Limestone springs – the wells of Wells
Modelling the underground flow of water through limestone passages to springs

Water flowing through rock
Take a specimen of sandstone and either drop some water on the surface, when it will usually sink in, or put it into a container of water, when you will usually see bubbles streaming out. This is because sandstone usually has linked-up gaps between the grains or pore spaces – this is called primary permeability.

Now try this with a specimen of limestone. Some limestones have no primary permeability, so a drop of water will run off and no bubbles will rise from specimens.

The reason why some limestones are not permeable is because, as lime sand or mud became changed into rock, the calcium carbonate that the lime sand/mud was made of recrystallised, filling all the spaces between the grains. However, like other sedimentary rocks, limestones have bedding planes and are usually well-fractured with joints or cracks that are often vertical. When acid rainwater, made more acid in passing through soil, flows down these cracks and planes, it reacts with the limestone. The reaction products are carried away in solution, widening the cracks. So these types of limestones often have excellent secondary permeability.

Many pupils picture groundwater flowing through rocks under the surface as flowing through caves and passages. For most rocks this is not so and is a misconception, but in the case of limestones, they are correct, water does flow though caves and passages underground.

Modelling underground water flow in limestone
This flow through limestone caves and passages can be modelled using a piece of rubber tube. Hold one end of the tube slightly below the other and pour water in that end, the tube fills up and overflows, so that does not work. But if the end that water is poured into is held higher than the other end, water will flow through and out of the other end. This shows that the part of the system where water flows in must be higher than the part where the water flows out. There must be a 'head' of water to drive the water through the system.

The rubber tube can also be used to show how dye-tracing of groundwater flow works. If you add dye to a stream flowing into an aquifer and discover where it comes out, you can map the underground flow of the water. You can even time how long it takes for the water to flow through the system. So add some dye to the upper end of the tube and add more water, the dyed water will soon flow out of the other end. Note: in dye tracing, biodegradable dye is used so that the environment is not damaged.

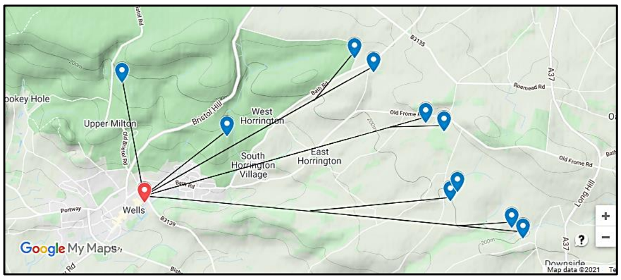
The Wells of Wells
The name of the small city of Wells in south west England comes from its springs. Because the springs were thought to have mystical or religious significance, the town was founded and later a great cathedral was built nearby. A significant moment in the history of Wells came in 1451 when the then bishop of Wells, Bishop Bekynton, realised that the people of Wells had no supply of fresh water, so he guided the water from the springs into channels flowing down the main street, giving free fresh water to everyone. The water still flows down the main street gutters today.

The springs of Wells rise in an area now surrounded by the gardens of the Bishop's Palace. The water can be seen bubbling up at the bottom of ponds. The springs flow all year, with an average flow of 18 million litres (four million gallons) per day.

Water bubbling into a pool in the Wells Bishop's Palace Gardens. (*Doug Robinson*).

Demonstrating the flow of water down limestone passages to flow out of a spring, in front of one of the springs of Wells. (*Doug Robinson*).

Dye-tracing has shown that the Wells springs are fed by twelve streams that enter higher up the limestone aquifer as shown in the map opposite. The longest flow path is 6.5 km. It is these twelve recharge streams which maintain the steady flow of the wells of Wells.



Dye-traced flow from the twelve recharge streams (blue) to the resurgence in the springs of Wells (red). *(Google maps image).*

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The back up

Title: Limestone springs – the wells of Wells

Subtitle: Modelling the underground flow of water through limestone passages to springs.

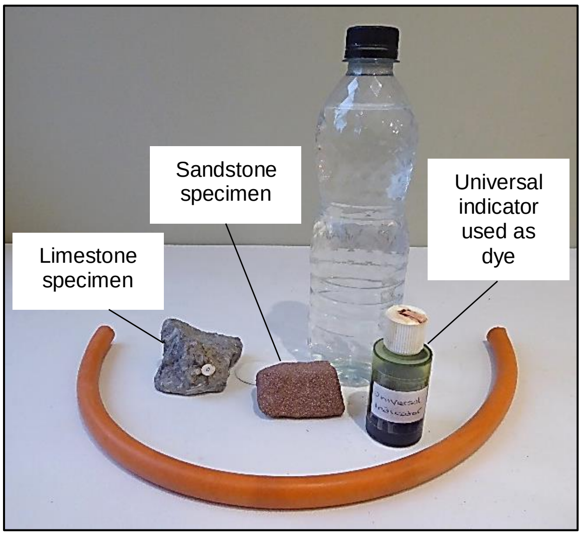
Topic: Using a simple model and specimens of sandstone and limestone to explain groundwater flow though limestone caves and passages to springs.

Age range of pupils: 7 years upwards

Time needed to complete activity: 10 minutes

Pupil learning outcomes: Pupils can:
- explain how water flows through rocks with primary permeability;
- explain how water flows through rocks with secondary permeability;
- explain how limestone springs form;
- explain how the sources of spring water can be found by dye-tracing.

Context:
This activity demonstrates how the water coming from a spring or resurgence in a limestone area travels to the spring through an aquifer, and how the springs which recharge the aquifer and feed the spring can be found though dye-tracing.



Demonstrating permeability in sandstone and limestone and groundwater passage flow and dye-tracing in limestone with rock specimens, rubber tubing, water and dye. (*Chris King*).

Following up the activity:
Towns or villages scattered along a line at the base of a range of hills are often called spring line settlements. Use the internet to discover why they are given this name.

Underlying principles:
- Rocks that have gaps between the grains through which water can flow are permeable; since the gaps were present when the sediment was deposited, this is called primary permeability.
- Some rocks that might otherwise have been impermeable allow water to flow along bedding planes and are jointed and fractured; this gives secondary permeability, which formed after the rock lithified.
- The flow of acid rain- and soil-water along limestone passages widens them because the acid reacts with limestone; the reaction products are carried away in solution.
- Limestones can be very effective water storage aquifers because of this secondary permeability.
- Rain- or stream-water penetrates the upper parts of aquifers and flows downhill as groundwater before emerging in springs, marshes or bogs or flowing up through the beds of lakes or rivers.
- The recharge stream sources of the waters which flow into aquifers and eventually out again, can be found by dye-tracing.

Thinking skill development:
Picturing how water flows through a tube when one side is higher than the other is a construction activity. Linking that to passage flow in limestone aquifers and to natural springs involves bridging.

Resource list:
- shown in the photo: specimens of permeable sandstone and impermeable limestone, rubber tubing, water and dye (Universal indicator, food dye, tea, coffee or similar)

Useful links:
Information on groundwater can be found at: http://www.groundwateruk.org/ and https://www.usgs.gov/special-topic/water-science-school/science/groundwater-what-groundwater?qt-science_center_objects=0#qt-science_center_objects

Try the Earthlearningideas:
Weathering limestone –with my own breath!
https://www.earthlearningidea.com/PDF/214_Weathering_limestone.pdf
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Source: Chris King of the Earthlearningidea Team, with background information from Doug Robinson.