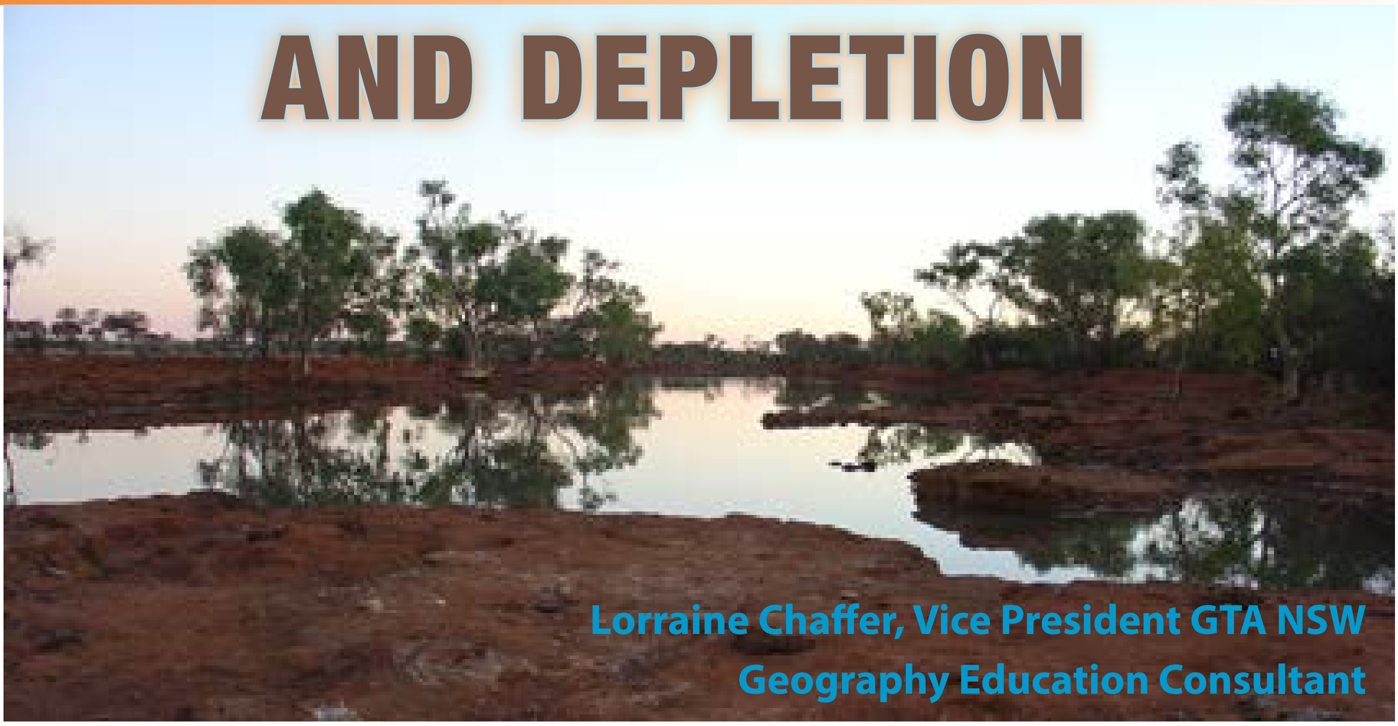
GROUNDWATER RESOURCES AND DEPLETION



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SYLLABUS LINKS

CONTENT:

Water in the world

- the characteristics and spatial distribution of global water resources
- how the operation of the water cycle connects people and places
- the quantity and variability of water resources – Australia and other places

(http://syllabus.bos.nsw.edu.au/hsie/geography-k10/content/1185/)

Also relevant to and connected with the following units in stage 5

Sustainable biomes

The depletion of groundwater for agricultural production can impact on biome productivity and functionality, and contribute to water scarcity and food insecurity in groundwater dependent countries.

Environmental change and management

Groundwater dependant ecosystems (environments) are threatened by groundwater depletion. Groundwater management to maintain groundwater to surface water links is essential for sustainable environmental management.

CONCEPTS

Aquifer – a body of permeable rock which can contain or transmit groundwater.

Biodiversity hotspot – a region with 1500 endemic plant species that have lost at least 70% of their habitat

Groundwater Dependent Ecosystems (GDE) use groundwater as part of their survival varying from partial to complete dependence to maintain their communities of plants and animals, ecological processes and ecosystem services. GDEs include caves, lakes, wetlands, rivers and vegetation.

Recharge Groundwater – recharge occurs where water moves downward from surface water to groundwater. Recharge is the primary method that water enters an aquifer.

Groundwater resources and depletion

Groundwater makes up 98% of earth's limited freshwater resources but is being depleted and contaminated at an unsustainable rate with serious consequences for:

- *Global freshwater supplies*
- *Environmental health* of aquatic environments such as rivers and wetlands and small Water Dependent Ecosystems
- *Human wellbeing* including future water and food security.

Threatened groundwater resources

NASA satellite analysis of alterations to earth's gravitational pull caused by large water storages is being used to accurately determine changes to groundwater basins due to natural and human processes such as drought, irrigation and domestic use. The data shows that 21 of Earth's 37 largest aquifers exceed sustainability tipping points resulting in depletion with 13 significantly stressed. GRACE (the Gravity Recovery and Climate Experiment) estimated a loss of 20.3 cubic kilometers of groundwater in California's Central Valley between 2002 and 2013 and 54 cubic kilometres in Northwest India where 54 trillion litres of water are extracted annually. In Bangladesh, groundwater levels below Dhaka fell by 35 metres between 1996 and 2007 due to excessive water withdrawal for the city's growing population and water hungry textile industries. By 2015 the water table had dropped to 70 metres below the city. **See Source 1 and Source 6**

Processes and connections

Groundwater is a part of the hydrological cycle. Biophysical processes determine the amount of groundwater in storage and connections to aquatic environments. These include

- *Infiltration* of rainfall or snowmelt, which is influenced by factors such as groundcover, rainfall intensity, precipitation and the presence of porous and permeable soil and rocks.
- *Recharge* from rivers and streams that occurs when the water table falls below river levels. **See Source 2**
- *Recharge* from groundwater into rivers, streams, lakes and wetlands when water levels in those environments fall below the water table
- *Underground flows* that transfer groundwater from mountain regions to oceans
- *Groundwater dependant ecosystems* (GDE) include aquifers, rivers, floodplain and riparian wetlands; karst cave systems and mound springs such those along the Australia's Great Artesian Basin which support high levels of endemic biodiversity and sacred and cultural sites for Aboriginal peoples. Without groundwater many plants and animals would not survive periods of extended drought.

Groundwater is stored in unconfined **aquifers** consisting of porous sediment and rocks and confined aquifers trapped between **impermeable** layers of rock at deeper levels, referred to as "fossil water". Aquifers become depleted if water is extracted at rates that exceed the recharge rate (known as overdraft). The average recycling time for groundwater is 1,400 years with some aquifers taking centuries to recharge, allowing pollutants to accumulate because unlike rivers, groundwater is not flushed by precipitation events. See Source 3

Increasing depletion

The crisis facing groundwater storages include

- *Depletion* due to excessive withdrawal of water for domestic, urban, agricultural and industrial use particularly in places with low or variable rainfall and with water supply systems inadequate to meet human needs eg India and Mexico City
- *Reduced recharge rates* due to urbanisation covering Earth's surface with hard impervious surfaces
- *Contamination* by pollutants from natural and human sources such as arsenic containing rocks, landfill sites, industrial and agricultural runoff and overuse of chemical fertilisers and pesticides.
- *Climate change* which affects environmental processes such as infiltration and recharge rates and sources of water for human use

The environmental consequences of groundwater depletion and pollution include ground subsidence, saltwater intrusion into coastal aquifers and wetlands, reduced river flows and loss of GDE, habitats and biodiversity. In Arizona, USA 90% of desert streams are degraded or dried up and flora and fauna species in the **biodiversity hotspot** of South West Western Australia are threatened due to groundwater extraction on the Swan Plain. See Source 4

Management and conflict

The sustainable management of groundwater resources is difficult as many aquifers underlie multiple drainage basins and political boundaries. It also requires accurate assessments of groundwater storages to balance the competing social, economic and environmental demands. Strategies at a national, catchment or groundwater basin scales could include:

Groundwater resources and depletion

- Legislation to create management agencies and set goals
- Groundwater budgeting to ensure extraction does not exceed recharge
- Extraction limits such as the Basin Plan for Australia's Murray Darling Basin which will caps water withdrawals from aquifers from 2019
- Artificial recharge of depleted aquifers as is occurring in many countries including Egypt, Argentina, USA and Australia.
- Scientific monitoring to determine accurate groundwater levels (NASA)
- Water efficient irrigation
- Contamination prevention
- Education programs

As a response to three years of drought and escalating groundwater depletion, California enacted its first Sustainable Groundwater Management Act in 2014. The target is to achieve sustainable groundwater use by 2042 by requiring agencies to develop management plans and implement strategies such as metering, extraction limits and water fees. A large number of groundwater conflicts are a reflection of the environmental impact of California's groundwater depletion on GDE and biodiversity. **See Source 5**

Managed aquifer recharge

Managed aquifer recharge is the intentional recharge of water to aquifers for water resource recovery or environmental benefit. Water from different sources can be used in the recharge process including creeks and rivers, stormwater and treated wastewater. If wastewater is used public health considerations are addressed by the pre treatment of water to remove pathogens and threats to human health.

In Western Australia the groundwater replenishment scheme in Perth, recharges high quality recycled water into the ground to guarantee the city's future drinking water

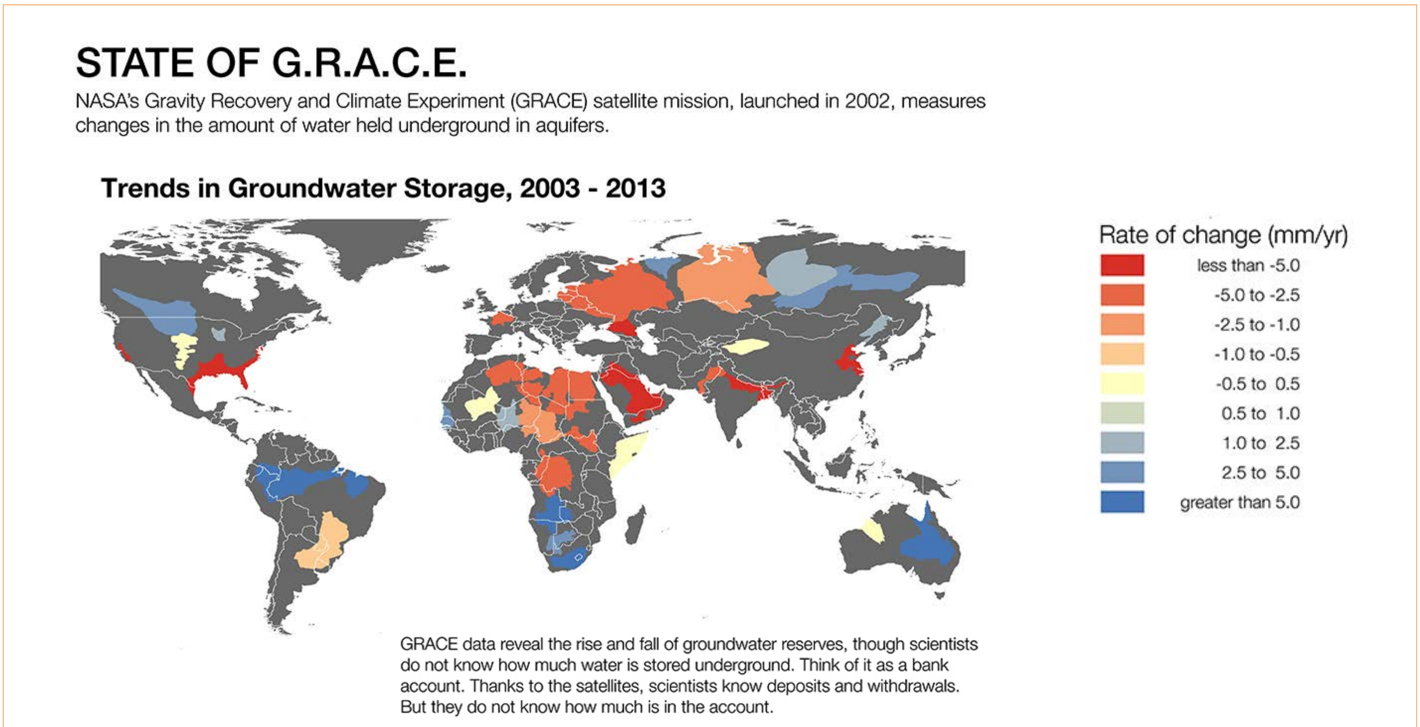
The benefits of using managed aquifer recharge to recycle water include:

- Creating water supplies from sources usually wasted
- maintaining wetlands and other WDE such as spring mounds
- storing water to meet future needs or for periods of drought
- reducing salt-water intrusion along coasts
- increasing water availability for individuals, businesses, agriculture and the environment
- supplementing drinking water resources

See Source 7

SOURCE 1: Groundwater storage trends in Earth's largest aquifers

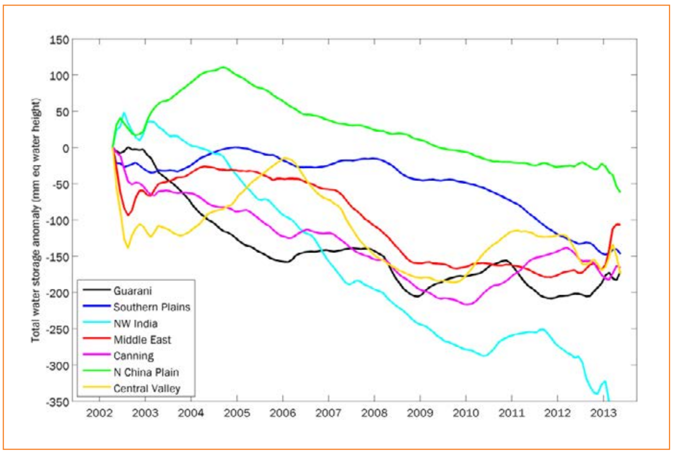
MAP: Trends in groundwater storage



Source: http://www.circleofblue.org/waternews/2015/world/groundwater-depletion-stresses-majority-of-worlds-largest-aquifers/

Groundwater resources and depletion

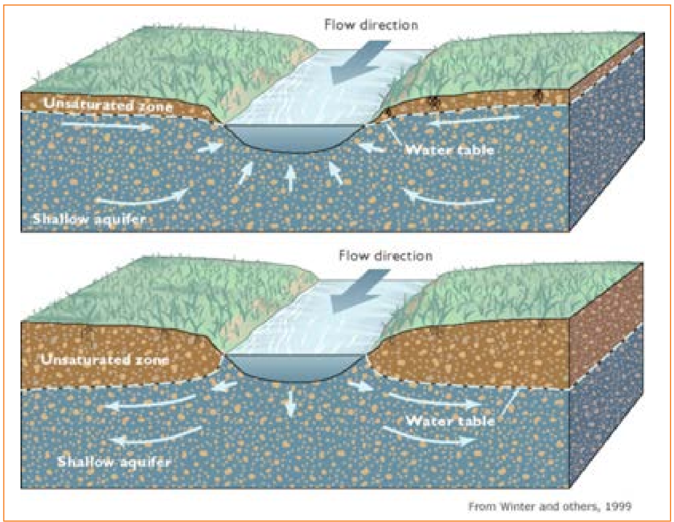
Graph: Trends in groundwater storage



Source: http://www.circleofblue.org/waternews/2014/commentary/editorial-in-the-circle-fresh-focus/earths-major-aquifers-trouble/

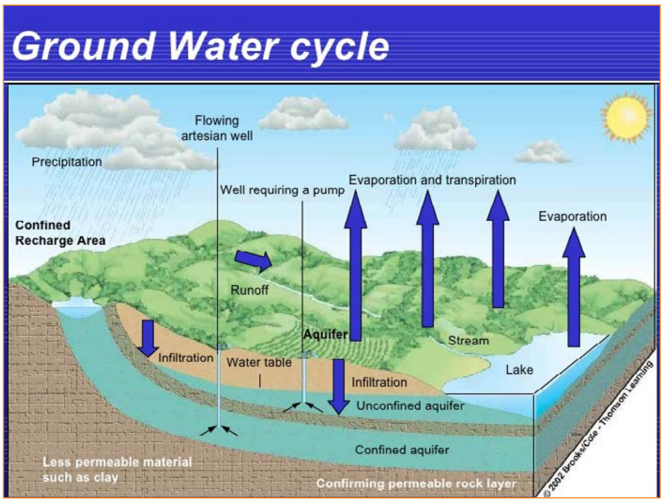
Gathering groundwater samples on a beach. CSIRO ScienceImage 201. Source: Wikimedia Commons

SOURCE 2: Groundwater – surface water connections



Source: http://coloradogeologicalsurvey.org/apps/wateratlas/chapter2page4.html

SOURCE 3: Aquifers are an important source of water



From Water pollution in Pakistan Slideshare – http://www.slideshare.net/hassanahmedkhan/water-pollution-in-pakistan

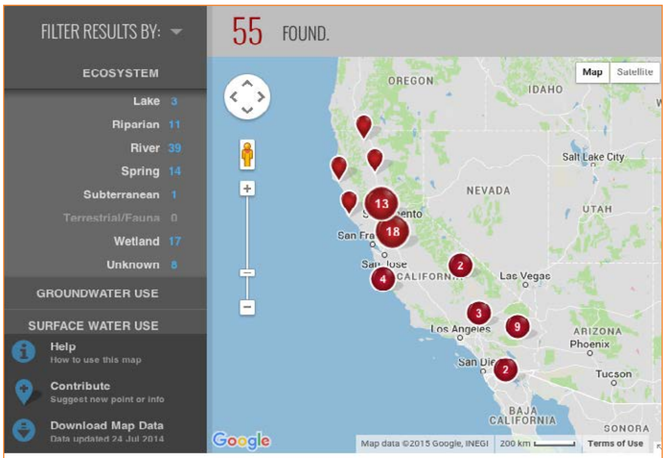
SOURCE 4: Depletion of groundwater is a global issue

13 of the planet's 37 largest aquifers studied between 2003 and 2013 were being depleted while receiving little to no recharge (NASA)	China's Yellow River fails to reach the sea for months at a time due to groundwater depletion and failure of aquifers to recharge rivers	54% of India's groundwater wells have declining water levels with 16% losing over 1 metre per year because there are no limits on groundwater extraction
Over 2 million people worldwide rely on groundwater as their primary source of fresh water for daily survival	Mound Springs around Lake Eyre, SA support rare and endangered species of flora and fauna prone to extinction if groundwater levels fall	Salt water has been detected in groundwater wells up to 8km from the California coast as a result of over pumping of coastal aquifers
In the UAE 65% of water use comes from groundwater resulting in extraction 20 times greater than natural groundwater recharge	If extraction from the Ogallala Aquifer in the Central Plains of the USA continues at current rates 6% of the aquifer will be used up every 25 years.	Parts of Mexico City have subsided by 8.5 meters due to years of groundwater extraction as the only source of water for the city's needs

Various sources

Groundwater resources and depletion

SOURCE 5: Consequences of groundwater extraction in California (conflicts in California)



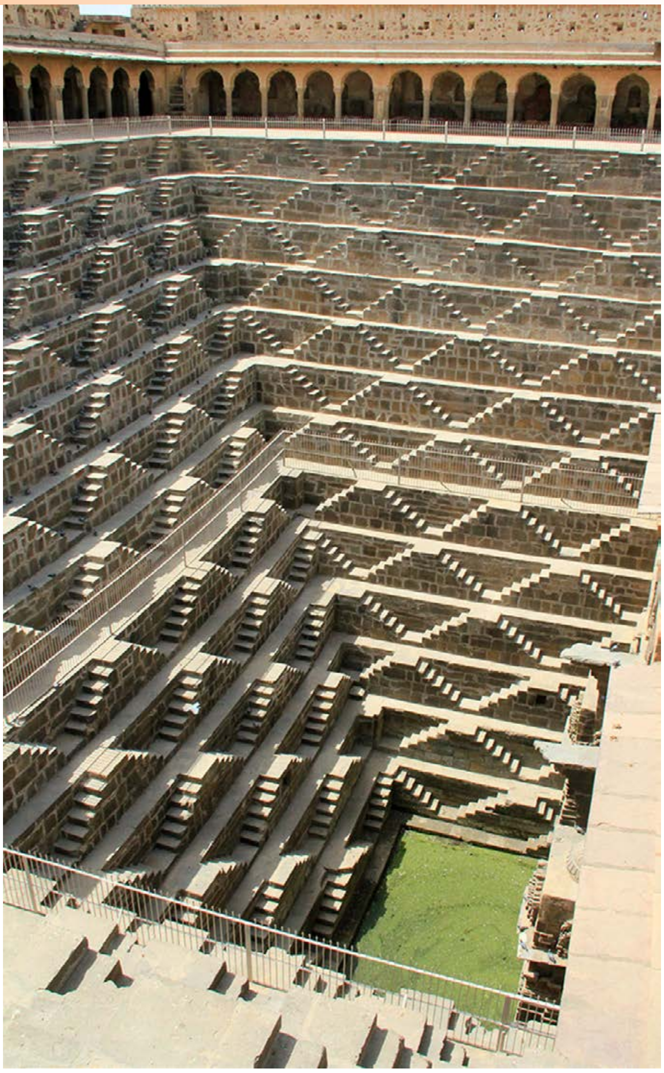
Example: Environmental groups allege salmon, groundwater dependant oak forests, riparian and wetland ecosystems have been affected by agricultural and urban groundwater use and subsequent reduced river flows in the Cosumnes River

Screenshot from interactive map – Water in the West website – http://waterinthewest.stanford.edu/groundwater/conflicts/index.html

SOURCE 6: Groundwater levels beneath Dhaka, Bangladesh

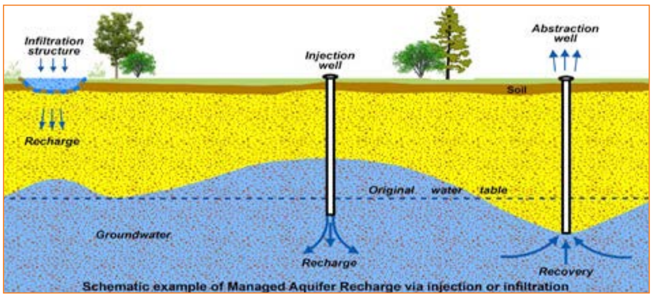
Groundwater depletion	
Year	Water table depth, m
1996	26.60
1997	28.15
1998	30.45
1999	31.86
2000	34.18
2001	34.18
2002	37.78
2003	42.00
2004	46.24
2005	57.42
2006	59.72
2007	61.18
2015	70.00

Various sources



Depleted groundwater, Chand Baori (stepwell) at Abhaneri (Dausa , Rajasthan). Source: Wikimedia Commons

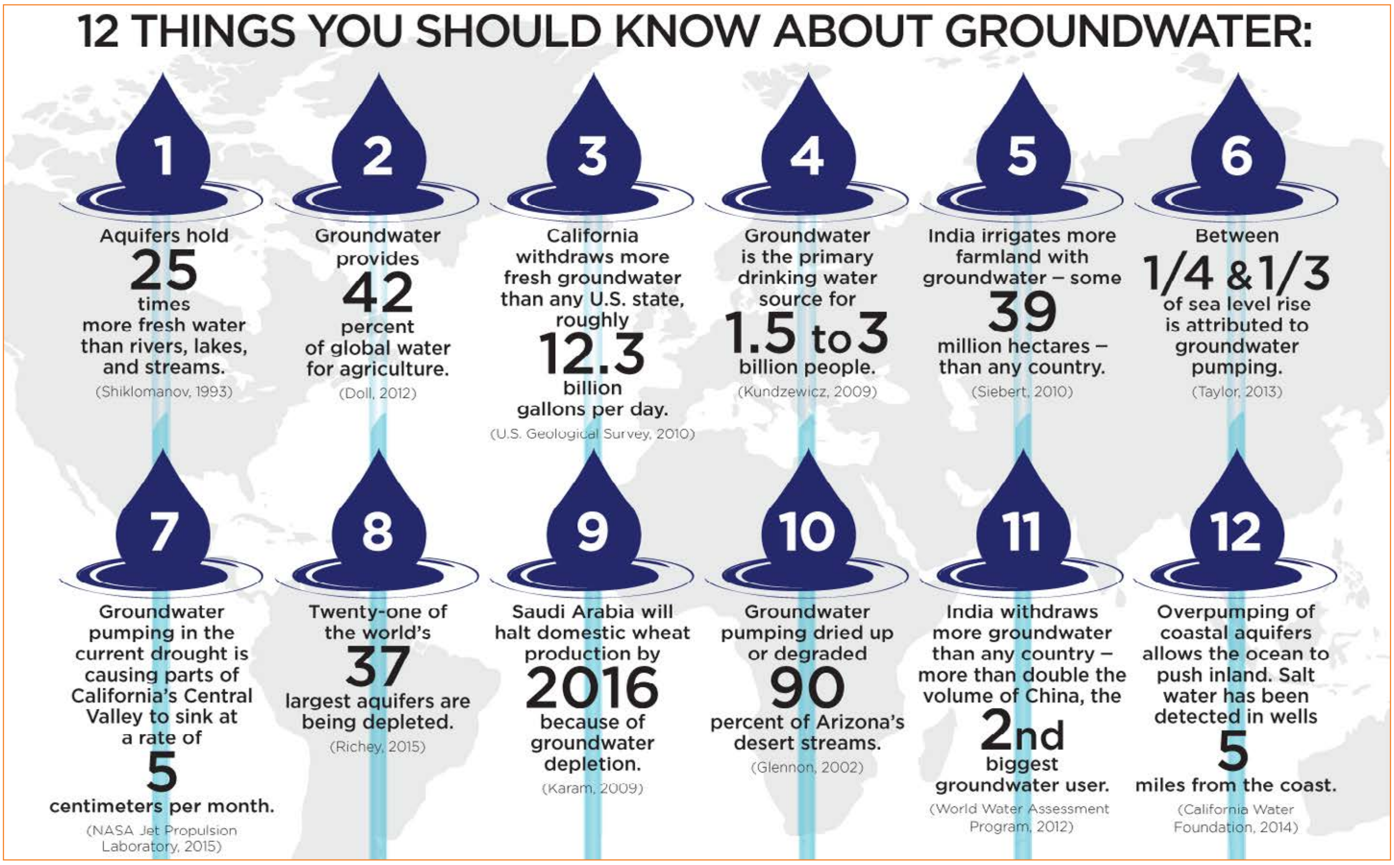
SOURCE 7: Managed groundwater recharge



Source: http://www.water.wa.gov.au/urban-water/water-recycling-efficiencies/managed-aquifer-recharge

Below: Cattle at bore, Ravenswood Qld. Source: CSIRO ScienceImage 4465

SOURCE 8: Facts about groundwater



Water data – http://www.circleofblue.org/waternews/CPX/cpx_data.shtml

This NASA photograph highlights the mostly dry bed of Owens Lake and lower Owens River, located in the southern Owens Valley between the Inyo Mountains (upper left) and the Eastern Sierra Nevada (bottom). Shallow groundwater, springs, and seeps support minor wetlands and a central brine pool. Two bright red areas along the margins of the brine pool indicate the presence of halophilic (salt-loving) organisms known as archaeans. Gray and white materials within the dry lake bed are exposed sediments and salt crusts. Source: NASA Earth Observatory , Wikimedia Commons

SOURCE 9: Australia's groundwater alert

DECLINING GROUNDWATER IS A BIG PROBLEM FOR AUSTRALIA
(Extract)

Groundwater is extensively used right across the Australian continent, which is why we should take very seriously a new study, which says supplies are on the decline.

The loss of groundwater stores poses serious threats to humans that need it to drink, crops that are irrigated with it, and natural ecosystems that rely on it for their survival.

That's why a new NASA study is cause for concern, particularly in a dry country like Australia.

Australia is of course a very dry country so it is no surprise to find that groundwater is extensively used right across the continent. Perth relies heavily on the Gnangara Mound aquifer for its water supply, but the water table has been dropping for the past 40 years or more because of reduced rainfall, increased extraction, and probably because of decreased recharge arising from vegetation water-use.

The Great Artesian Basin (GAB), underlying about 1.7 million square kilometres of Australia, contains about 65,000 km^3 of water, but the water is up to 2 million years old so it is easy to extract this resource far faster than it is being replenished. As the water pressure in the GAB has declined and the water table drops, mound springs (where groundwater is pushed to the ground surface under pressure) have begun to dry up in South Australia and Queensland. Associated paperbark swamps and wetlands are also being lost and it gets more and more expensive to extract the groundwater for irrigation and other commercial applications.

On average, rates of groundwater extraction across Australia has increased by about 100 per cent between the early 1980s and the early 2000s, reflecting both the increased population size and commercial usage of groundwater stores.

The international study released by NASA showing declines in groundwater resources globally should alert us to the pressing need to manage groundwater resources sustainably. Australia is not immune to the challenges posed from declining groundwater resources.

Source: **ABC The Drum: Opinion –** http://www.abc.net.au/news/2015-06-18/eamus-declining-groundwater-is-a-big-problem-for-australia/6556586

Many streams and rivers are supported by the availability of groundwater.

Groundwater resources and depletion

STUDENT ACTIVITIES

1. Why are Earth's groundwater resources considered to be in a state of crisis?

2. Draw a drainage basin diagram to illustrate the biophysical processes that impact on groundwater resources

3. Explain why confined aquifers are referred to as fossil water?

4. Mind map the impacts of groundwater depletion on people, places and environments

5. Refer to **SOURCE 1**

Graph

a. Which region experienced the largest decrease in groundwater storage between 2002 and 2013?

b. Describe the trend for the Central Valley of California. Suggest reasons for the variations over the 11 years

Map

a. Name the five basins that experienced large groundwater storage change between 2002 and 2013

b. Suggest why Australia's Great Artesian Basin is not suffering from groundwater depletion.

6. Refer to **SOURCE 2**

a. Describe the links between groundwater and rivers shown in the diagram

b. What other aquatic environments have similar connections to groundwater?

c. Predict the impact of disconnected groundwater in streams over an extended time period?

7. Refer to **SOURCE 3**

a. Explain the difference between a flowing artesian well and a well requiring a pump.

b. What type of aquifer is the most accessible?

c. Suggest consequences of lowering the water table.

d. Investigate how groundwater extraction and land subsidence will impact on the potential impacts of sea level rise and climate change in coastal cities such as Perth.

8. Refer to **SOURCE 4**

Write a 100-word paragraph describing the crisis facing Earth's groundwater

9. Refer to **SOURCE 5**

a. How many riparian and river ecosystems were a source of conflict in California?

b. Visit the Water in the West website and use the interactive map to outline two conflicts involving GDE.

10.

a. Graph the statistics in **SOURCE 6**.

b. Describe and explain the trends shown

c. Calculate the % change in groundwater depth below the city.

11. With reference to **SOURCE 7** discuss the need to artificially recharge depleted aquifers.

12. Analyse the statement "Lakes, wetlands and streams are windows to the water table".

13. Choose ONE fact from **SOURCE 8** as the basis for a geographical inquiry. Develop inquiry questions, conduct research and communicate results digitally.

14. Identify the main message of the article in **SOURCE 9**.

RESOURCES

Circle of Blue – http://www.circleofblue.org/waternews/2014/commentary/editorial-in-the-circle-fresh-focus/earths-major-aquifers-trouble/

NASA: Groundwater storage trends in Earth's largest aquifers – http://www.jpl.nasa.gov/images/earth/grace/20150616/grace20150616-16.jpg

Water in the West (California's groundwater crisis) – http://waterinthewest.stanford.edu/groundwater/overview/index.html

California's groundwater conflicts – http://waterinthewest.stanford.edu/groundwater/conflicts/index.html

National Atlas of Groundwater Dependent ecosystems – http://www.bom.gov.au/water/groundwater/gde/

Groundwater Dependent Ecosystems – http://wetlandinfo.ehp.qld.gov.au/wetlands/ecology/aquatic-ecosystems-natural/groundwater-dependent/

Wetland info / Groundwater Dependant Ecosystems – http://wetlandinfo.ehp.qld.gov.au/wetlands/ecology/aquatic-ecosystems-natural/groundwater-dependent/

Groundwater Dependant Ecosystems/ Learning Module – http://wetlandinfo.ehp.qld.gov.au/wetlands/resources/training/15-gde-ecology/