years ago. The Wright fault is younger than Fault 2.

Dam sites are indicated by a letter (A, B, C, D, E, or F) and a line, showing the orientation of the dam across the valley. **Note that the lines are not to scale, they are merely indicators of the dam's position**.

Consulting opportunities:

- Purchase a cross section along line X-Y
- Consultation on rock types or geological map
- Second opinion on your geological conclusions
- Explanation of dip and strikes

BRIEF:

Your team is a contractor vying for the deal to build and supply hydroelectric power facilities to Anningville. You must choose where to build your dam(s), from six potential sites which have been selected in the valleys around Anningville. The project must meet the following criteria:

- The site(s) must be geologically suitable to accommodate a dam
- There must be reservoir capacity for a minimum of 30 million cubic metres of water
- The budget for the project must not exceed £950 million

You have the following resources to help you make your decision:

- A copy of the intro presentation
- A satellite map of the area, showing the six potential dam sites.
- A geological map of the area
- A detailed specification and overview of each site

It is recommended you stick to the following timings:

- 10 mins: Read brief, site specifications and budget sheet **carefully**
- 15 minutes: identify which sites are geologically suitable for a dam
- 15 minutes: discuss advantages and disadvantages of building on these areas. Choose which site or sites you want to build on
- 15 minutes: prepare your budget and summary. **Divide these tasks amongst your team.**
- 15 minutes: double check budget, gather main points for presentation to judges

You will be marked on your scientific application, reasoning, team working skills and your pitch to the judges. Try to think outside the box, and feel free to use the full budget – you will **not** lose marks for spending money.

After your time is up, you will turn in the following:

- Your budget sheet (via google sheets)
- Your summary sheet (via google forms)

You will be sent the link for these via Zoom.

You will then be called in your teams to pitch to the judges. You have **three minutes** to summarise the information on your sheet and show why you should be offered the building contract.

Tips to help you:

- Study the satellite and geological maps carefully. You may notice important details which are not included in the site specifications.
- You can look up information using the web, but it isn't recommended!
- Time management is key; divide tasks among your team, and try to narrow down your options quickly.
- There is more than one "right" answer. Decide which is the best option as a team; use prior knowledge, common sense, and the information given to you.
- Think outside the box to make your team stand out to the judges – highlight any unconventional solutions you propose during this time.

This symbol means there is an opportunity to buy information from a consultancy. You can find prices for this in your budget sheet. Send a message to Rose via Zoom if you would like to discuss this.

SITE A SPECIFICATION

Dam size (m^3)	210 000
Dam height (m)	110
Reservoir length (m)	1700
Reservoir volume (m^3)	21 000 000
Catchment area (km^2)	25
Sediment depth in river valley (m)	7
Forested area to be flooded (km^2)	1.7
Ecological notes	The valley of the proposed site is home to a population of the critically endangered Lakin's Boreal Owl, a keystone species which inhabits high altitude forest away from human habitation. Previous attempts to relocate populations of this owl have been successful in 70% of cases
Additional road required for construction access to site (km)	6.3
Population of valley	87
Population displaced if dam built	19
Social notes	Valley is very sparsely populated, and households are concentrated at the valley mouth. Whilst only 19 people would be displaced if the valley was flooded, the others would face significant disruption while the dam was constructed.

SITE B SPECIFICATION

Dam size (m^3)	345 000
Dam height (m)	75
Reservoir length (m)	6000
Reservoir volume (m^3)	95 000 000
Catchment area (km^2)	215
Sediment depth in river valley (m)	35
Forested area to be flooded (km^2)	12
Ecological notes	River is wide here and the heavy sedimentation provides spawning ground for several species of fish
Additional road required for construction access to site (km)	0
Population of valley	1 390
Population displaced if dam built	634
Social notes	Wide, flat and fertile valley means that it is heavily populated compared to surrounding areas. Also home to 2 ruins of archaeological significance. There has been a net loss in population in the last 10 years due to flash flooding events causing damage to property.

SITE C SPECIFICATION

Dam size (m^3)	195 000
Dam height (m)	100
Reservoir length (m)	2100
Reservoir volume (m^3)	14 200 000
Catchment area (km^2)	36
Sediment depth in river valley (m)	5
Forested area to be flooded (km^2)	1.8
Ecological notes	Due to the remoteness of this area, many species of local flora and fauna flourish here. Populations of Ibex are known to spend winters in the valley, however they are well distributed in valleys across the region.
Additional road required for construction access to site (km)	8
Population of valley	0
Population displaced if dam built	0
Social notes	Valley is uninhabited and popular for hikes. Long distance walking route passes through on its way across the mountains to Anningtown.

SITE D SPECIFICATION

Dam size (m^3)	247 000
Dam height (m)	85
Reservoir length (m)	3 800 (y-shaped reservoir as it would flood the convergence of two valleys)
Reservoir volume (m^3)	48 500 000
Catchment area (km^2)	115
Sediment depth in river valley (m)	18
Forested area to be flooded (km^2)	2.7
Ecological notes	Several fish species spawn in the sediment on the river bed
Additional road required for construction access to site (km)	9 (Renovating the roads at this site is a compulsory cost, in order to give good access to those living in communities higher than the dam site).
Population of valley	643
Population displaced if dam built	128
Social notes	Valley is well populated and home to several chalets that host tourists in summer and winter

SITE E SPECIFICATION

Dam size (m^3)	168 000
Dam height (m)	100
Reservoir length (m)	2200
Reservoir volume (m^3)	16 750 000
Catchment area (km^2)	15
Sediment depth in river valley (m)	3
Forested area to be flooded (km^2)	1.2
Ecological notes	This valley is home to fewer fauna species compared to the surrounding valleys, due to the presence of a road leading to a weather station (see below). There are no known populations of endangered species in this valley.
Additional road required for construction access to site (km)	3.5 NB: the current road in the valley leads to a weather monitoring station. If a dam was built, this would have to be rerouted along the construction access road once the dam was completed. Renovating the construction road for public use it is therefore a compulsory cost at this site (see budget sheet).
Population of valley	8
Population displaced if dam built	8
Social notes	Very sparsely populated, however all those in the valley would have to be rehomed if this site was flooded. There have been proposals in the past to build a climate and meteorology museum associated with the weather station, which would offer training opportunities for young people interested in climate science. Previous proposals were dismissed due to poor infrastructure leading to the site.

SITE F SPECIFICATION

Dam size (m^3)	185 000
Dam height (m)	110
Reservoir length (m)	950
Reservoir volume (m^3)	11 400 000
Catchment area (km^2)	10
Sediment depth in river valley (m)	3
Forested area to be flooded (km^2)	1.1
Ecological notes	Flora and fauna are relatively undisturbed. Valley has difficult access and so is popular with several populations of ground nesting birds, which return each year to breed.
Additional road required for construction access to site (km)	12.7
Population of valley	0
Population displaced if dam built	0
Social notes	Valley is uninhabited and popular for hikes. A road would be beneficial to opening the area to tourists

Stuck or can't decide which site to choose? Consider an appointment with a consultant.

BUDGET TEAM NAME: _____

Below are costs you need to factor into your project. **Your maximum spend is £950million.**

COMPLETE VIA YOUR ONLINE SPREADSHEET.

Compulsory costs			
Item	**Cost per unit (£)**	**Qty**	**Total (£)**
Turbine	£110 million each Dam less than 300 000m^3 – 1 turbine Dam more than 300 000m^3 – 2 turbines		
Generator and transformer	£190 million	1	190 000 000
Dam construction (including labour, concrete and other materials, transport, machinery)	£350 000 per day. Use dam size as a proxy to calculate daily rate; assume the dam will be built at a rate of 500 cubic metres per day.		
Sediment excavation from valley floor	£120 000 per metre depth		
Relocation of displaced people, inc compensation for drowned property	£150 000 per person		

Optional Costs				
Item	**Cost per unit**	**Qty**	**Total**	**Included in budget?**
Concrete slipway to allow movement of aquatic animals above and below dam	£13 million			
Aeration system to prevent dead water build up. (Dead water is oxygen-deprived and can therefore have severe detrimental impacts on ecosystems)	£15 million per 10 million cubic metres of water in reservoir			
Deforestation and disposal of plant material prior to valley flooding, to prevent methane release	£270 000 per km^2			
Rewilding management for flora and fauna disrupted by dam	£2.5 million per year after dam's completion. Choose how many years you would like.			
Grouting for fractured bedrock (NB this is a compulsory cost if the geology of the site requires remediation)	£35 million per dam			
Renovation of the road used to access construction site; this would make it accessible to the public for use such as hiking trail access.	£500 000 per km			
Preparation of designated water-side area, ready to sell as plots to business owners in the outdoor tourism industry.	£17. 5 million			
Outdoor leisure complex for tourists and locals. Activities would include sailing, windsurfing and paddleboarding.	£190 million			
Consultations	£10 million each or 3 for £25 million			

TOTAL:

SUMMARY SHEET **COMPLETE VIA GOOGLE FORMS**

TEAM NAME

SITE(S) CHOSEN:

Please briefly outline why this was your choice; include your scientific conclusions for the sites chosen, advantages of building here, and any other information you feel is relevant.

Please note any disadvantages to building on this/these site(s). Please explain how or if you will address these issues.

What is your total budget for the project (in £GPB)?

Which optional items, if any, did you include in your budget?

If you included any optional costs in your budget, please briefly explain why you chose these (if you haven't previously).

BUDGET TEAM NAME: _____

Below are costs you need to factor into your project. **Your maximum spend is £950million.**

Compulsory costs				
Item	**Cost per unit (£)**	**Qty**	**Total (£)**	
Turbine	£110 million each Dam less than 300 000m^3 – 1 turbine Dam more than 300 000m^3 – 2 turbines			
Generator and transformer	£190 million	1	190 000 000	
Dam construction (including labour, concrete and other materials, transport, machinery)	£350 000 per day. Use dam size as a proxy to calculate daily rate; assume the dam will be built at a rate of 500 cubic metres per day.			
Sediment excavation from valley floor	£120 000 per metre depth			
Relocation of displaced people, inc compensation for drowned property	£150 000 per person			
Optional Costs				
Item	**Cost per unit**	**Qty**	**Total**	**Included in budget?**
Concrete slipway to allow movement of aquatic animals above and below dam	£13 million			
Aeration system to prevent dead water build up. (Dead water is oxygen-deprived and can therefore have severe detrimental impacts on ecosystems)	£15 million per 10 million cubic metres of water in reservoir			
Deforestation and disposal of plant material prior to valley flooding, to prevent methane release	£270 000 per km^2			
Rewilding management for flora and fauna disrupted by dam	£2.5 million per year after dam's completion. Choose how many years you would like.			
Grouting for fractured bedrock (NB this is a compulsory cost if the geology of the site requires remediation)	£35 million per dam			
Renovation of the road used to access construction site; this would make it accessible to the public for use such as hiking trail access.	£500 000 per km			
Preparation of designated water-side area, ready to sell as plots to business owners in the outdoor tourism industry.	£17. 5 million			
Outdoor leisure complex for tourists and locals. Activities would include sailing, windsurfing and paddleboarding.	£190 million			
Consultations	£10 million each or 3 for £25 million			

TOTAL:

<u>SUMMARY SHEET</u>

TEAM NAME

SITE(S) CHOSEN:

Please briefly outline why this was your choice; include your scientific conclusions for the sites chosen, advantages of building here, and any other information you feel is relevant.

Please note any disadvantages to building on this/these site(s). Please explain how or if you will address these issues.

Which optional items, if any, did you include in your budget?

If you included any optional costs in your budget, please briefly explain why you chose these (if you haven't previously).

Problem Solving

Schools Geology Challenge 2021

Welcome to sunny Anningville!

- Town of approximately 25000 residents; administrative centre for wider district of c.60000 people

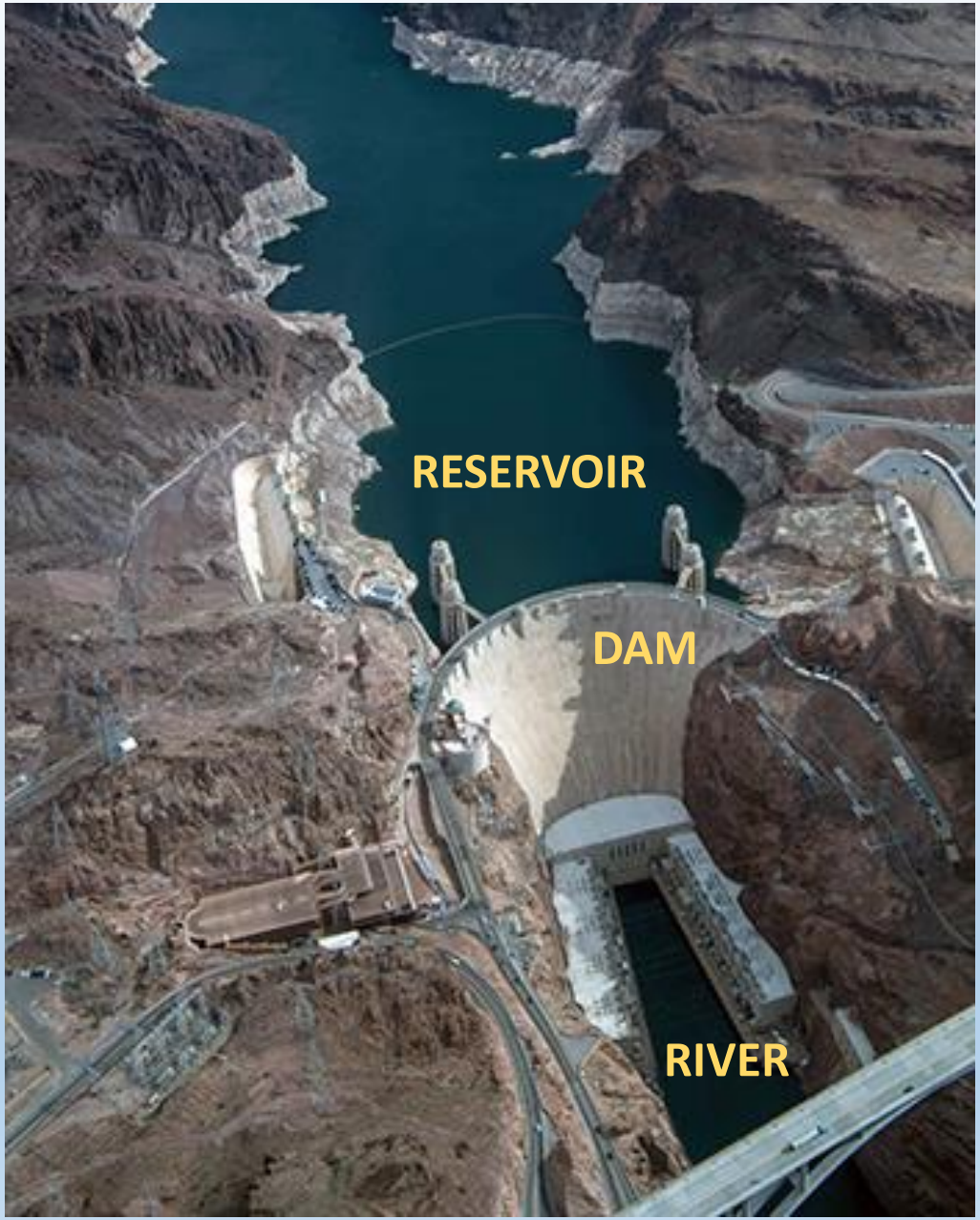
- We need you to build a hydropower facility for Anningville!

Welcome to sunny Anningville!

- An overview to hydropower plants and Dams
- Explain your task and how to complete it
- Questions
- Resource pack is available

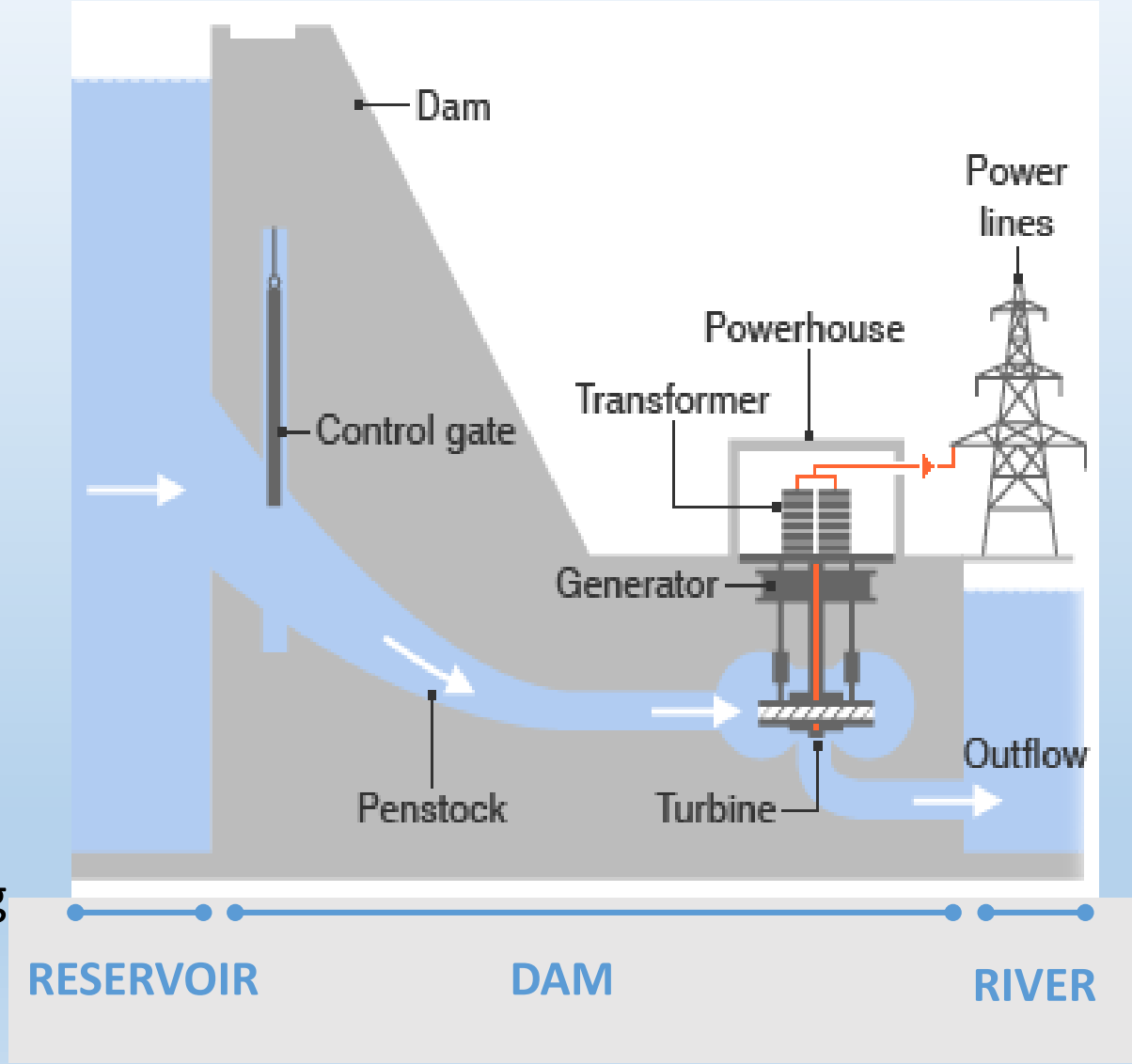
What is hydropower?

- Renewable energy resource
- Conversion of energy from flowing water to electricity.
- We will be focussing on conventional hydroelectric plants
  - Concrete structure (**dam**) is built across a river valley
  - This creates a large artificial lake (**reservoir**)
  - The reservoir is used to store water, which is passed through a **turbine** in the dam, producing electricity as it turns.



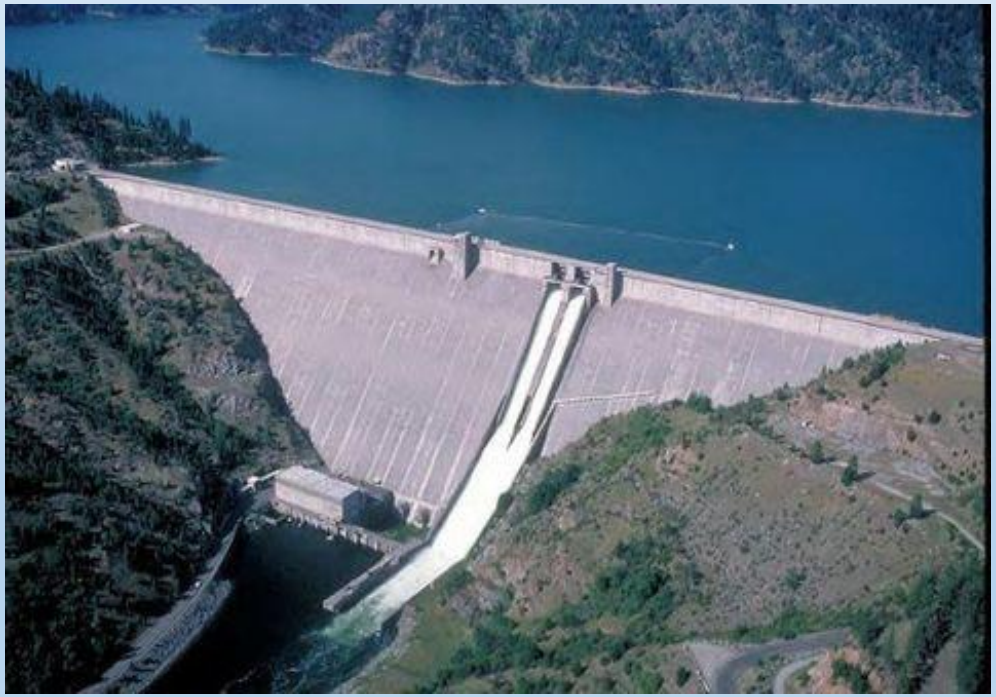
What is hydropower?

- Renewable energy resource
- Conversion of energy from flowing water to electricity.
- We will be focussing on conventional hydroelectric plants
  - Concrete structure (**dam**) is built across a river valley
  - This creates a large artificial lake (**reservoir**)
  - The reservoir is used to store water, which is passed through a **turbine** in the dam, producing electricity as it turns.



Where can we build dams?

The most suitable sites for dams are narrow river valleys or canyons. This allows a relatively small dam to be built, but large volumes of water to be held.



What geology is suitable?

The geology of the dammed valley is critically important.

Siting a dam on unsuitable rocks can allow water to leak from the reservoir, make the dam unstable or even lead to its failure.

What geology is suitable?

Rock type

Rocks should be impermeable, i.e., they do not let water flow through them.

- Most igneous rocks (e.g. granite, gabbro)
- Some metamorphic rocks, such as gneiss and quartzite
- Massive, well-cemented quartz sandstone

What geology is suitable?

Rock type

Rocks should not dissolve in water. Rocks with a high $CaCO_3$ content are unsuitable, including:

- Limestone
- Marble
- Sedimentary rocks cemented with calcite (CaCO3)

What geology is suitable?

Structure

Faults and joints can make rocks permeable, by creating cracks for water to migrate through.

The effects of these can be mitigated with concrete **grouting**, where concrete is injected at high pressures to fill the gaps.

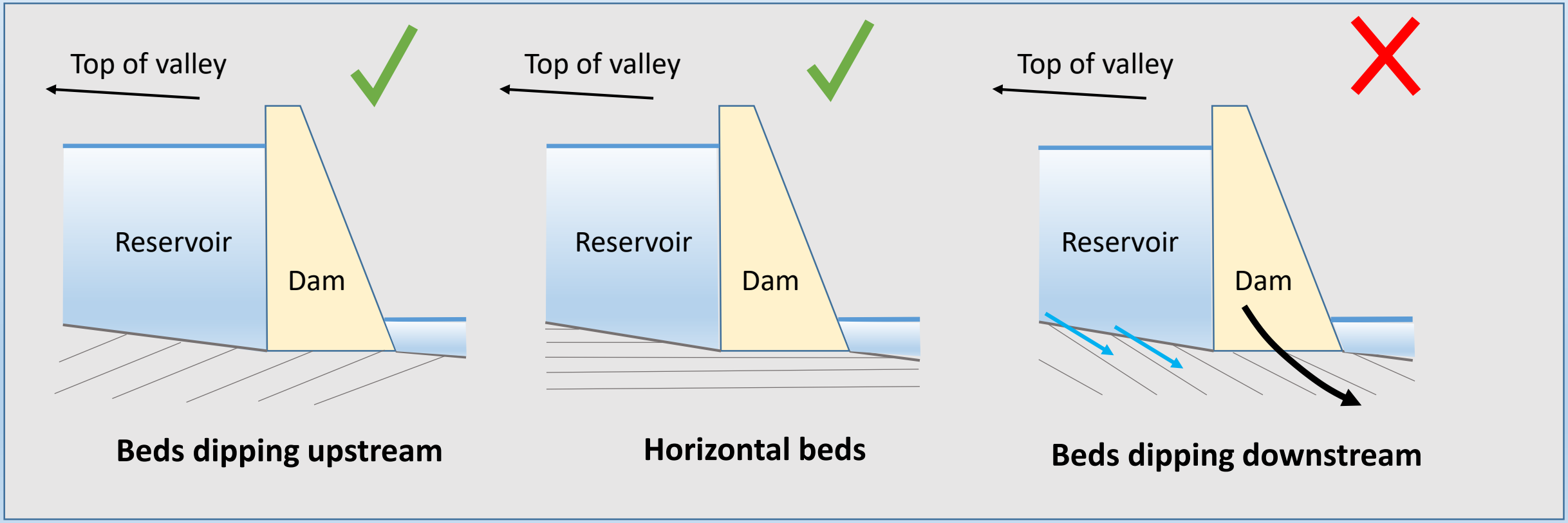
Dams should **not be built** near large-scale active faults – grouting will not help if there is an earthquake!

What geology is suitable?

Sedimentary rocks usually build up in layers; these layers can be horizontal, or they can tilt (dip) in different directions.

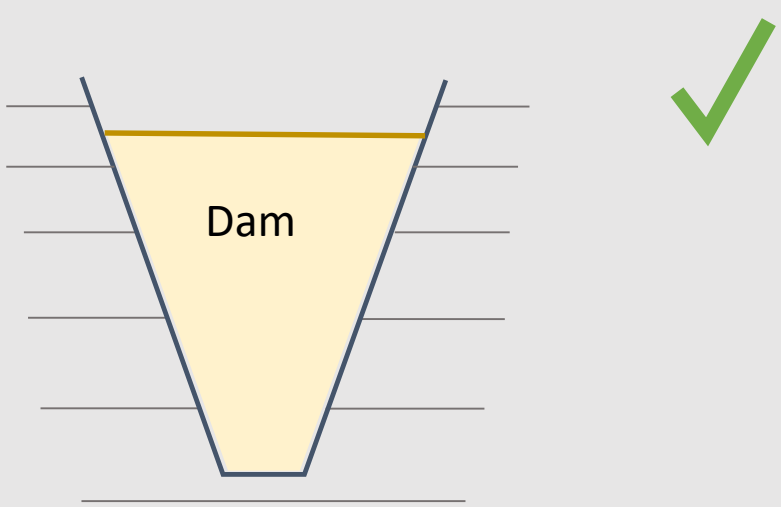
What geology is suitable?

Sometimes, dipping beds can be highly beneficial to dam construction. At other times, they can be dangerous.
It all depends on the **direction of the dip**.

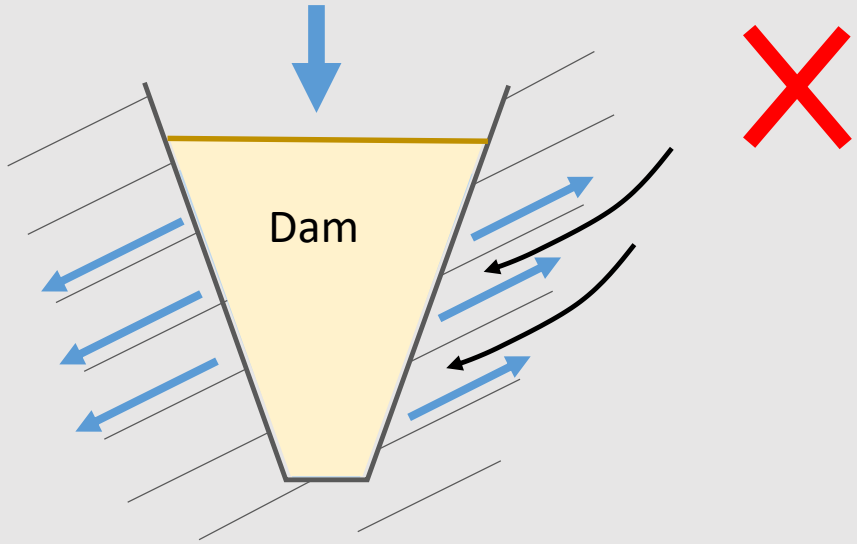


What geology is suitable?

Layers (beds) of rock can dip in different directions. Sometimes the dip can be highly beneficial to dam construction, others not.



Bedding strike is across the valley



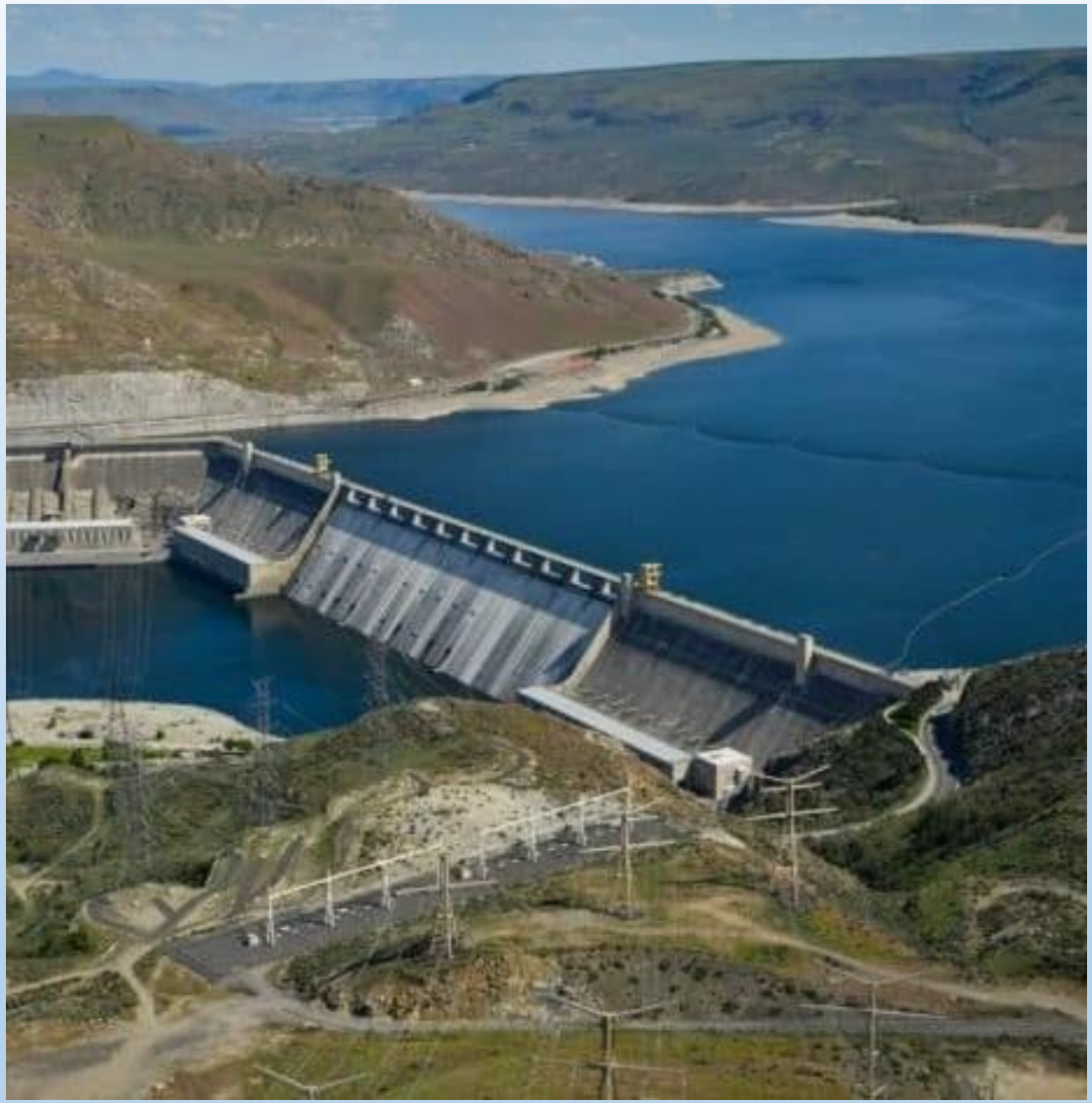
Beds dipping into valley

Suitable Geology: Summary

- Rocks should be impermeable
- Rocks should not dissolve in water
- Rocks should not be excessively fractured by **faults** or **joints**
- If the rocks are no longer actively being fractured, e.g. by an active fault, concrete grouting can be applied to make a site suitable
- Rock beds should not dip downstream of the dam
- Rock beds should not dip into the valley that holds the reservoir.

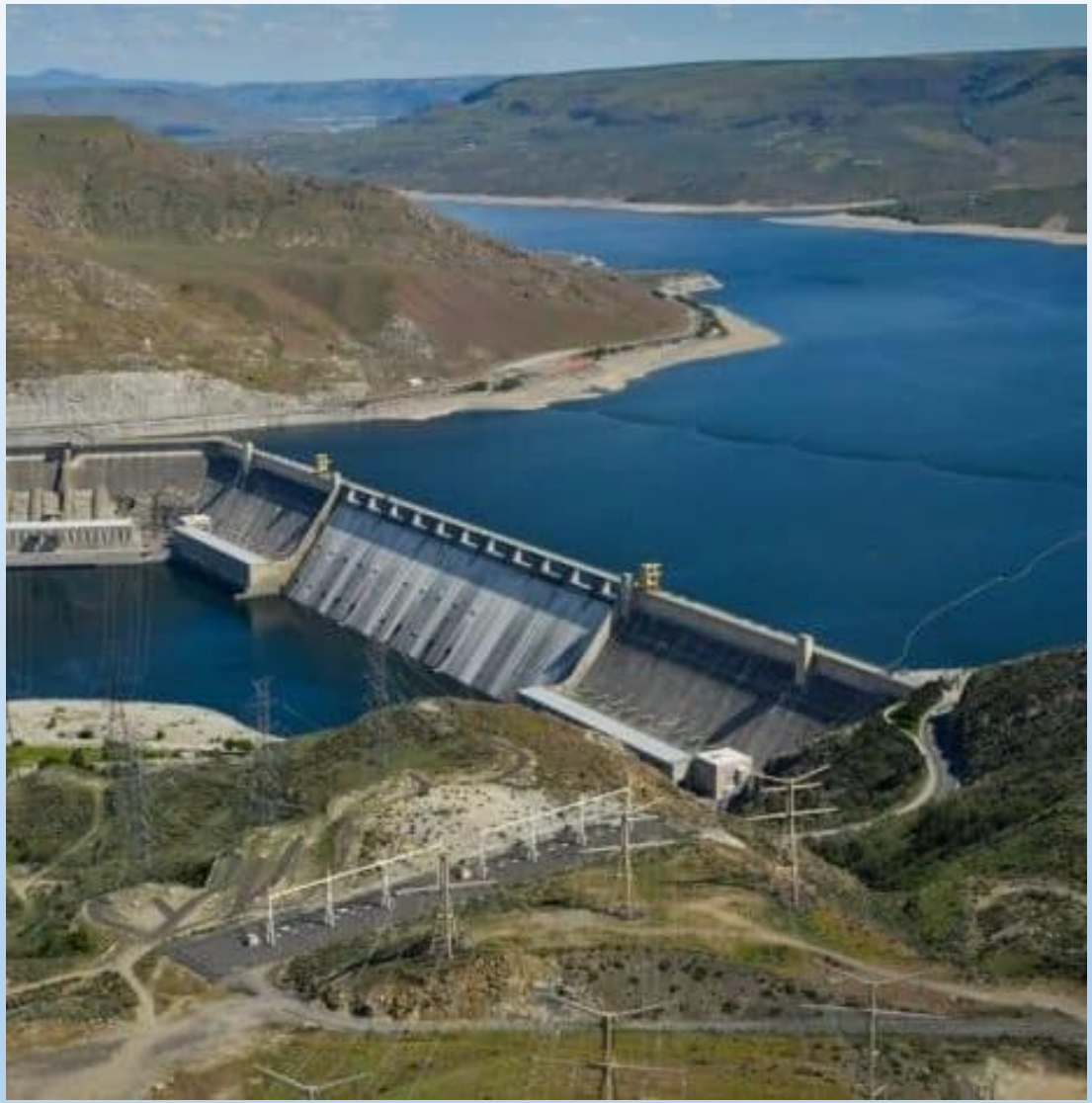
Advantages of hydropower use:

- Renewable energy resource
- Expensive to set up, but cheap to produce energy once running
- Potential to mitigate flooding
- Water storage for dry seasons
- Minimal CO2 emissions
- Flexible energy supply – release more water when demand for power is higher



Disadvantages of hydropower use:

- Large areas are flooded to create reservoirs
- Loss of homes or habitat incurred
- Dams can block important sediment transport down rivers, leading to significant erosion downstream
- Dams may block important migration routes for aquatic wildlife
- Significant methane release when forested areas are flooded



Your challenge…

Welcome to sunny Anningville!

- Town of approximately 25000 residents; administrative centre for wider district of c.60000 people
- Local industry was formerly farming and fishing, due to wide flat plain on which the town is built
- Main industry now is tourism.

Welcome to sunny Anningville!

- Threat from climate warming; Anningville has experienced 3 exceptional flooding events in the last 12 years

- Cause identified as higher than average **glacial meltwater** levels in the spring, combined with **seasonal storms.**

- State-wide, the area is suffering from prolonged periods of **drought in the summer**

Welcome to sunny Anningville!

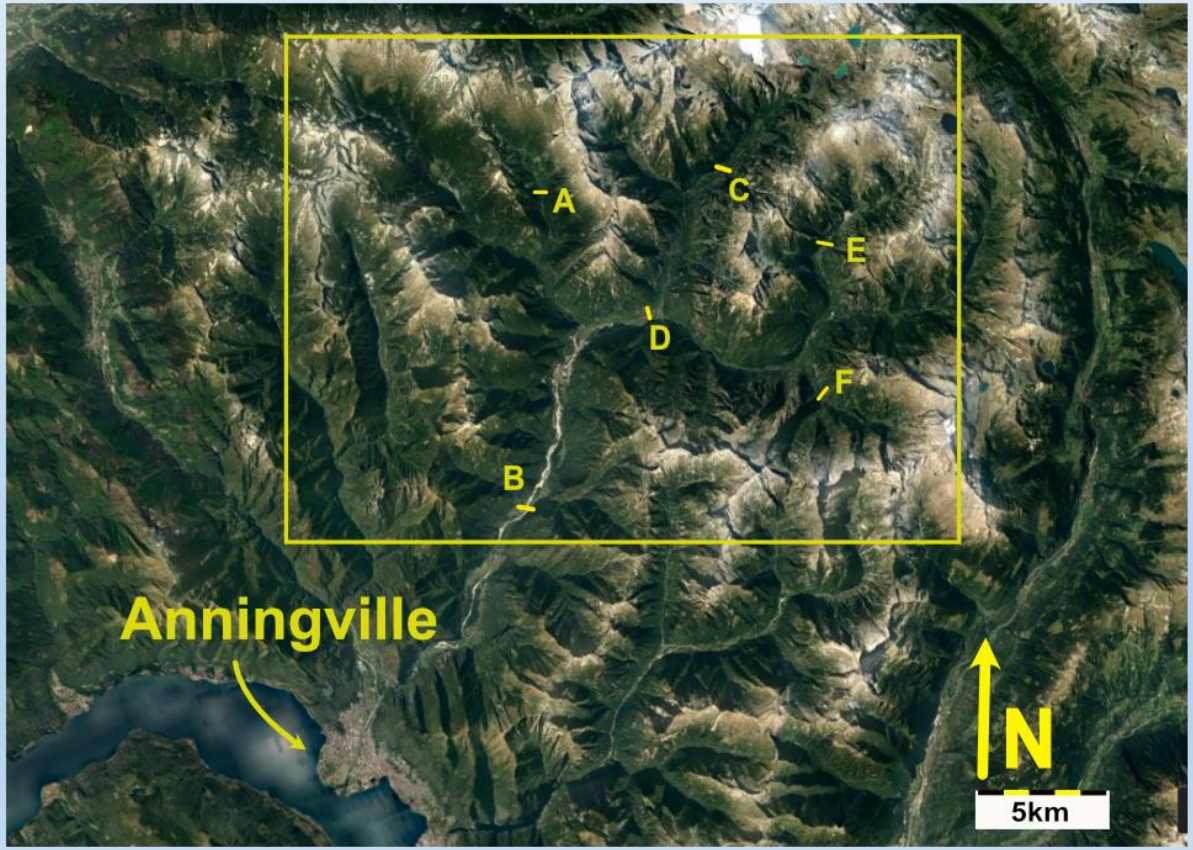
- Local government has created new “climate charter”
- Commitment to use 100% renewable energy in the local grid within 20 years.
- Hydropower is preferred source; abundant availability of water in region, minimal CO2 output, and option of storing water for summer months

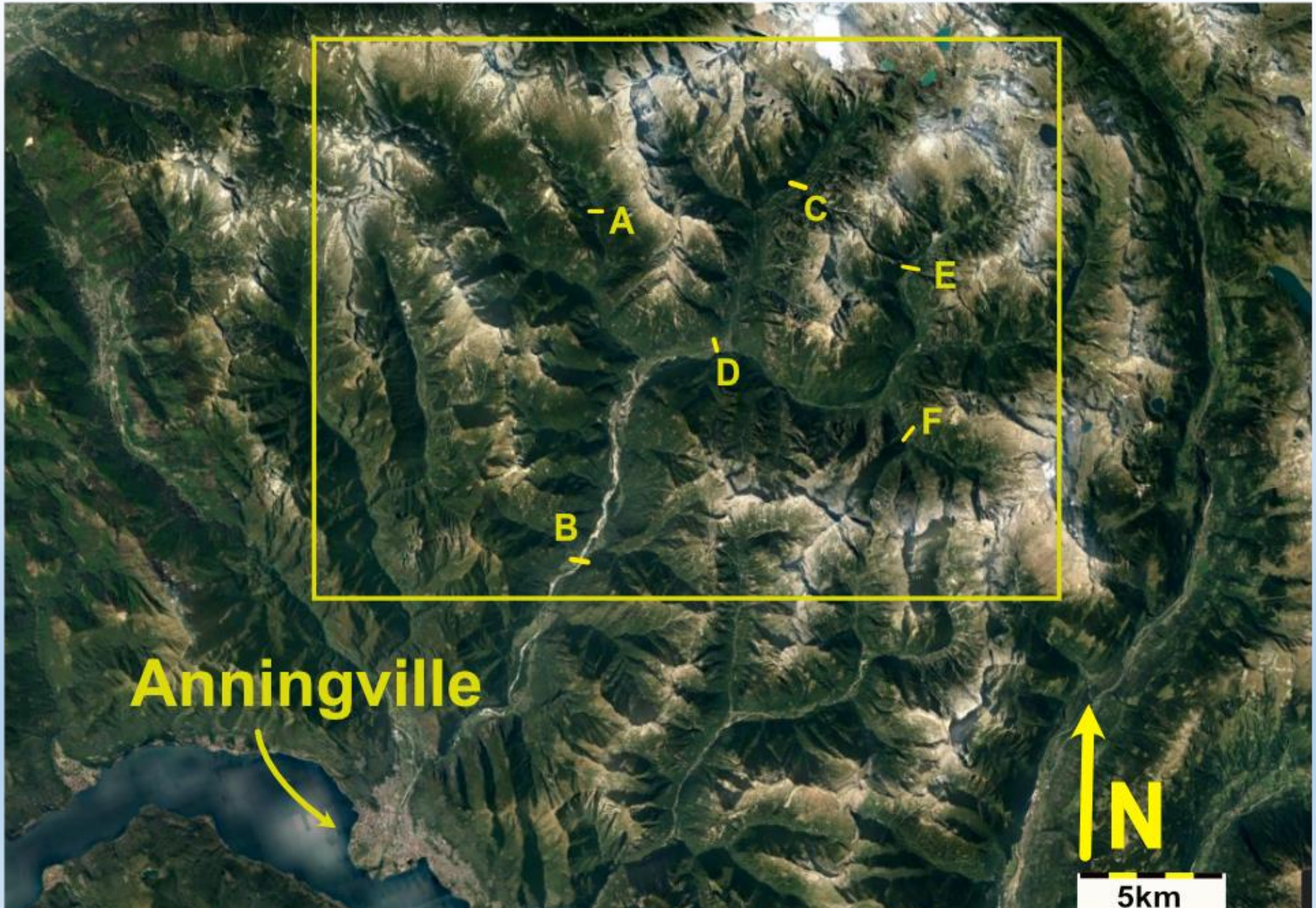
Your task…

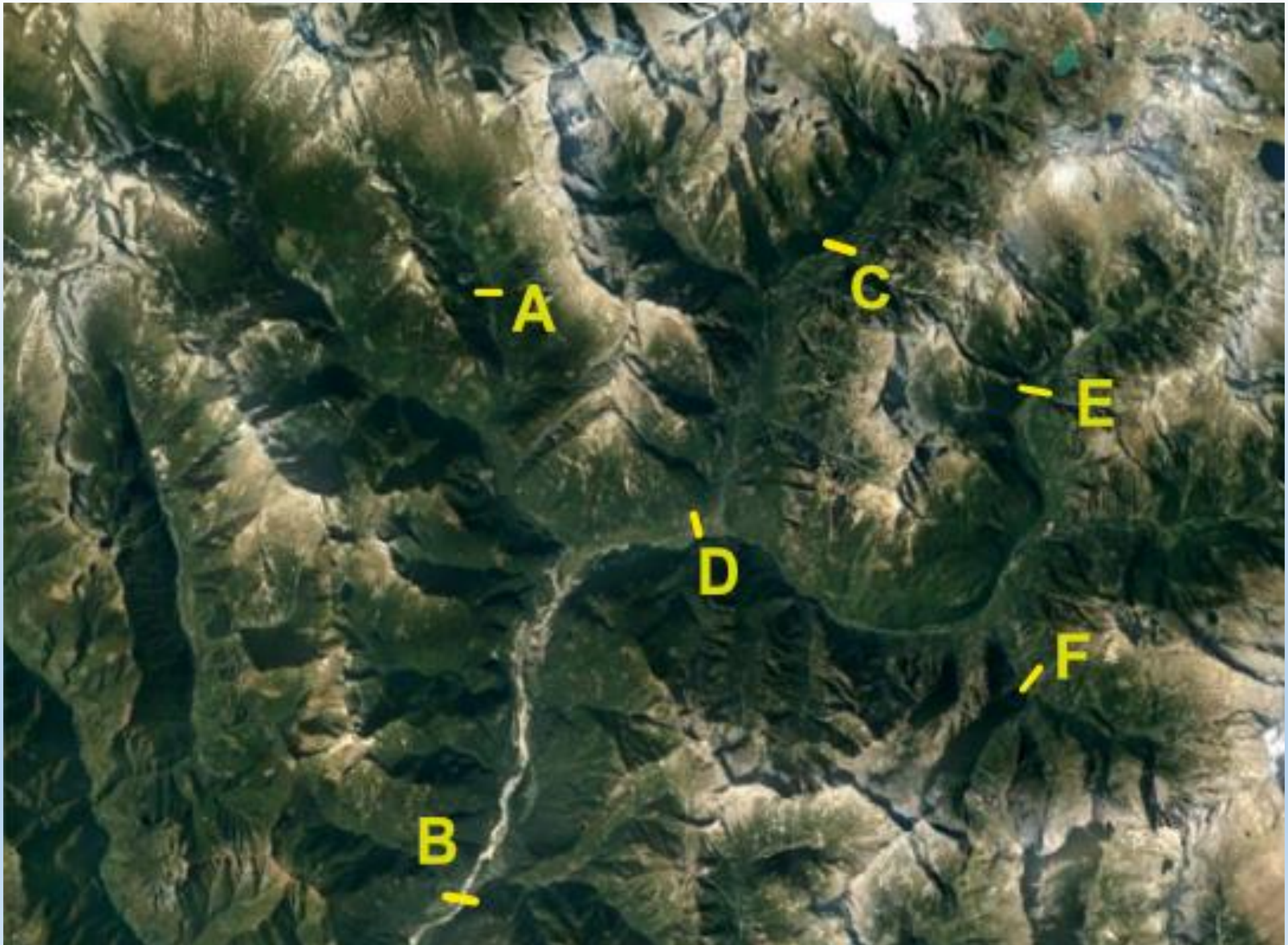
You are contractors vying for the rights to construct and supply hydropower facilities to Anningville.

Six potential sites have been identified for dams. You need to:

1. **Identify** which sites are **geologically suitable**
2. **Choose where** to build your dam(s)
3. Propose a **budget** for the project
4. Convince Anningville Town Council (aka the judges) that your team should be contracted to build the hydropower plant(s)!




A
B
C
D
E
F
Anningville
N
5km


A
B
C
D
E
F

Resources to help you:

You will have access to a Google or DropBox folder with the following:

- A brief and a copy of this presentation
- A satellite map of the area, showing the six potential dam sites
- A geological map of the area
- A detailed overview of each site
- A sheet to help you calculate your budget

How this will be assessed

- You have just over **1 hour** to decide where to build your dam(s), complete a budget, and prepare a presentation.

- During this time, you will complete a budget via Google Sheets, and a summary of your decisions via Google Forms

- **After** you have submitted your budget and summary, you will be called in a random order to pitch to the judges**. You will have 3 minutes to tell them which site(s) you chose, why you chose them and why they should choose your team to build the hydropower plant(s).**

Resources to help you:

Budget

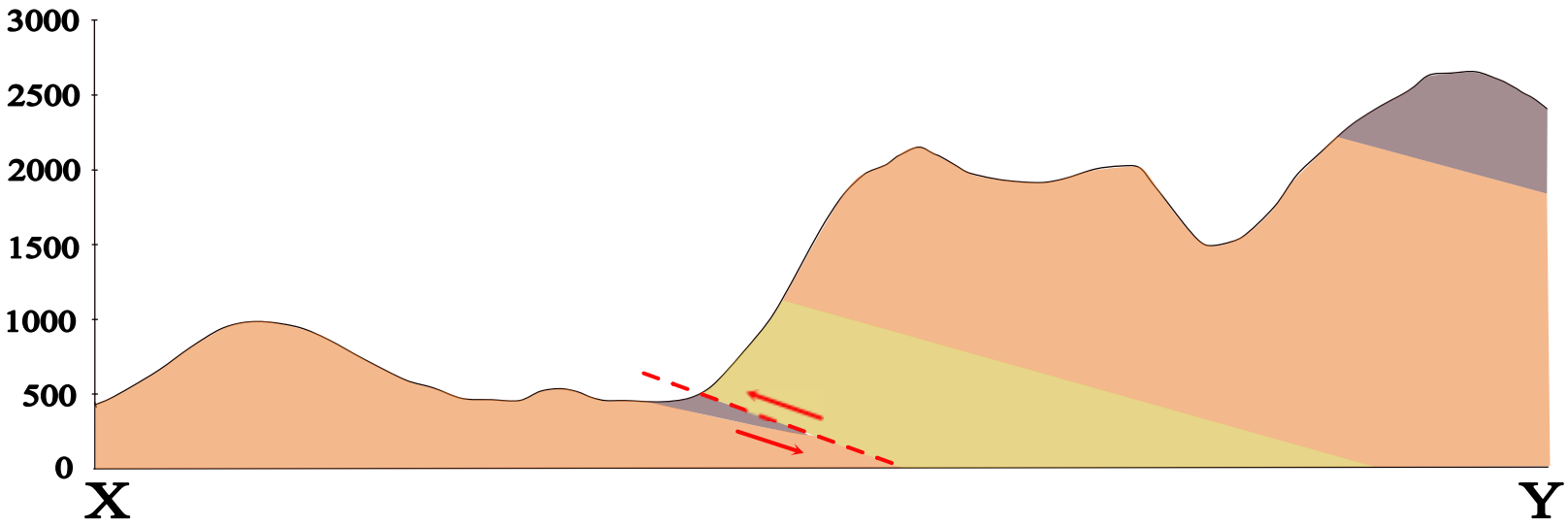
- Part of the assessment is the budget you produce for your project, and how wisely you spend money
- All the information you need for this is on the budgeting sheet
- The maximum you can spend is **£950 million**; marks are **not** gained for saving money!
- You have the opportunity to “buy” information from an external contractors, if you would like to.

Finally, some tips…

- There are suggested timings to complete this activity in the Brief – make sure you read them!

- There are some wrong answers, but there is more than one “right” answer. Decide which is the best option as a team; use prior knowledge, common sense, and the information given to you

- 3 minutes is not long for a presentation. Highlight the information which is **most important**!


3000
2500
2000
1500
1000
500
0
X
Y