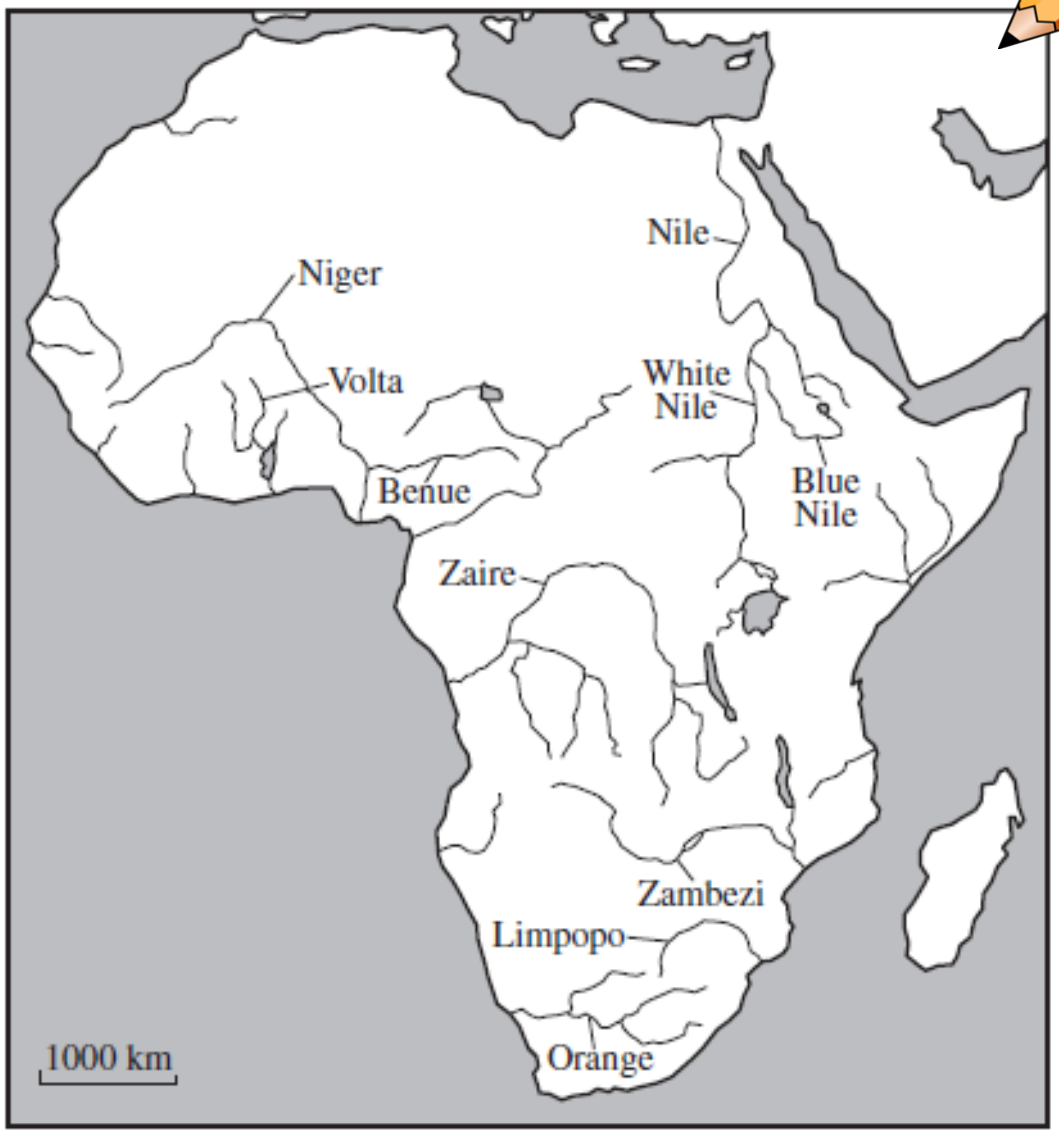
River Basin Management

CASE STUDY: THE ORANGE RIVER BASIN; LESOTHO HIGHLANDS WATER PROJECT, AFRICA.

Four Nations, One river!

Distribution of River Basins in Africa



Collect a blank map of Africa's river basins

Mark onto it the names of the major Drainage basins shown here.

Paired Discussion

What factors might determine the distribution (patterns) of these rivers?

Distribution of River Basins in Africa

There are 5 major River Drainage basins in Africa:

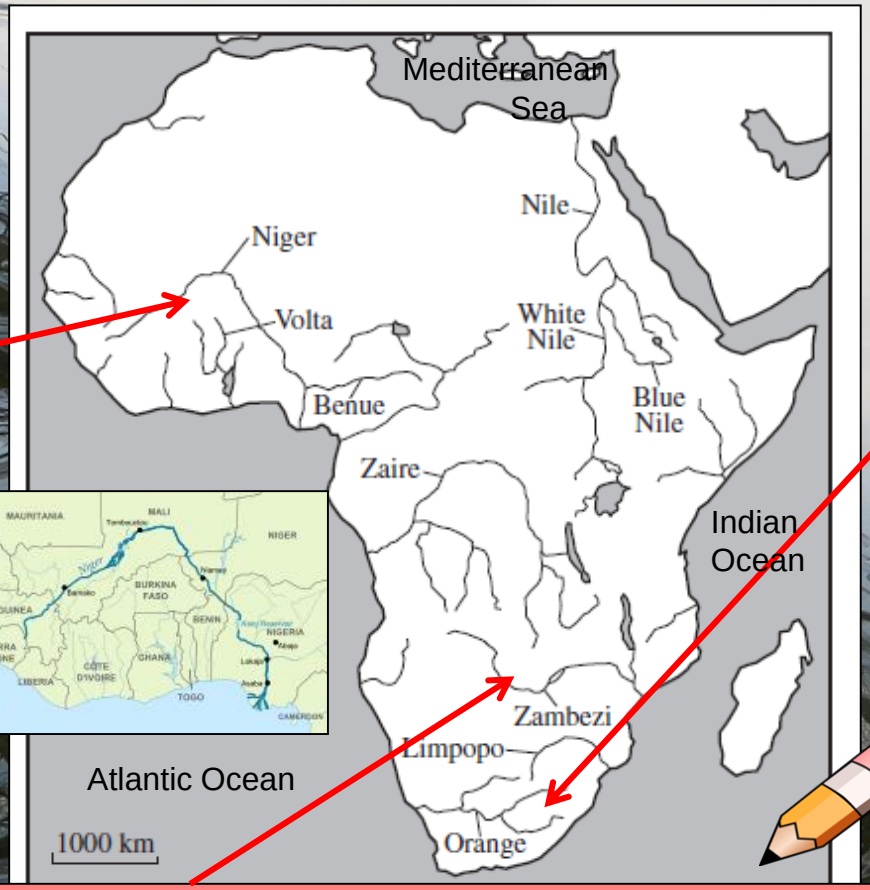
- The Nile
- The Congo
- The Zambezi
- The Orange
- The Niger

Their distribution is determined by the physical geography of the Continent, namely the relief.

Distribution of River Basins in Africa

The Mountains of Africa are the source of some of the continent's major rivers.

The Niger river rises in the mountains of Guinea and travels a peculiar boomerang shaped route (away from the sea and towards the Sahara). A consequence of the fact that the Niger River is two ancient rivers joined together. It finally enters the sea through its delta in southern Nigeria; it is about 2,600 miles in length.



The Orange River makes its way from the highlands in Lesotho in the east with its source 3,300 metres above sea level. Rainfall and snowmelt from the mountains add to its discharge. It flows westwards through the Kalahari depression to empty into the South Atlantic Ocean.

Annotate Your Map

The Zambezi river rises in a marshy region in north-west Zambia about 1,524 m above sea level. It travels through Angola where it accumulates more drainage, and re-enters Zambia again flowing south but substantially enlarged by the entry of various tributaries. In its lower course it flows into Mozambique and eastwards out towards the Indian Ocean,

The Congo River rises in the highlands of north-eastern Zambia at 1,760 metres above sea level. Its course then takes the form of a giant counter clockwise arc, flowing to the northwest, west, and southwest before draining into the Atlantic Ocean in the Democratic Republic of Congo

Annotate Your Map

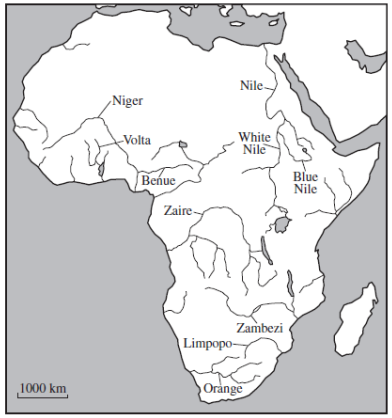
The Nile is a north-flowing river generally regarded as the longest river in the world at 6,853 km long. It has two major tributaries; the White Nile and Blue Nile. The White Nile is considered to be the source of the Nile itself. The Blue Nile, however adds most of the water. The White rises in the Great Lakes region of central Africa, It flows north through Tanzania, Lake Victoria, Uganda and Sudan. The Blue Nile begins at Lake Tana in Ethiopia and flows into Sudan from the southeast. The two rivers meet near the Sudanese capital of Khartoum. The Nile ends in a large delta that empties into the Mediterranean Sea.

Exam Type Question

(*a*) Study Maps Q3A, Q3B and Q3C.
For North America, Africa or Asia, **describe** and **explain** the general distribution of river basins. (6)

Map Q3A:
Major river basins of North America

Map Q3B:
Major river basins of Africa



Map Q3C: Major river basins of Asia

Answer Frame:

- Refer to the general patterns and number of rivers
- Describe their sources
- Explain their sources (link to rainfall and snowmelt in mountains for example)
- Describe their directions of flow
- Describe where their mouths are.

Check your answer

Description should include reference to the general patterns / numbers of rivers, and should refer to the directions of flow. Explanation should refer to the fact that drainage basins are determined by the location of the main continental watersheds and that major rivers rise in the main mountain ranges that have greater precipitation.

Example Answer:

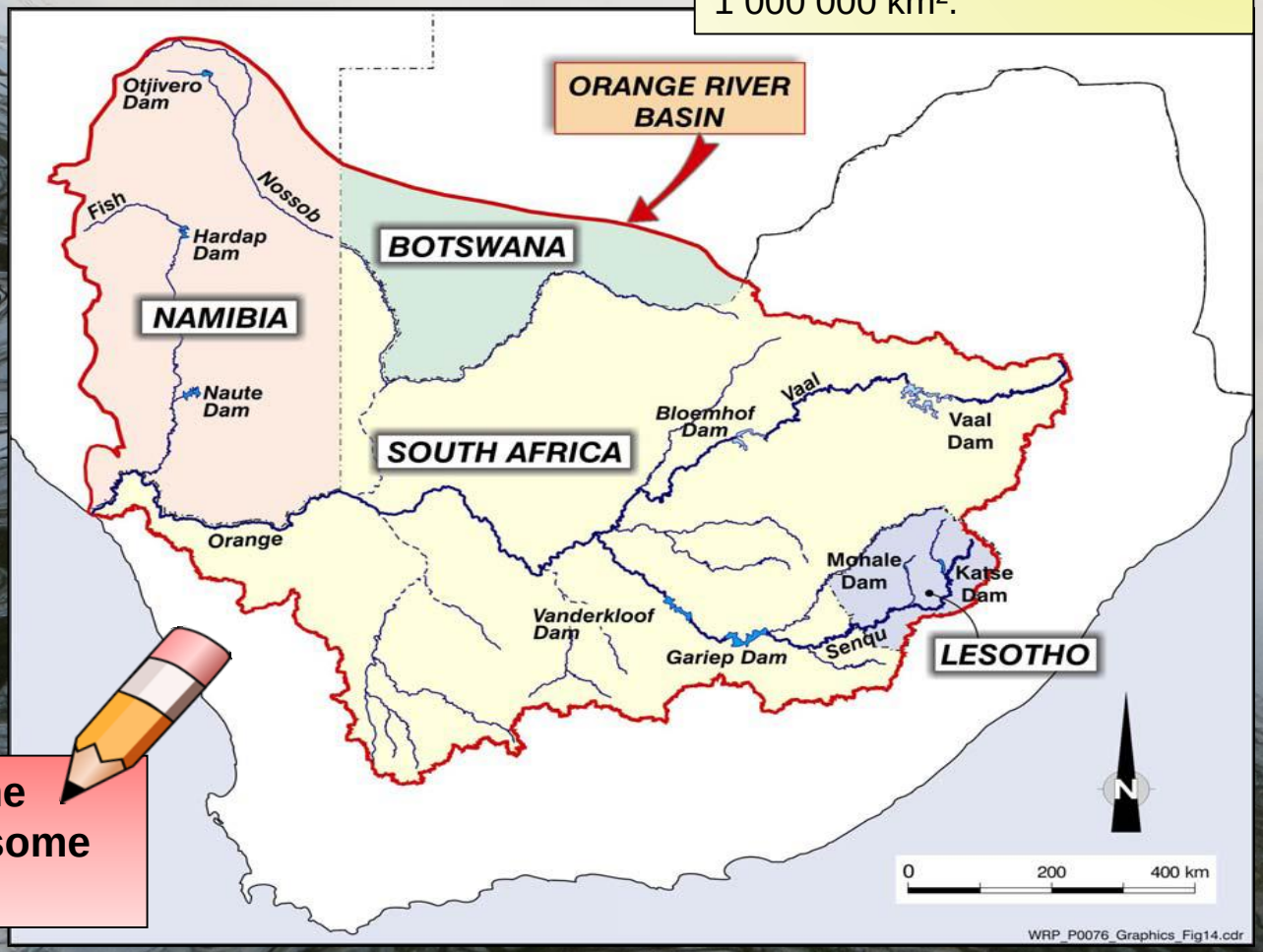
There are 5 major river basins in Africa, namely the Congo, Zambezi, Orange, Nile and Niger. Their distribution can be explained by relief. For example the Niger rises in the mountains of Guinea while the Orange River has its source in the Highlands of Lesotho. These mountainous areas collect lots of rain and snowmelt, hence why they are the source of Africa's rivers. Likewise the river Congo rises in the highlands of north-eastern Zambia at 1,760 metres above sea level. The Zambezi also has its source in a high marshy area in Zambia, the marshy ground giving rise to the river. The Nile river's source is different; it forms when two rivers join (The white Nile and Blue Nile). The White rises in the Great Lakes region of central Africa, where water from Lake Victoria develops the river. The major rivers are diverted in varying directions across the continent. The Nile has a general northerly flow, emptying out in a delta in the Mediterranean Sea. In contrast, the Zambezi flows from west to east outwards to the Indian Ocean. Other rivers like the Orange and Congo have a westerly route, flowing out towards the Atlantic Ocean. The Niger travels a peculiar boomerang shaped route (away from the sea and towards the Sahara) before flowing south and emptying out into the Atlantic.

Introducing The Orange River Basin

The geography of the river basin is varied. It includes the mountains of Lesotho, the semi-arid and arid landscapes of South Africa's Karoo and Richtersveld regions, and the deserts of southern Namibia.

The total river basin extends over four countries, **Botswana, Lesotho, Namibia, and South Africa,** and covers an area of 1 000 000 km².

64.2% of the basin falls within South Africa, 24.5% in Namibia, 7.9% in Botswana and 3.4% in Lesotho



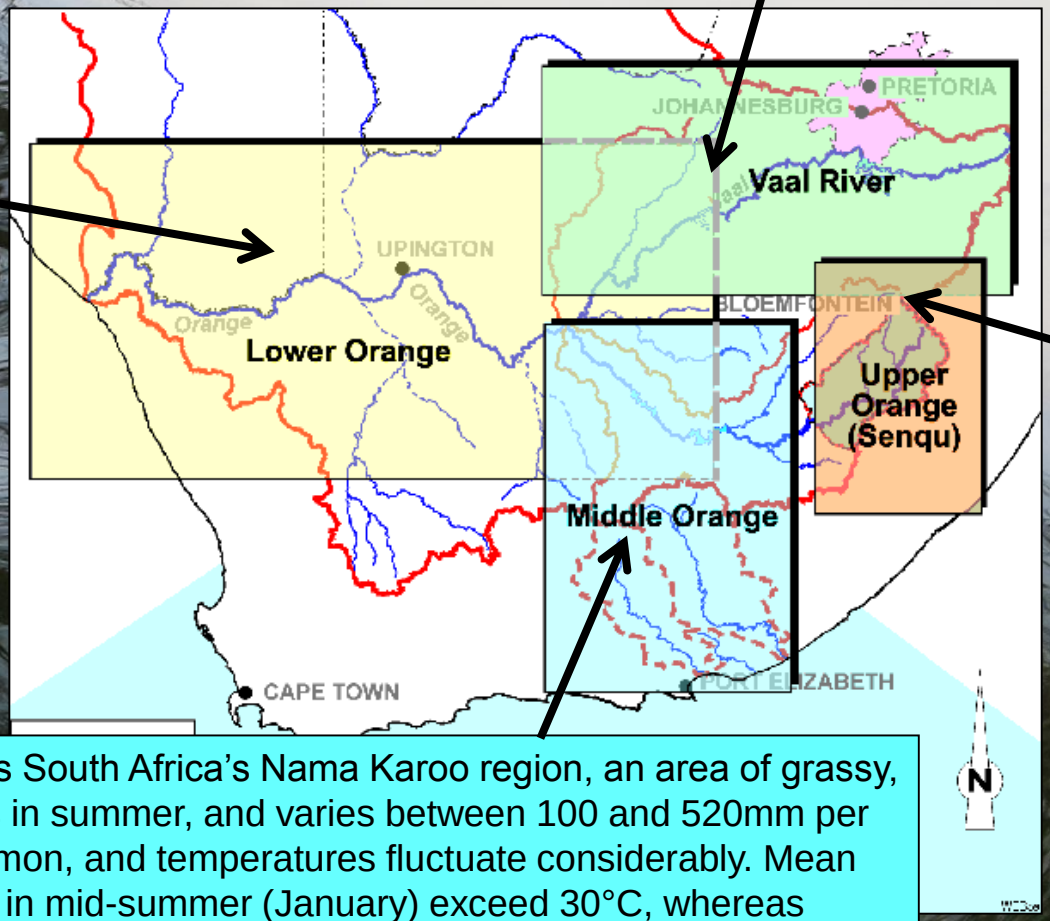
Glue in your copy of the map. Annotate it with some notes.

Physical Characteristics of the Orange River Basin

Landscape

The Vaal River drains most of the north-eastern portion of the basin. It originates on a plateau and drains much of the central area of South Africa. The mean annual rainfall varies from 400 mm to 800 mm. The basin has higher temperatures in the summer and high evaporation rates

The Lower Orange River comprises the Orange River from the confluence with the Vaal River to the Orange River Mouth. The river drains arid and semi arid areas. There is relatively lower rainfall as compared to most parts of the basin. The mean annual rainfall varies from 100 mm to 400 mm. Temperatures are warm throughout the year.



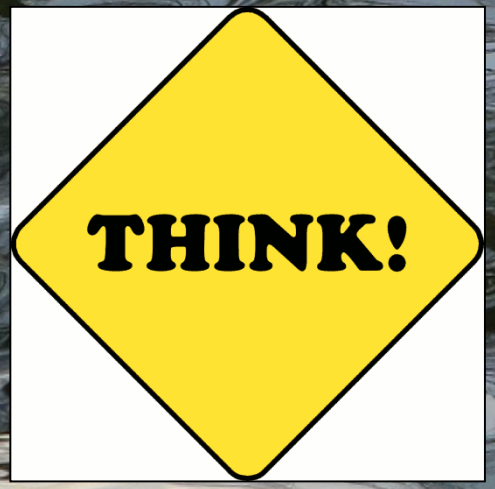
The Upper Orange Basin drains the mountains of Lesotho. The mean annual rainfall varies from 600 mm to more than 1000 mm. Snowmelt from the mountains adds to the river's discharge. In summer temperatures are warm, causing high evaporation rates.

The Middle Basin covers South Africa's Nama Karoo region, an area of grassy, shrubland. The rain falls in summer, and varies between 100 and 520mm per year. Droughts are common, and temperatures fluctuate considerably. Mean maximum temperatures in mid-summer (January) exceed 30°C, whereas mean minimum July temperatures are below freezing.

Physical and Human Characteristics of the Orange River Basin

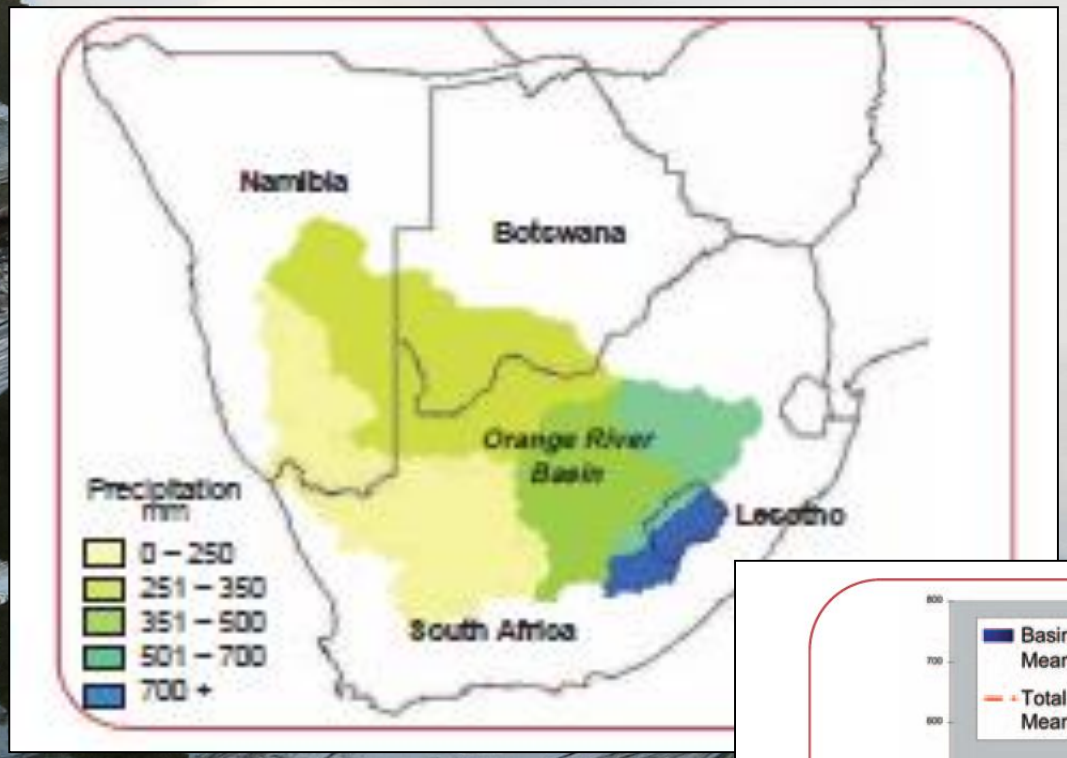
Collect a resource sheet

As we move through the next few slides, STUDY the relevant resources from your sheet, then annotate / make notes on the patterns shown and how they cause the need for river basin management in the Orange River Basin.



Rainfall

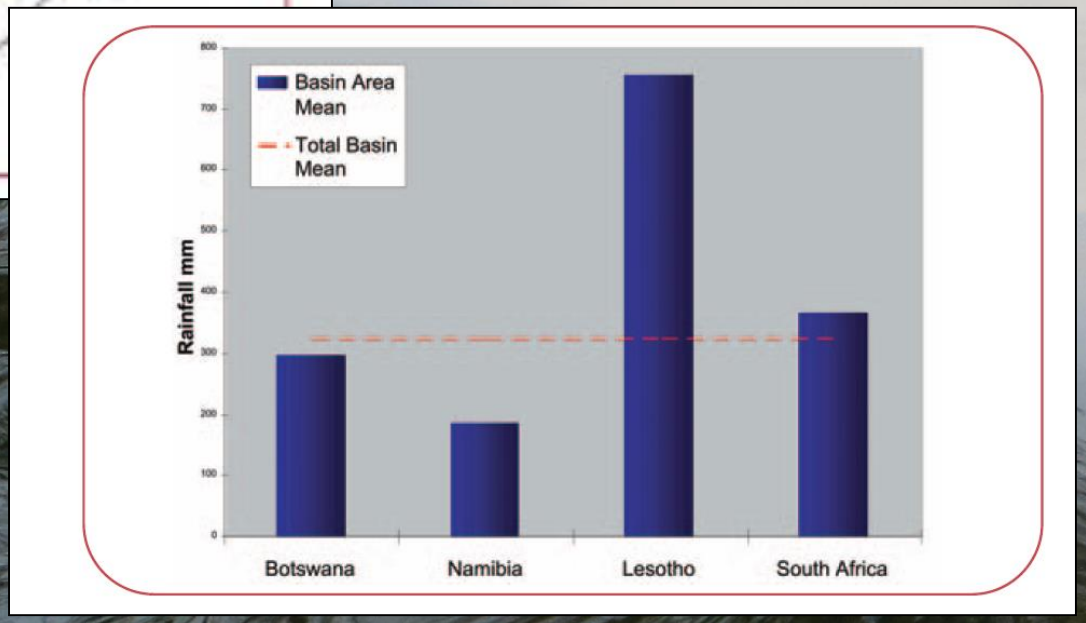
Rainfall variation in the Orange Basin



Describe the patterns shown on the map and graph.

How would these rainfall patterns cause the need for river basin management here?

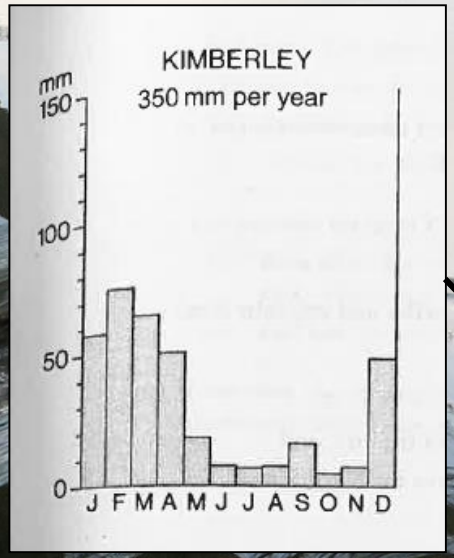
Average Rainfall Orange Basin Countries

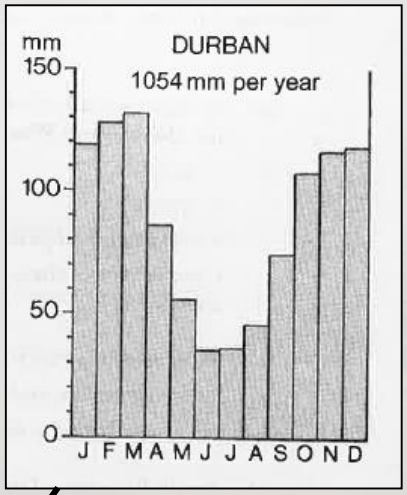


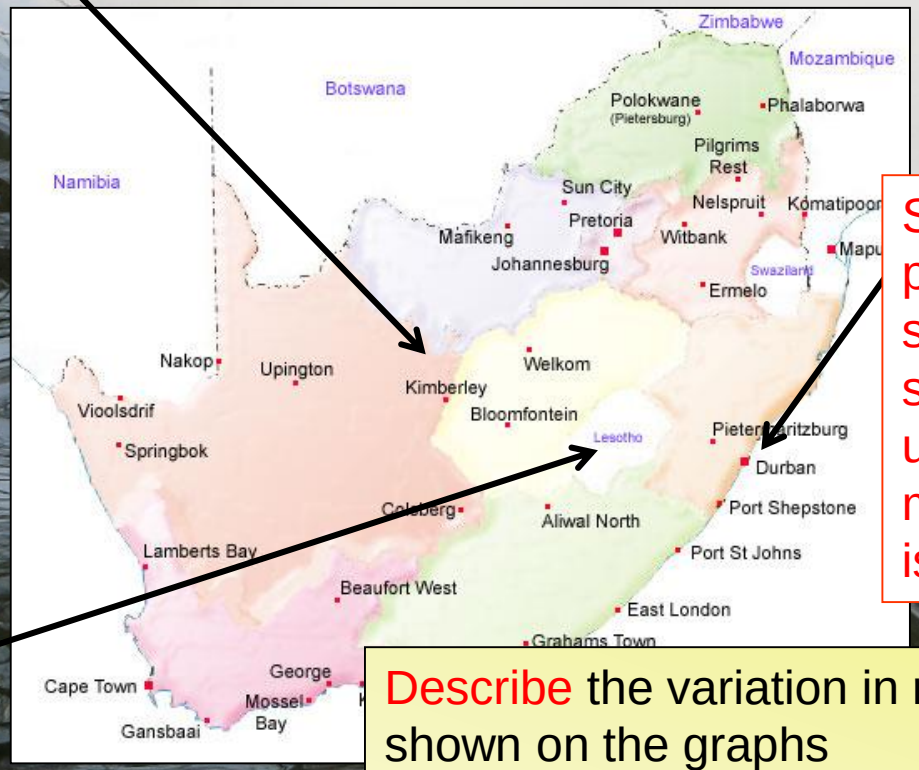
Rainfall varies across basin. Surplus areas and deficit areas exist. Water in surplus areas could be stored and used in deficit areas.

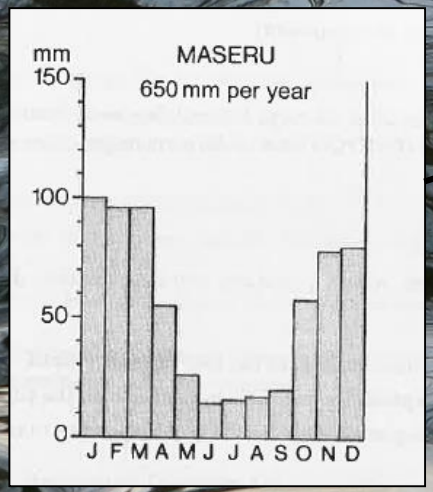
Risk of flooding In Lesotho. Dams would control this.

Rainfall graphs for selected cities in South Africa









Seasonal rainfall patterns. Need to store water in surplus months to use in the middle months when there is far less rainfall.

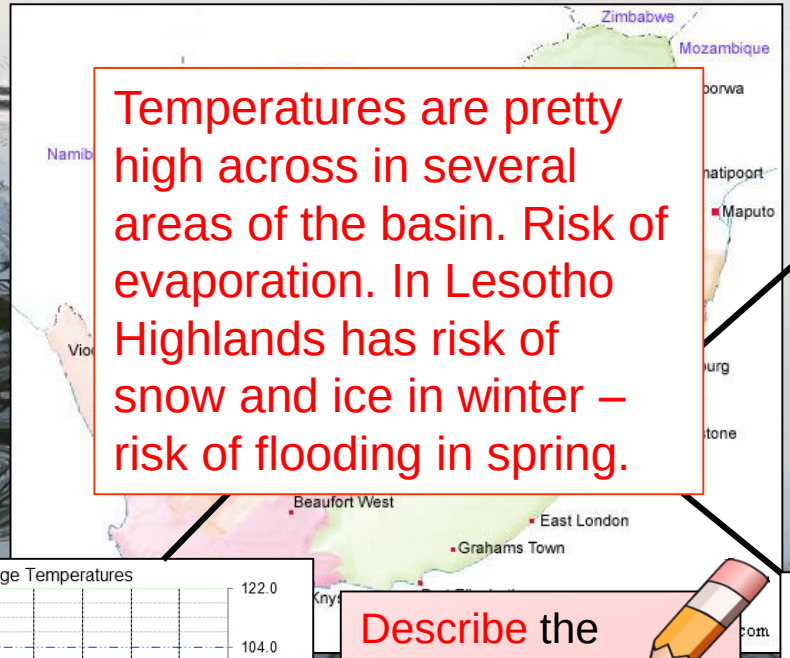
Describe the variation in rainfall shown on the graphs

Explain how these rainfall patterns cause the need for river basin management In South Africa?

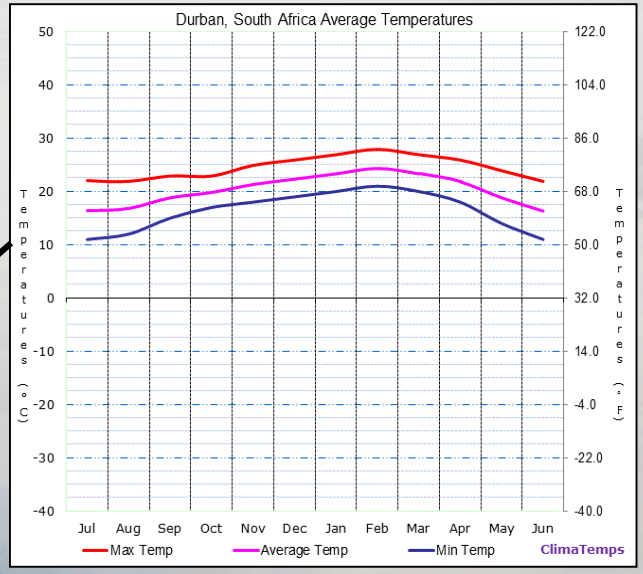
Temperature

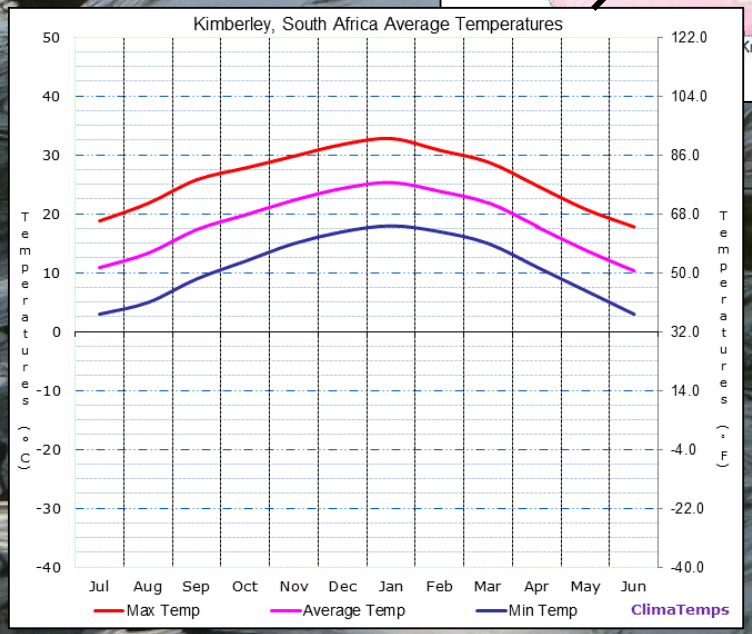
Average temperatures range from 12°C in the Lesotho Highlands to more than 22°C near the Orange River mouth. Extreme temperatures in excess of 50°C can be experienced in the lower Orange River in South Africa. Temperatures below –10°C are common in the winter months in the Lesotho Highlands.

Temperature data for 3 selected Orange Basin Cities



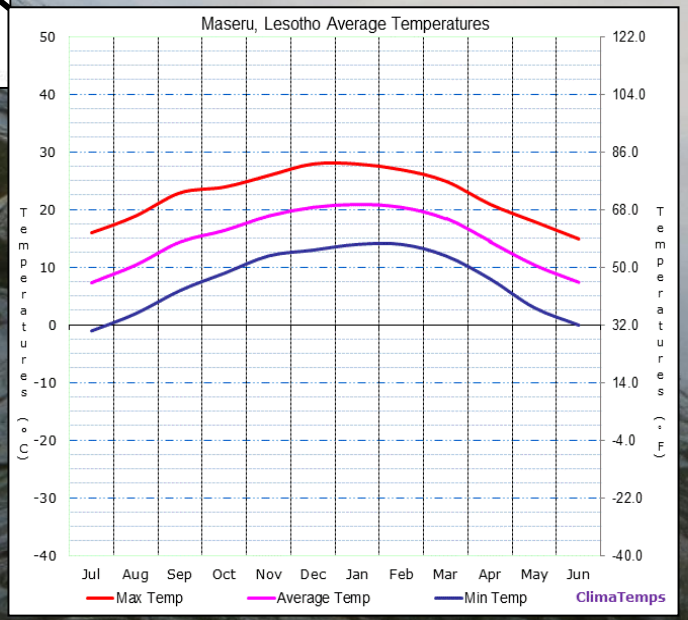
Temperatures are pretty high across in several areas of the basin. Risk of evaporation. In Lesotho Highlands has risk of snow and ice in winter – risk of flooding in spring.





Describe the temperature patterns shown on the graphs

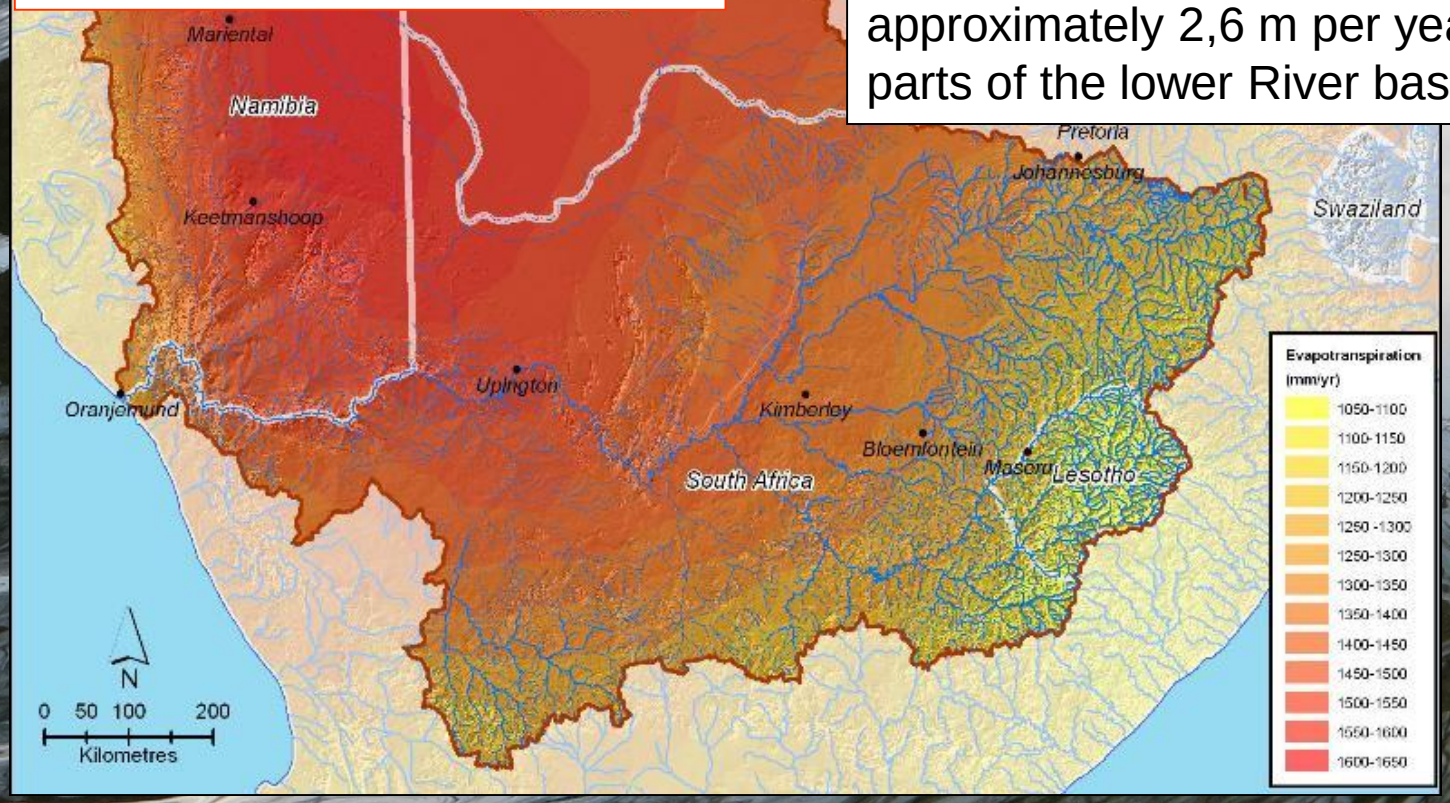
Explain how these patterns cause the need for river basin management in the Orange Basin



Evaporation

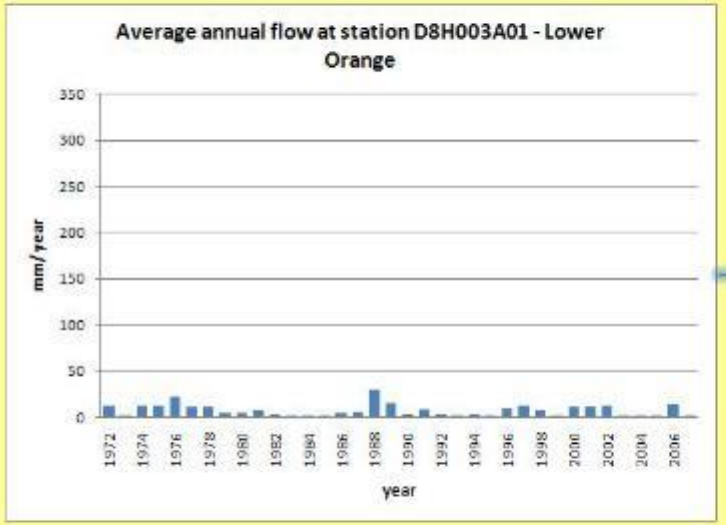
High average temperatures across most of the basin result in high evaporation rates, especially in the arid and semi-arid western basin. This, combined with low rainfall, results in an average water deficit of approximately 1,9 m per year in the middle reaches of the Orange River and approximately 2,6 m per year in the western parts of the lower River basin.

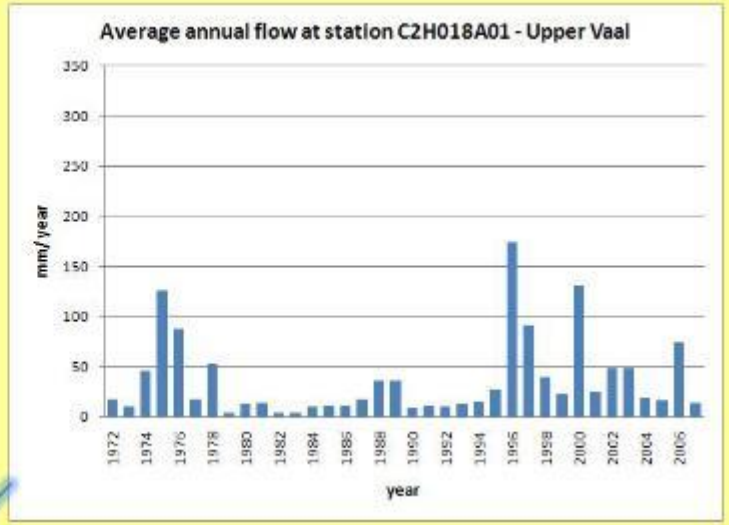
High evaporation rates across basin. Significant risk of water loss. Dams could help to store more water and reduce evaporation

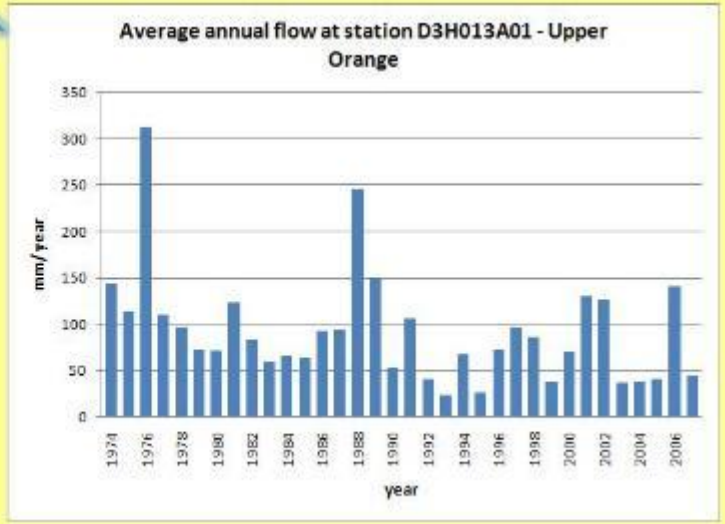


Comment on the pattern of evapo-transpiration rates shown on the map. Explain how this could cause a need for River Basin management

Discharge







Compare the river discharge patterns shown for the Upper and Lower Basins, as well as the Vaal River.

Explain how such varying discharge patterns would cause the need for river basin management in the Orange Basin.

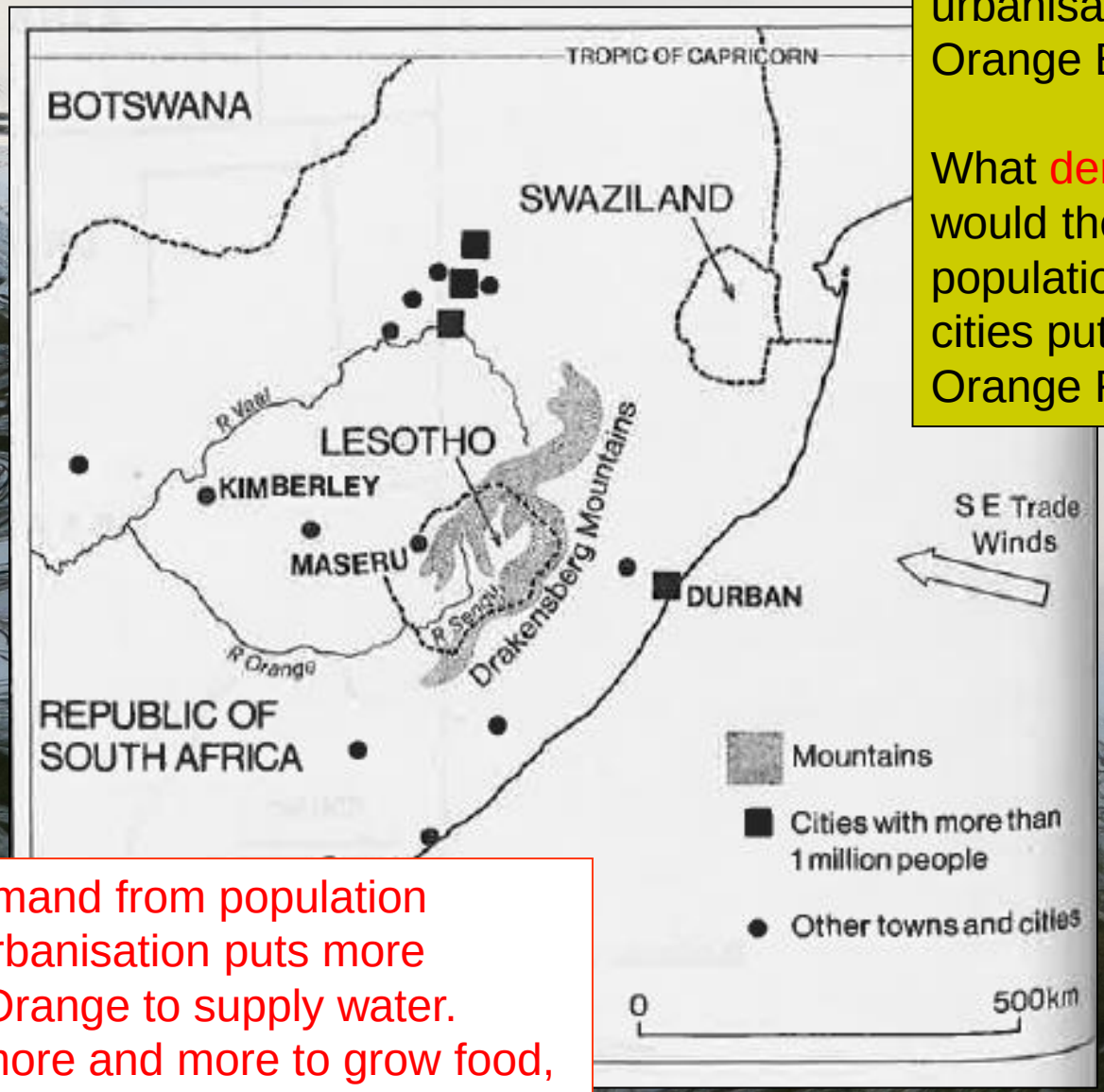
Varying discharge. Lower Orange has significantly less water, so could do with dams for storage. Other sections are highly variable. Dams could help to regulate discharge.

Demand

The population of the basin is about 19 million people

Throughout the basin there has been a trend towards increased levels of urbanisation

Several major cities now have populations of over 1 million people



Explain the high rates of urbanisation in the Orange Basin.

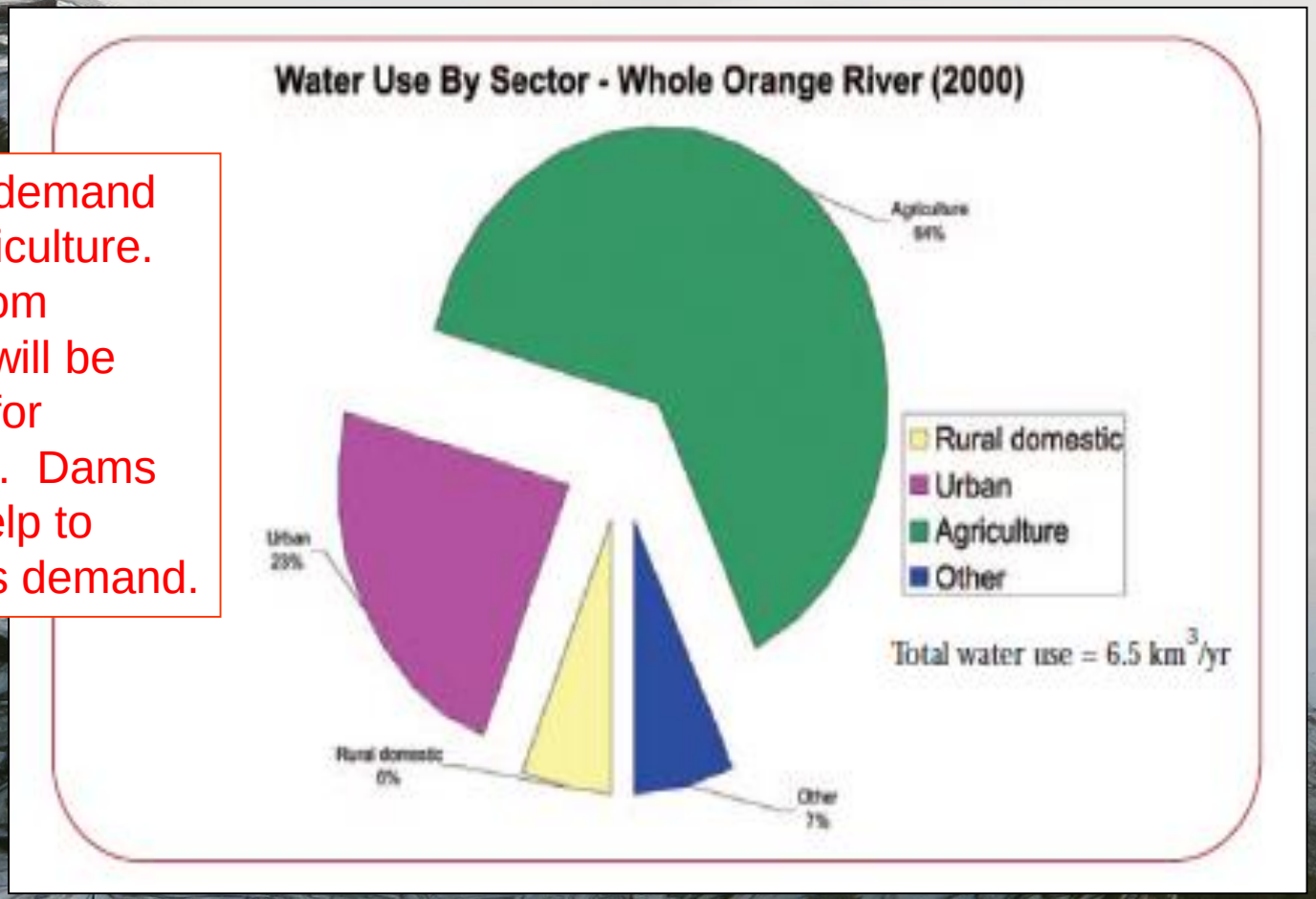
What demands would the population of these cities put on the Orange River?

Increased demand from population growth and urbanisation puts more pressure on Orange to supply water. Water need more and more to grow food, for domestic reasons and for industries.

Demand

Comment on the land uses that put demands on the Orange River's water supply. Which is the largest water user? Why? What will the water be needed for?

Highest demand from agriculture. Water from Orange will be needed for irrigation. Dams would help to meet this demand.



Example Exam Question

For a named river basin you have studied, explain the physical and human factors that have contributed to the need for river basin management (8)

Answer Frame:

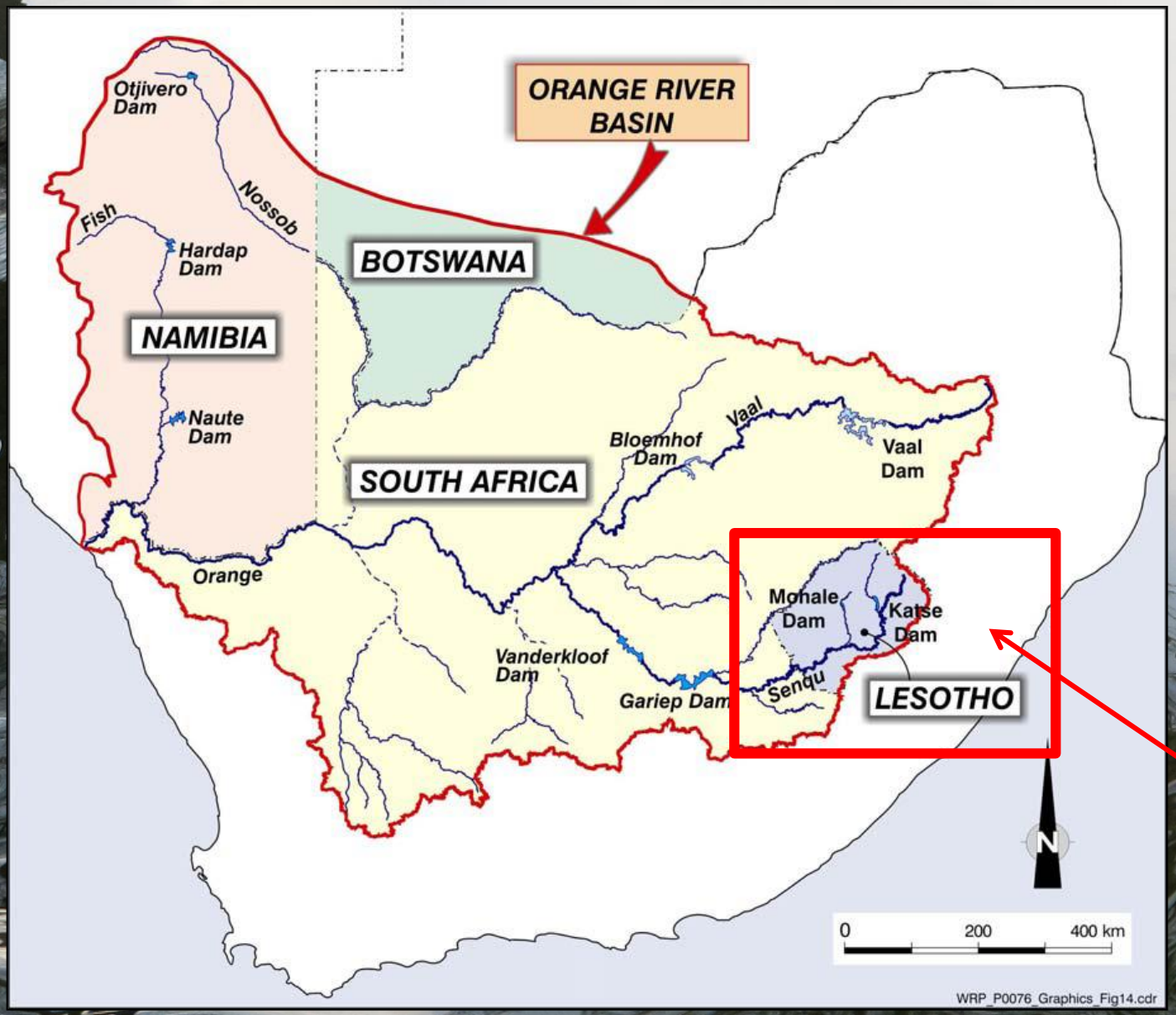
Physical Factors (the following should be explained):

- Snow melt in the mountains of Lesotho
- Semi arid and arid zones in the Mid and Lower Basin
- High temperatures and High evaporation rates
- Unreliable rainfall
- Variation in river discharge

Human Factors (the following should be explained):

- Shared demands from 4 countries
- Population growth
- Urbanisation
- Demands from domestic, industrial and agricultural use

River Basin Management in the Orange River Basin

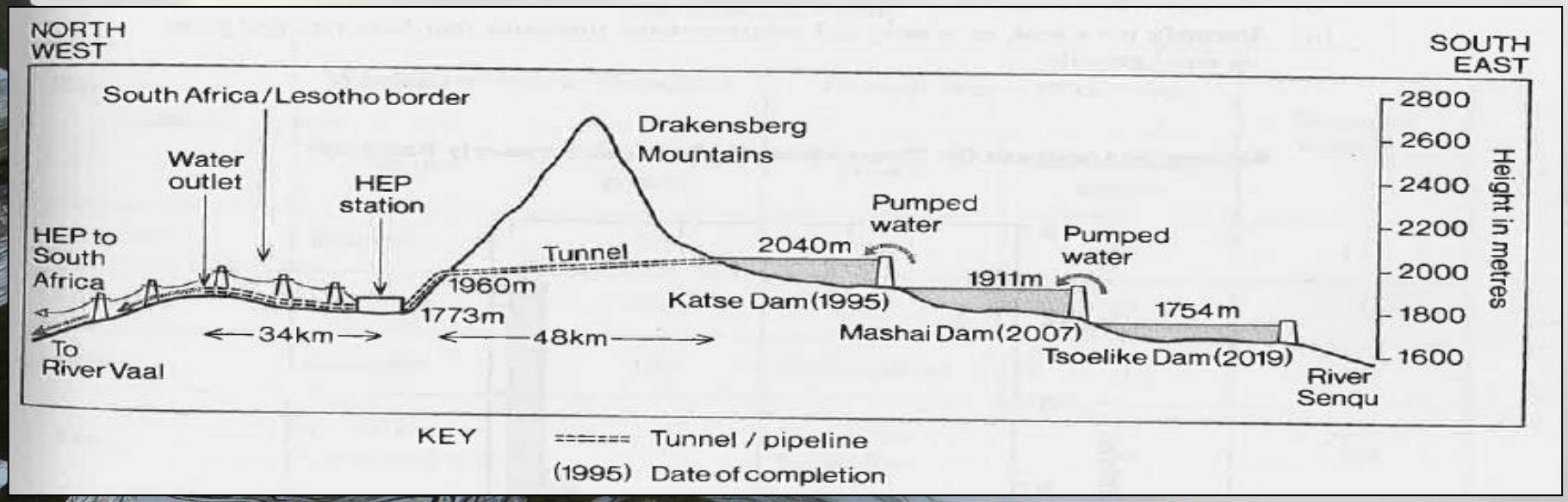


The Orange River Basin has been extensively controlled in order to store and manage its water supply.

The map shows **several of the major dams that have been constructed**, with more proposed for the future.

By far the most controversial project is the **Lesotho Highlands Water Project.**

The Lesotho Highlands Water Project



The **Lesotho Highlands Water Project** is an ongoing water supply project with a hydropower component, developed in partnership between the governments of **Lesotho and South Africa**. It comprises a system of several large dams (5 in total) and tunnels throughout the two countries.

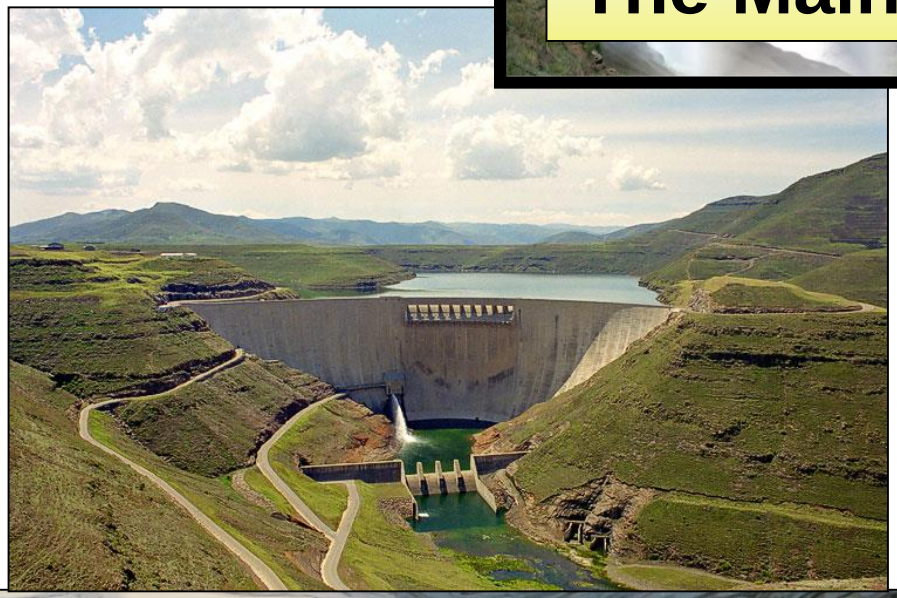
The purpose of the project is to provide Lesotho with a **source of income** in exchange for the provision of water to the central Gauteng province where **industrial and mining activity** occurs in South Africa, as well as to generate **hydroelectric power** for Lesotho

Describe the aims and purpose of the Lesotho Highlands Water Project

The Main Components

The Katse Dam:

Katse Dam is the highest dam in Africa at 185 metres. It forms the main collecting storage reservoir in Lesotho from which all transfers to South Africa are made through approximately 80 km of concrete-lined tunnels. The reservoir is very narrow, winding and deep, and exposes a surface area of 35,8 km^2 at maximum capacity. The total effective storage capacity is 1 520 Mm^3.



The Mohale Dam:

The Mohale Dam is located on the Senqunyane River immediately downstream of the confluence with the Jorodane River. The dam is approximately 145 metres high with a total capacity of 947 Mm^3.

The dam started to impound water in November 2002.

The Main Components

The Muela Dam:

The Muela Dam and Hydropower Plant. The Muela Dam is a double curvature concrete arch dam with a height of 55m. At Muela the water en route to South Africa powers an underground hydroelectric power station that generates electricity to supply the needs of Lesotho. Before the station was built, electricity had to be bought from South Africa.

The Polihali Dam :

The Governments of South Africa and Lesotho signed an agreement in August 2011 to build a second phase of the LHWP, with the construction of the Polihali Dam. The scheme will have the capacity for 2.2 billion cubic metre capacity and will include the dam itself, a tunnel to transfer the water, a pumped storage scheme and other associated infrastructure. The completion date is 2020.

A suitable area to build dams?

Think back to what makes a site **suitable** for dam construction. **Read** the statements below about the Lesotho Highlands Water Project. Use them to **evaluate the suitability** of this location for building dams. **Create a table with advantages and disadvantages as headings.**

More than 20,000 people lived in the area flooded by the Katse Dam, and another 7,400 in the area of the Mohale Dam.

Temperatures in the project area range from well below 0°C in the winter to 25-30 °C in the summer. At the Katse dam site, the temperatures fall below zero at night for prolonged periods in winter.

Lesotho is one of few African countries to see snow regularly

The entire project is expected to cost $8 billion, with Phase 1A at US$2.5 billion and Phase 1B estimated at $1.5 billion.

Mean annual rainfall, which varies from 600 mm in the lower Sengu valley to over 1000 mm on the Maluti Mountains, occurs mainly between October and April and averages 900 mm in the catchment area of the Katse dam.

Some 3,000 hectares of grazing land and 925 hectares of arable land have been flooded by Phase 1A. Phase 1B eliminated another 575 hectares of arable land – some of the best soils in the region – as well as 1,635 hectares of grazing land.

Although the highland region of Lesotho constitutes only about five percent of the total catchment area, it provides fifty percent of the total catchment run-off.

The dominant rock is igneous with patches of sedimentary rocks occurring towards the southern parts of the basin.

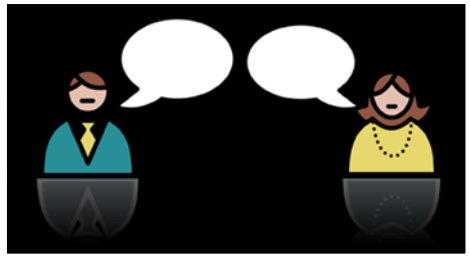
The reservoir formed by the Katse Dam is very narrow and deep with a surface area at full supply level of only 35,8 km². The small surface area together with the low evaporation rate at the dam result in very low evaporation losses from the reservoir.

The effects of Dam building

The dams of the Lesotho Highlands Water Project have brought about a number of benefits and consequences for the people and landscape of the region.

These can be categorised into Social, Economic and Environmental impacts

Pair and Share



What might some of these impacts be? How will the people, economy and environment be affected by the dams? Try to identify some positive and negative impacts

Click on the photo to watch a short clip

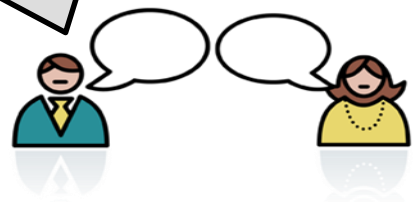
Your turn!

Take a **double page** in your notes. Draw a table like the one below.

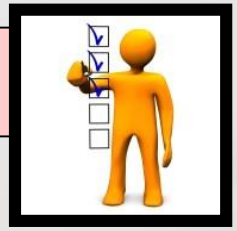
	Benefits	Problems
Social		
Economic		
Environmental		

Pair Up

Collect an envelope of statements about the LHWP's impact. Sort them out into the correct categories then write them into your table .



Check Your Answers



Social Benefits

The Project diverts the water in Lesotho to large South African cities like Johannesburg to ensure that its residents get a clean reliable water supply. This enables South Africa to meet water demands for domestic use and industrial use.

The infrastructure of Lesotho has been improved through the project. This has included the building of new roads and improvement of existing ones. 11 bridges have been built which help to improve access to Lesotho and between Lesotho and South Africa.

Social Problems

The reservoirs flood considerable areas of pasture which are used mainly in winter, when the higher ground is too cold for the livestock. This area also produces thatch grass, a scarce commodity in the mountains. The valley pastures are used mainly by livestock owners, who lose out on grazing land as a result of the reservoirs.

The influx of workers into the area to build the dam has had an impact on health. A widespread prevalence of Sexually Transmitted Diseases (STDs) and an increased likelihood of HIV/AIDS have been reported in the highland communities since the project started.

All the water from the LHWP is transferred to South Africa leaving the people of the Lesotho Highland region thirsty and without access to its use for irrigation.

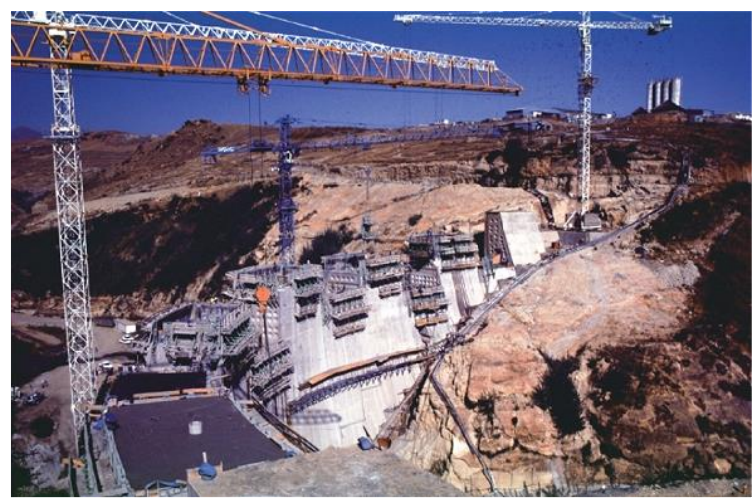
People have had to be resettled as the reservoirs have flooded their villages. Loss of dwellings is estimated at 598, with 24000 people being displaced. While compensation has been offered, locals complain that the compensation money is not enough to live on.

Rich prehistoric rock paintings and stone implements of archaeological importance are known to exist in the project area. It is expected that many of these will be lost because of the project.

Economic Benefits

7000 jobs have been created through this project so far. Some of these jobs went to the Basotho people who live in the region, bringing much needed income. This has enabled them to improve their standard of living.

One of the extra benefits of the construction of the Katse dam for example, was to be the creation of a recreational area. Katse has attracted some recreational visitors which brings in extra income to Lesotho.



The dams also generate hydroelectric power. Muela Hydropower Station takes advantage of the yield from the Katse Dam to generate electricity. Previously, Lesotho depended entirely on electricity imported from South Africa's state-owned energy utility. Muela Hydropower Station has a combined generation capacity of 72 MW. This generally meets Lesotho's electricity requirements.

The LHWP has had a profound impact on Lesotho's economy. In 1998 it accounted for 13.6% of Lesotho's GDP.

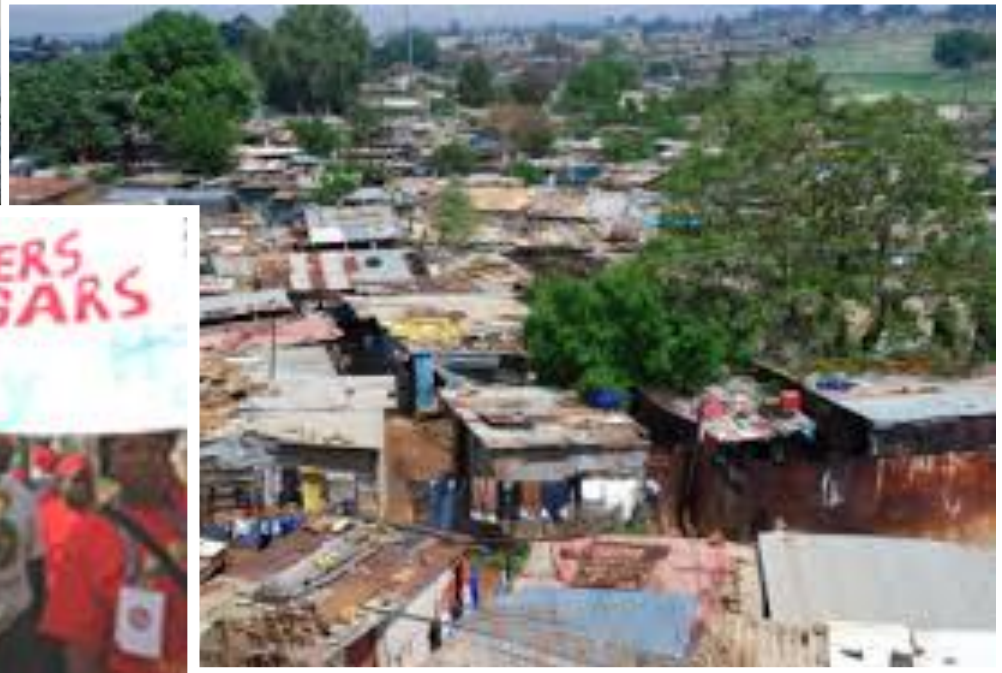
Lesotho Highland Development Authority (LHDA) has formulated a compensation policy which is designed to ensure an income stream over the life of the project, and to replace lost food crops and fodder production with food and fodder. Households losing arable land will receive the equivalent volume of food crops and grain for fifteen years to replace the loss of crops.

Economic Problems

A number of farmers lost their land as a result of the project and they have not successfully re-established their livelihoods. The surrounding mountains where people have been resettled have poorer soil so do not make for good arable land. Total loss of arable land as a result of the dams and reservoirs will be 4002 hectares, or one percent of total arable land.

The project has been very expensive. Official estimates put the total project cost at $8 billion.

Much of the water is wasted. Residents of Johannesburg's townships, the final consumers of LHWP water, collect water from apartheid-era systems that waste up to 50 percent of water piped to them.



Environmental Benefits

Large lakes like the Katse reservoir are thought to enhance the beauty of the area

The river's flow is much more consistent and reliable. The dams control and store the water which reduces the likelihood of flooding, especially after snowmelt.

Environmental Problems

Farmers are using the stored water for irrigation. The large-scale use of fertilisers by commercial agriculture in some parts of the basin leads to substantially increased levels of phosphates and nitrates in the river. These degrade the quality of the water for downstream users.

Earthquakes caused by the filling of the Katse Dam's reservoir have terrified local people for more than a year. Houses in seven villages beside the reservoir have been damaged by tremors, and in the village of Mapeleng, 11 houses were made uninhabitable by the quakes.

The relief of the construction region is steep and susceptible to high rates of soil erosion, and increased erosion is one of the effects of the construction work. The increase in soil erosion has started causing downstream dams to accumulate silt at a higher rate than before. The higher silt loads cause problems for the operation of the dams.

Wildlife habitats have been affected by the dams. Some species like the Maloti minnow and trout are reaching the point of extinction. There has however been an explosion in rodent populations, which could affect crops along the riverbanks.

Example Exam Question

Explain the positive and negative impacts of any named water management project.

In your answer you must refer to socio-economic **and** environmental impacts. **(10)**

An Answer Frame:

1) State you named river management project
2) Structure your answer sensibly i.e. with headings:

<u>The Social Benefits</u>

One of the social benefits is that large South African cities like Johannesburg gets a clean, reliable supply of water for domestic use (washing, drinking water)……..

<u>The Social Problems</u>

A social problem caused by the project is that as so much of the water is diverted to South Africa, the Lesotho residents don't get an adequate water supply leaving them thirsty and without access to its use for irrigation……

Political Issues

Four Nations, One river!

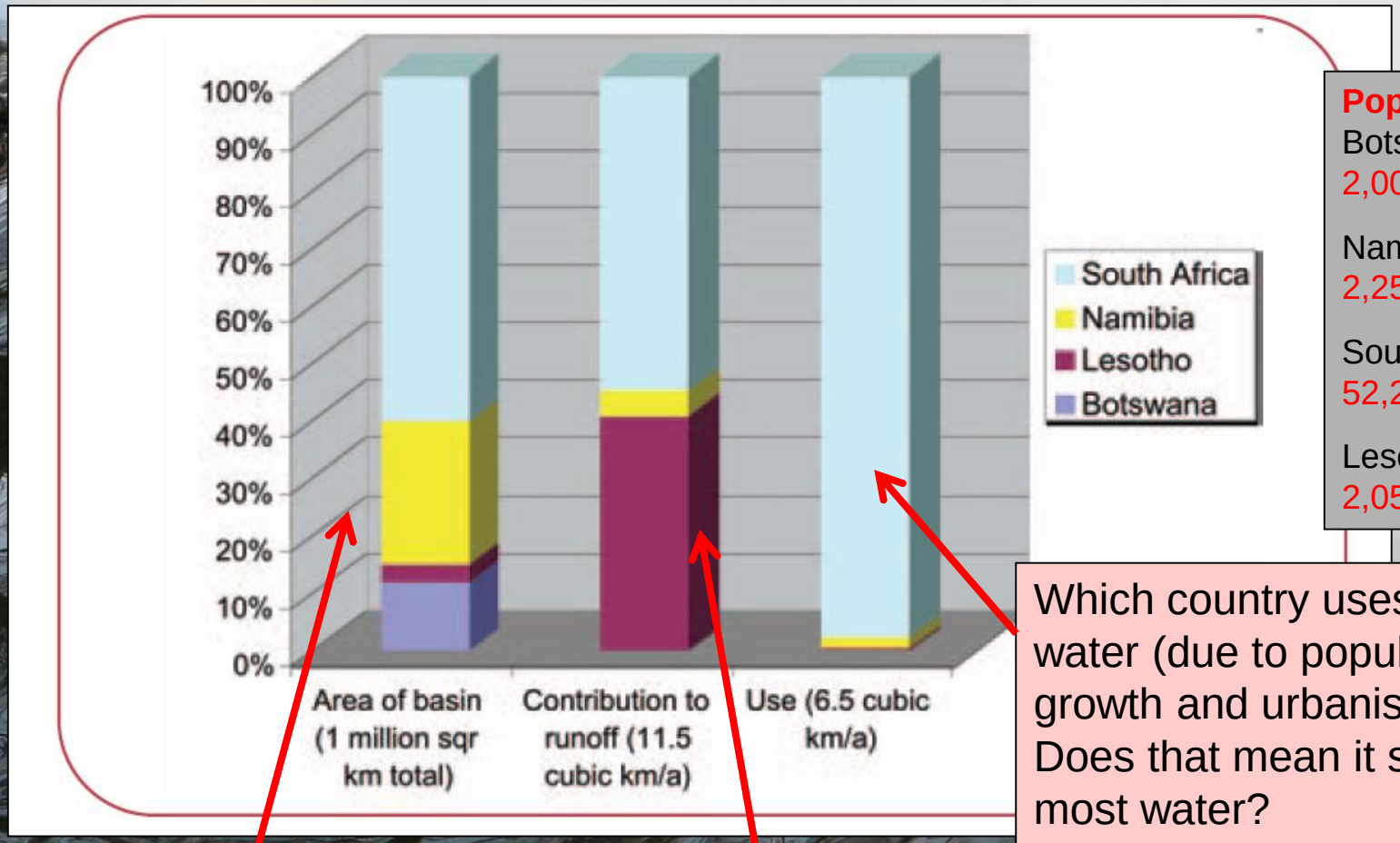
As with many other river basins in the world, the political issues of water management in the Orange River Basin arise from the fact that the river drains **4 Countries** (South Africa, Lesotho, Namibia and Botswana). Each has varying demands on the river's water supply, so questions arise as to how the water should be divided.

Questions to consider?

Which of the following factors should determine water allocation?

- **Should the country with highest population growth receive most water?**
- **Should the country with the largest % of land in the basin receive most water?**
- **Should the driest / most arid areas gain more water than those with wetter climates?**
- **Should countries which contribute most water through rainfall and run-off to the river receive most water?**

Study the Graph below. Comment on the patterns shown (using relevant statistics). In your opinion how should such patterns affect water allocation?



Population

Botswana
2,003,910

Namibia
2,259,393

South Africa
52,274,945

Lesotho
2,051,545

Which country uses most water (due to population growth and urbanisation)? Does that mean it should get most water?

Which country takes up the largest proportion of the basin? Does it deserve most water?

Which country contributes most water to the river? Does it deserve the biggest share?

Other Issues

Make some notes

Rainfall varies annually which affects river discharge, therefore any fixed political allocation of water can be difficult to achieve

Lesotho can't use the water from the LHWP. Many argue that as Lesotho has water in its midst, it should be able to use it. But this project was designed with the sole purpose of selling water to South Africa. If Lesotho wants to use that water Lesotho will have to buy it back. Lesotho being the developing country that it is will not be able to buy any of its own water.

Dams are hugely expensive and issues arise as to how much each country pays. South Africa wants Namibia to contribute to the full cost of the water from its infrastructure. At the moment Namibia is using about 50-70 Mm^3/a of water from the Lower Orange River. Presently, this water is allocated for free to Namibia.

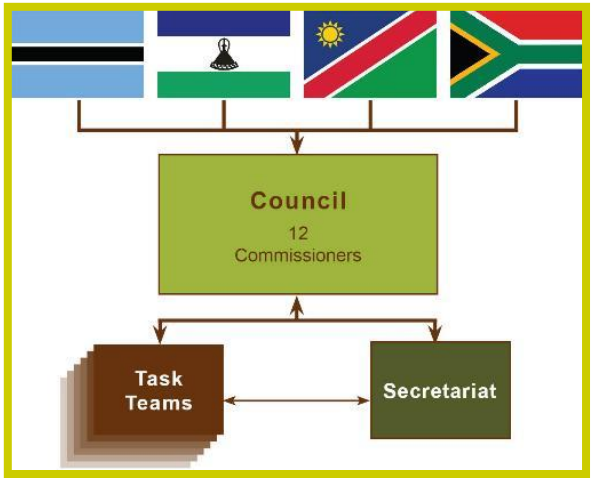
Agriculture, mining, and lack of sewage treatment facilities contribute to water pollution. The Orange river carries the pollution across borders. Namibia blames South Africa for the high pollution levels it faces in the lower basin.

Many argue that the agreement between Lesotho and South Africa to put in place the LHWP is presented as economic, when in fact the project was a political arrangement between the military government in Lesotho and the apartheid state in South Africa. There is a feeling that the stronger more powerful South African Government has excessive influence over the weaker Lesotho regime.

Namibia wants to discuss reduced flows and environmental quality concerns downstream due to the LHWP. However, South Africa sees its discussion with Lesotho as bilateral, thus refuses the participation of Namibia. Currently, Lesotho and South Africa, without the involvement of Namibia, are negotiating to divert up to 70 m^3/s from the Lesotho Highlands Project to South Africa for phase two 2. Namibia feels there is no trust and transparency in its negotiation with South Africa.

Political Issues: Solving the conflict

Water has played a unifying role in this region. In the year 2000, the first multi-lateral cooperation agreement through the Orange-Senqu River Commission (ORASECOM) was signed. Prior to that there had been only bilateral agreements between countries e.g South Africa and Lesotho. The ORASECOM agreement is seen as a major step towards international cooperation for the utilisation and management of the Orange River Basin. All four countries are involved in ORASECOM, even though Botswana has no direct benefit from it, it uses its involvement for political purposes, as well as the future need to obtain water from Lesotho. A Council oversees the agreement. It consists of delegates from each member Country.



Its aims:

- Develop a comprehensive perspective of the basin
- Study the present and planned future uses of the river system
- Determine the requirements for flow monitoring and flood management

ORASECOM is expected to strengthen regional solidarity and enhance socio-economic cooperation within the region.

ORASECOM
One River, Four Nations

Example Exam Questions

a) For any river basin management project **explain** the political problems that may have resulted from the project.

b) suggest ways in which these problems may be overcome.

(6)

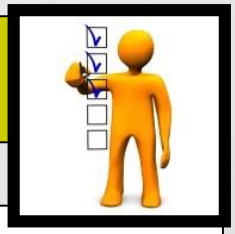
General Mark Scheme:

a) Problems might include:

•difficulties between states which are represented by different political parties
•sharing allocation of water rights
•changing needs of different states including increasing populations and increasing irrigation
•increased pollution and salinity downstream affecting water quality
•shared costs of purification and desalination plants
•impact of dam construction on consumers downstream
•relationship between neighbouring countries

b) These problems could be overcome by having political agreements e.g. the Colorado River Compact which divided up water allocations based on historical rainfall patterns. International agreements may be needed where different countries are involved.

Check your answers



a) In the Orange River Basin political problems arise from the fact that the river flows through four countries (Lesotho, Botswana, Namibia and South Africa). There can be conflict over how the water resource should be allocated. Should the country with the largest population (South Africa) get more water, or should the country that contributes most water through rainfall and run-off (Lesotho) get the largest share? Some argue that the country that has the largest area of land in the basin (South Africa) deserves most water. These decisions are made more difficult as rainfall varies annually which affects river discharge, therefore any fixed political allocation of water can be difficult to achieve.

There is a feeling that in building the Lesotho Highlands Water Project the stronger more powerful South African Government has excessive influence over the weaker Lesotho regime. Lesotho can't use the water from the LHWP and in future would have to buy its own water back from South Africa, which as a developing country would be difficult to afford.

Namibia in the lower basin gets reduced river flow as the water has been held back in dams. It also suffers water pollution which is carried downstream from agricultural and urban areas in South Africa. Namibia wants to discuss these issues but South Africa sees its discussion with Lesotho as bilateral, thus refuses the participation of Namibia.

At the moment Namibia is using about 50-70 Mm^3/a of water from the Lower Orange River. Presently, this water is allocated for free to Namibia. However, dams are hugely expensive and South Africa wants Namibia to contribute to the full cost of the water from its infrastructure.

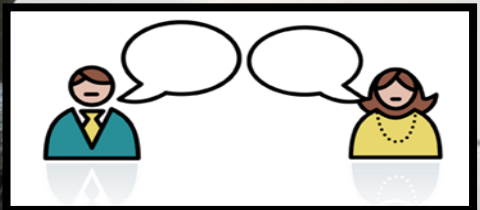
Check your answers

b) Solving these problems can be achieved through the countries involved forming water treaties where they get together and agree the allocation of water.

This has happened in the Orange River Basin where in the year 2000 the four countries signed a multi-lateral agreement called the ORASECOM agreement to establish guidelines and policy in dividing up and utilising the water resource.

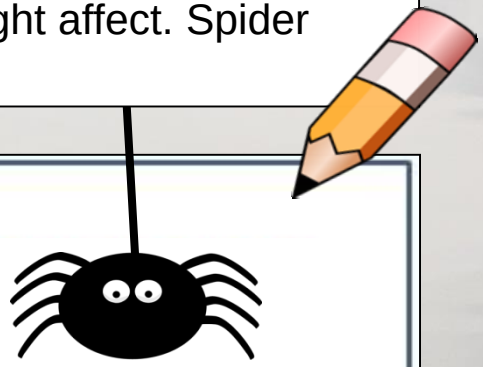
The agreement ensures that the countries consult and cooperate with each other over their use and management of the Orange River. It has led to increased unity between the countries in the Orange Basin.

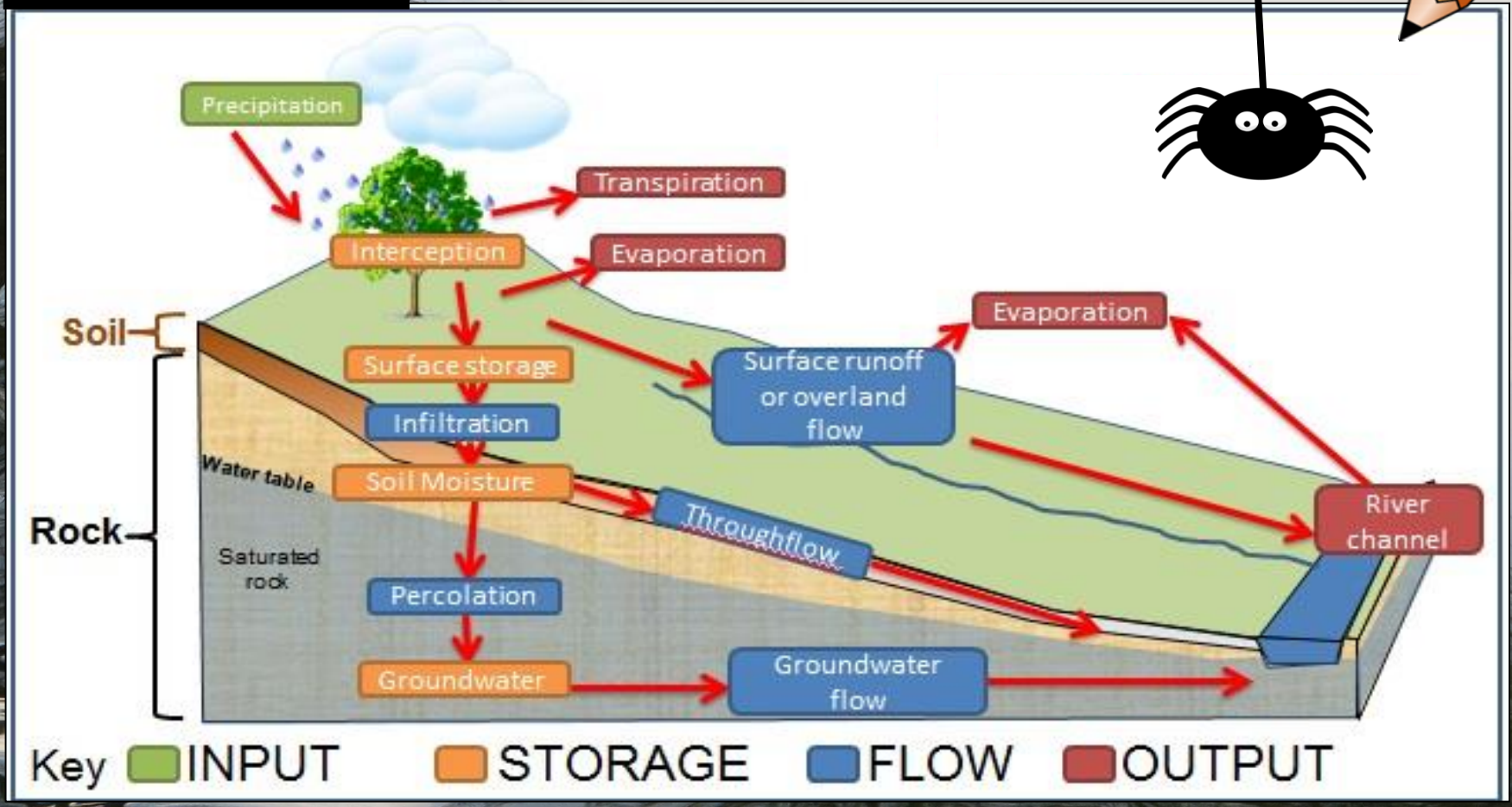
How do Dams Impact on a Drainage Basin?



Pair and Share

Think back to the **Hydrosphere Unit.** Discuss how building dams could impact on a drainage basin. Think about the **processes, stores and outputs** that it might affect. Spider Diagram your ideas.





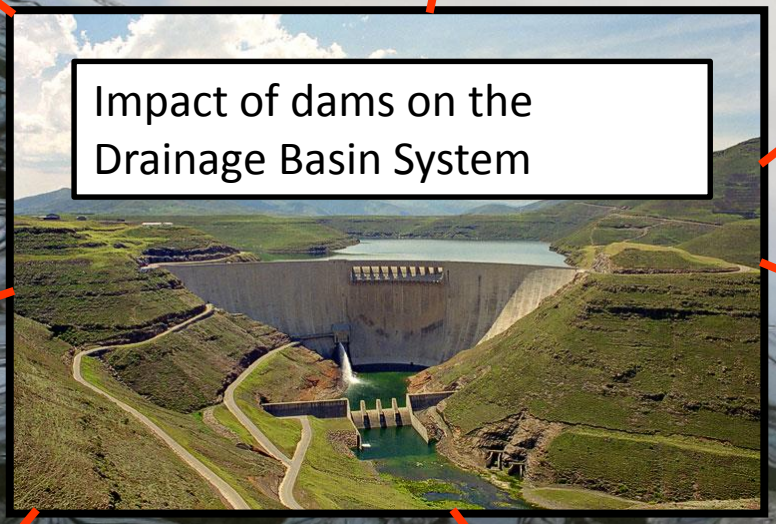
Did you come up with these?

Seasonal variations in river discharge and levels will be altered.

The volume of water reaching the river's mouth may be significantly reduced

Surface run-off is reduced, with less water flowing in the river below the dam and therefore into the sea.

Reservoirs may develop their own microclimates, possibly keeping surrounding land cooler or even increasing precipitation amounts.



Infiltration rates into the ground may change, as a result of the vast amounts of water held in reservoirs.

There will be more evaporation from the surfaces of reservoirs.

There will be more surface storage as dams hold many cubic metres of water in storage