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WATER FOR THE WORLD

Water Engineering & Sustainability Session

A Collaboration between
Engineers Without Borders UK
and Arup Cause

WATER FOR THE WORLD

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SESSION SUMMARY AND REQUIREMENTS

Session Title:

Water for the World: Water Engineering and Sustainability

Description and Aims:

Water for the World (WftW) is an interactive classroom session for pupils between the ages of 11 to 18, that aims to stimulate thought on global water sustainability, thus adding an important element to the school curriculum. WftW aims to stimulate critical thinking and encourage pupils to think about global water sustainability via presentations, quizzes, games and hands-on experience. It highlights to young people issues such as global water scarcity, the challenges people face when sourcing water and maintaining a water supply in developing countries and the role of the engineers in solving these problems.

A key part of each 90-minute WftW session is a water filter workshop that demonstrates the basic principles of water filtration; and explain the work of civil engineers in the context of design, problem solving, team working and multidisciplinary management.

The WftW programme is divided into three age-specific modules, ensuring it hits appropriate levels of technical understanding and learning style. Well designed facilitator packs include all the information needed to run WftW in UK classrooms.
This document contains the instructions and presentation required to run the Water for the World "Water Engineering and Sustainability" session.

Curriculum subjects suited to:

A-Level or equivalent curriculum Subjects: Geography, Science, Citizenship, Functional Skills, General Studies

Suited Age Group:

Age 16 to 18 years old. Curriculum years 12 – 13.

Session Time:

90 minutes (including 45 minutes for the workshop)

Number of Students:

The session is designed for 16 students. However if you want to engage a larger class, arrangements need to be made for workshop materials and relevant printouts. For the workshop the students should be divided into groups of up to 4 students.

SESSION SUMMARY AND REQUIREMENTS

Activity Breakdown:

- Introduction and ice breaker
- Class questionnaire and presentation to provide an understanding of water consumption on a local and global scale
- Presentation and discussion on decontamination and health risks
- Presentation about the components of water infrastructure
- Cut and paste water system activity in groups to understand the layout of water infrastructure and also enable students to go through a design process
- Presentation on alternative water sources and treatment technologies
- Practical Workshop to design, build and test a basic water filter
- Summary and tidy up

Materials required:

A comprehensive materials list for the workshop, and suggested quantities, are detailed in the table below.

2L Plastic Bottle (1 per group)	Cotton Wool (1 bag)
1L Plastic Bottle (1 per group)	Jar of mud - to mix with approximately 2 litres of water (1 bucket)
Washing up bowl of dirty water, made from mixing tap water with mud (250ml per group)	Gravel - Coarse (2 cups per group)
250ml Beakers/cup (2 per group)	Gravel - Fine (2 cups per group)
Rubber Band (10)	Sand - Coarse (2 cups per group)
Activated Charcoal (1/4 cup per group)	Sand - Fine (2 cups per group)
Sellotape (1 roll)	Iron filings (1 cup)
Latex Gloves (1 box)	Sugar (1 beaker)
Sodium chloride (1 bottle)	Sawdust (Quarter bucket - approx 2 litres)
Cheesecloth (2 x 10cm square per group)	Scrap A3 paper (12 sheets)
Toilet paper (2 rolls)	Plastic drinking cups (40)

Equipment Required:

The following equipment would be required to run the session: **Laptop connected to projector, clamp to hold bottle, whiteboard markers, adhesive stick, scissors and access to sink and tap or bucket of water.**

Preparation

School Lab

1. The school technicians should be contacted in advance to confirm the materials are available.
2. Ensure that materials and equipment are brought to the class prior to the session
3. Prepare the materials and presentation and test-run the main session before the presentation day.

The Quiz

1. You need four pieces of paper with a letter **A,B,C,D** on each. Put up in different areas of the classroom beforehand.
2. It would be good to have a bucket from the school, to visually display 10-14 litres of water (depending on size of bucket)

The Workshop

1. Collect equipment and materials required for workshop including PowerPoint presentation on CD or USB stick.
2. Print activity sheets (Design Brief, Bill of Quantities).
3. Prepare 2 bottles/beakers (1 with muddy water, 1 with clear water). Use labels showing the different water qualities.
4. Organise 4 sets of materials for water filter activity.

The Global Picture

Useful sites for background knowledge to explain the maps shown on the slides
http://www.waterfootprint.org
http://www.iwmi.cgiar.org/
http://www.wateryear2003.org/en/ev.php-URL_ID=5878&URL_DO=DO_TOPIC&URL_SECTION=201.html

Decontamination and Health Risks

Use 2 transparent beakers or bottles: 1 filled with muddy water and 1 filled with clear water

The Infrastructure Activity

For each group of 3 or 4 students, print out A3 colour copies of each, the **water cycle landscape (p.19)** and the **water infrastructure components (p.20)**. Scissors and glue will be required for each group. Students must cut the components from page 20 and paste them in page 21. Detailed instructions on how to run the activity are provided in page 10-11. A model solution for the activity is provided in the presentation (slide 20). However, it should be understood that there is **no** model solution and that there are different ways of doing this according to the assumptions that each group has made.

Useful Reading Material

- Water Supply, Third Edition (or later), A C Twort, F M Law and F W Crowley (available from Arup Library)
- www.thameswater.co.uk –information on drinking water treatment processes, also contains information about the Beckton desalination plant (from a Thames Water perspective)

Instructions for the Presentation

The instructions below follow the PowerPoint presentation. The instructions are divided in sections.

Introduction (6mins)

Slide 1

Introductions

Give the name of the presentation (WftW – Water Engineering and Sustainability) and the name of the company/organisation that has put this together (Arup/EWB)

Objectives

Run through the objectives of the workshop:

1. Gain an understanding of water consumption on a local and global scale
2. Provide a brief overview of how water gets to your taps and also consider other ways of getting clean water
3. Introduce you to what water engineers do and how they approach design challenges
4. Inspire an interest in water conservation

Ice Breaker

Explain ice breaker (See 'Ice Breaker' file for description and pictures)
Give out printed ice breaker pictures
Run the Ice breaker activity

Why the Water Issue (8mins)

Quick Quiz

Slide 2

Put up papers with **A,B,C,D** in different areas of the classroom beforehand

Ask the students to stand up and once a question has been read out, to stand by the letter which they think is the correct answer. After each question give a bit of background.

Slides 3, 4

About 3/4 of earth's surface is covered by water. What percentage of the world's water can we drink?

a) **0.8%** b) 6% c) 19% d) 30%

Source: *http://www.waterencyclopedia.com/Da-En/Drinking-Water-and-Society.html*

Slides 5, 6

How many people in the world are without access to drinking water?

a) 1.1 million b) 210 million c) **1.1 billion** d) 2.3 billion

Source: *http://www.worldwatercouncil.org/index.php?id=25*

Slides 7, 8, 9

(Use bucket if available)

On average how many litres of water do we use a day?

a) 50 b) 100 c) **150** d) 200

Source: *http://www.waterwise.org.uk/reducing_water_wastage_in_the_uk/the_facts/water_in_the_uk.html*

Slides 10, 11

How many litres could be lost through leaks in this country per day?

a) 2 million b) 50 million c) 500 million d) **900 million**

Source: *http://www.thameswater.co.uk/cps/rde/xchg/corp/hs.xsl/5163.htm*

Slide 12, 13

What percentage of domestic water is used for flushing toilets in the UK?

a) 10% b) 20% c) 25% d) **30%**

Source: http://www.waterwise.org.uk/reducing_water_wastage_in_the_uk/house_and_garden/toilet_flushing.html

Additional questions if time allows

No slide

What percentage of preventable diseases are caused by unsafe drinking water, poor sanitation and hygiene?

a) 33% b) 44% c) 66% d) **88%**

Source: http://www.cdc.gov/healthywater/global/wash_statistics.html

No slide

How much do you think it costs to fill a bath in the UK?

a) 2p b) **15p** c) 20p d) 25p

Source: http://www.uswitch.com/water/how-much-water-use/

No slide

How many river systems are there worldwide?

a) 1020 b) 560 c) **260** d) 130

Source: http://en.wikipedia.org/wiki/Water_crisis

The Global Picture (5mins)

Slides 14-17

Explain statistical maps. Water Scarcity is the most important map, it can be seen as an overlap of the Consumption and Availability of Water maps.

Global Water Consumption / Water Footprint (Slide 14)

A country's internal water footprint is the volume of water used from domestic water resources. Water is then used in agriculture, industry and domestic uses. Therefore this map actually illustrates the per capita water consumption from domestic water resources around the world (Comments can be made regarding the very low water consumption in African Countries, India and China in comparison with the high water consumption in the USA).

Read more on: http://www.unesco.org/water/wwap/wwdr/wwdr3/pdf/WWDR3_Water_in_a_Changing_World.pdf
http://www.waterfootprint.org/?page=files/Publications (Hoekstra and Chapagain 2008)

Availability of Water (Slide 15)

On our blue planet 97.5% of the water is saltwater, unfit for human consumption. The majority of freshwater is beyond our reach, locked into polar snow and ice. Less than 1% of freshwater is usable, amounting to only 0.01% of the Earth's total water. Even this would be enough to support the world's population three times over, if used with care. However, water like population isn't distributed evenly. Asia has the greatest annual availability of fresh-water and Australia the lowest. But when population is taken into account the picture looks very different. (Point out in the map that though Asia has the greatest annual availability of fresh-water as a region, the availability of water per capita is very low because it is so densely populated. Moreover, though Australia has the lowest annual availability of fresh-water as a region, the availability of water per capita is high because of its low population.

Source: http://www.newint.org/issue354/facts.htm
Source: http://highered.mcgraw-hill.com/sites/007248179x/student_view0/chapter14/web_map_4.html

Water Scarcity (Slide 16)

Explain what Physical and Economic water scarcity is.
Physical water scarcity: Areas where people have to physically cover long distances (up to several hours) to reach a water source and then carry water back to the household.
Economic water scarcity: Clean treated water is available but it has become too expensive to afford. People that cannot afford it travel to closest water source from where they get untreated water but free of charge.
Point out on the map the difference between USA, Europe and Africa, Middle East and India.

Source: http://www.cspo.org/gck/picweek.htm

Mention that lack of fresh water consequently means no irrigation and thus food shortage. The food price is going up, causing more misery for the world's poor. The geopolitical shockwaves have spread round the world, with food riots in Haiti, strikes over rice shortages in Bangladesh, tortilla wars in Mexico, and protests over bread prices in Egypt.

Source: http://www.iwmi.cgiar.org/news_room/pdf/Water_Scarcity_%20he_Real_Food_Crisis.pdf

Virtual Water (Slide 17)

Virtual water (also known as embedded water, embodied water, or hidden water) refers, in the context of trade, to the water used in the production of a good or service. For instance, it takes 1,300 cubic meters of water on average to produce one metric tonne of wheat. The precise volume can be more or less depending on climatic conditions and agricultural practice. The virtual-water content of a product (a commodity, good or service) is "the volume of freshwater used to produce the product, measured at the place where the product was actually produced".

Decontamination and Health Risks (2mins)

Slide 18

Preparation

Prepare beforehand 3 water bottles/ beakers (1 with muddy water, 2 with clear water). You may want to use labels on the bottles showing the different water qualities to aid the demonstration - but do not show these until the students have provided their suggestions.

Introduce Topic

Show the class 3 bottles (1 with muddy water, 2 with clear water)

Ask class: 'Would you drink this?' 'Why not?'

There are reasons why people don't drink water:

- Turbidity (appearance)
- Temperature
- Source – where it came from/who gave it to you!
- Smell
- Taste….. etc

There are reasons why people shouldn't drink water. Mainly because of Physical impurities – i.e. it's dirty! There are two types of impurities to consider. Ask class to name some impurities that fall into these categories:

- Biological impurities – Bacteria, virus', animals living and dead, plants (inedible). Essentially things that are going to make you ill. E.g., dysentery, cholera.
- Chemical impurities – oils, radioactive substances, chemical fertilisers, dissolved metals. Essentially things that are going to poison you.

Infrastructure (16mins)

Explain Water Infrastructure (2mins)

Slide 19: How do we get clean water?

River regulating reservoirs store water in wet periods such as winter for use in drier seasons. After this reservoir, water can be abstracted to a nearby treatment works. Sometimes water is supplied to other catchments or river systems by pumping it in an underground network.

The water is then treated at the water treatment plant to a potable quality. We will go into more detail of the treatment processes later.

Treated water can then be pumped by high lift pumps to service reservoirs usually hidden in the natural landscape or water towers. From here they supply settlements by gravity. It is normal for the water companies to guarantee 10bar pressure to a building. In some places they will require pressure booster pumps, and tall buildings will have to install their own pressure booster pumps. Sometimes industry will have its own private supply.

The water is distributed through water network mains– which are usually blue pipe work beneath the ground. From here there will be a connection to your house, which is sometimes metered to measure how much water you use.

Used water enters the wastewater network and usually ends up at a sewage treatment works. Conventionally these treat the water (however we won’t go into any details on this) and release it to the river system or directly to the sea. Sometimes the treatment works are located upstream of another water treatment plant and in this way, waste water can be recycled before reaching the sea.

Explain Activity (1min)

You have been provided with the components that form the mains infrastructure and a landscape showing the water cycle – in groups design your mains infrastructure from source to waste treatment

Activity (10mins)

Each group should have:

- A3 printed sketch of landscape showing the water cycle
- A3 printed water infrastructure components
- 1 glue stick and 1 pair of scissors
- During the activity assist/guide the groups and answer any questions

Summarise activity (1 min)

Slide 20: Designed infrastructure

Explain that there are different ways of doing this. The design will have depended on each team's thought process, just as it depends on the opinions of different engineers, the different situations you are in, and the assumptions that are made.

You may want to highlight the desalination plant and ask where these are used. Explain the high energy consumption and therefore it is better to reduce water consumption. You may want to draw attention to the planned desalination plant in London.

Water Treatment Processes (2mins)

Slides 21,22

We will look at the different processes for cleaning water at the treatment works:

Settling – reservoirs, clarification, flocculation

Storage reservoirs allow blending of different qualities of water. Water abstracted from the ground is cleaner than that from surface sources. Long storage time allows some quality improvements such as debris and solid contaminants settling out and sunlight breaking down organic materials.

Screening is mainly used for surface water to remove solid objects.

Clarification involves the addition of a chemical coagulant which forms a precipitate and then flocculation is the process of the building up of particles of flow which can be removed by sedimentation or filtration.

Filtration – rapid sand filters, slow sand filters

Rapid sand filters remove physical impurities by sieving suspended material from the water. Slow sand filters also do this, but they have a natural biological layer of microorganisms at their surface which capture organic materials and break them down. Slow sand filters can contain a layer of granular activated carbon, which removes pesticides. Ozone treatment is also used to remove pesticides.

Chemical Treatment – disinfection with chlorine

Disinfection is usually provided using chlorine. Chlorine is dosed at the end of treatment, before the water is sent into supply to destroy harmful micro-organisms. The tanks are designed with a series of baffles to ensure that the chlorine has sufficient contact time for disinfection.

How do people get water outside the mains infrastructure? (4mins)

Slides 23-28

Alternative Sources (1 min)

When people do not have access to a mains supply such as we have, they have to firstly find some water

- Ground (Wells)
- Springs
- Rivers
- Roofs (Rainwater)
- Water delivery (back of a truck)
- Sea

Contamination (1 min)

Explain that these sources are contaminated or can become contaminated and may need to be treated at the point of use.

When they find this water it is rarely of a drinkable quality. Therefore they must treat it themselves, or at least prevent it from contamination.

For example, rainwater is deemed clean when it lands on your roof, however it can pick up pollution in the sky, and then also wash in things like bird excrement and bacteria from your roof.

Rivers can be clean near to source, but people or animals discharging their own waste into them, or dying in them can render them undrinkable. In addition pollution from industry and agriculture can poison the river. Dumping of waste chemicals from industrial processes or pesticides from farming can cause this.

Why use Water Treatment (2mins)

Slides 29,30

Provide examples of point of use water treatment:
Chemical: chlorine, iodine and ozone disinfection
Physical: Membrane, porous ceramic, composite and granular media filters
Biological: Biosand slow sand filter
UV: Solar disinfection and UV lamps
Thermal: Boiling, pasteurization and solar cookers

Combination: Using a series of different technologies to achieve the required water quality.
Do we need potable water quality for WC flushing or irrigation? Water should be treated according to its end use, thereby saving resources, energy and cost.
In the next task, you will be an engineer and you will need to design a household product to provide clean water for someone that has obtained their water from a well or a river.

Water Filter Workshop (45mins)

General Introduction

- Refer to 'Water Engineering Workshop'
- In groups, make a workable water filter
- Follow the instruction sheet
- Buy supplies from front
- Demonstrate filter at end.

Rules

- Only one Person buys at a time.
- You can only buy in the first 20 min
- You can talk and deal with other groups

Conclusions (2mins)

Summarise the Workshop

Slide 31

Today we have spoken about water consumption, water sources, decontamination, how the water gets from its source to your tap, and what happens after the tap. We have seen that not everyone can access mains infrastructure and that there are different technologies for treating water.

You should now have an idea of the role of a water engineer and also some of the processes you go through when creating a design for a product.

Provide any useful websites found in this pack or the presentation.

Information for the Teachers

Background information

This workshop forms the practical part of the Water for the World "Engineering" presentation. The task involves the design, build, presentation and testing of a water filter. The workshop highlights the importance of an engineer, in the context of solving global issues, and to introduce the students to the innovative and practical skills required of engineers.

Please hand the Design Brief and Bill of Quantities documents to the students (one of each for each group). This should be followed by an explanation of the design challenge. Do not show them the filter diagram provided in this instruction document.

In order to help them through the task go around and guide the students by giving hints or asking key questions. Prepare and distribute any drawings or diagrams you think might be helpful.

The workshop is intended to take 45 minutes. Follow up discussions can be tailored to time constraints.

The task and suggested timings

Task	Timing (mins)
Read through the Design Brief with students	1
Clarify any early queries	1
Split the group into teams. Suggested group size: 3 or 4	1
Activity – Students design filter, build filter, and prepare presentation	20
Each group presents and tests their filter	20
Decide winner – offer justification for choice (based on water quality, scalability, cost)	2
Post-workshop analysis/discussion	Continues into presentation

Materials

A comprehensive materials list for the workshop, and suggested quantities, are detailed in the table below. The quantities have been assumed for a class of 16 students (4 groups). For larger numbers of students and groups the materials should be scaled appropriately.

Description	Quantity	Available?
2 litre bottle	4	
1 litre bottle	4	
Jar of mud (to mix with approximately 2 litres of water)	1	
250ml beaker/cup	8	
Rubber band	10	
Sellotape	1 rolls	
Iron filings	1 cup	
Activated charcoal (granules) - not essential	2 x 250ml beaker full	
Cheesecloth or equivalent	4 x 10cm squares	
Sugar	1 small bag/beaker full	
Cotton wool	1 bag	
Latex gloves	1 box	
Gravel - coarse	Quarter bucket (approx 2 litres)	
Gravel - fine	Quarter bucket (approx 2 litres)	
Sand- coarse	Quarter bucket (approx 2 litres)	
Sand - fine	Quarter bucket (approx 2 litres)	
Sodium chloride	1 bottle	
Sawdust	Quarter bucket (approx 2 litres)	
Toilet paper	2 rolls or 20 sheets	
A3 paper	12 sheets	
Plastic drinking cups	40	

Equipment Required:

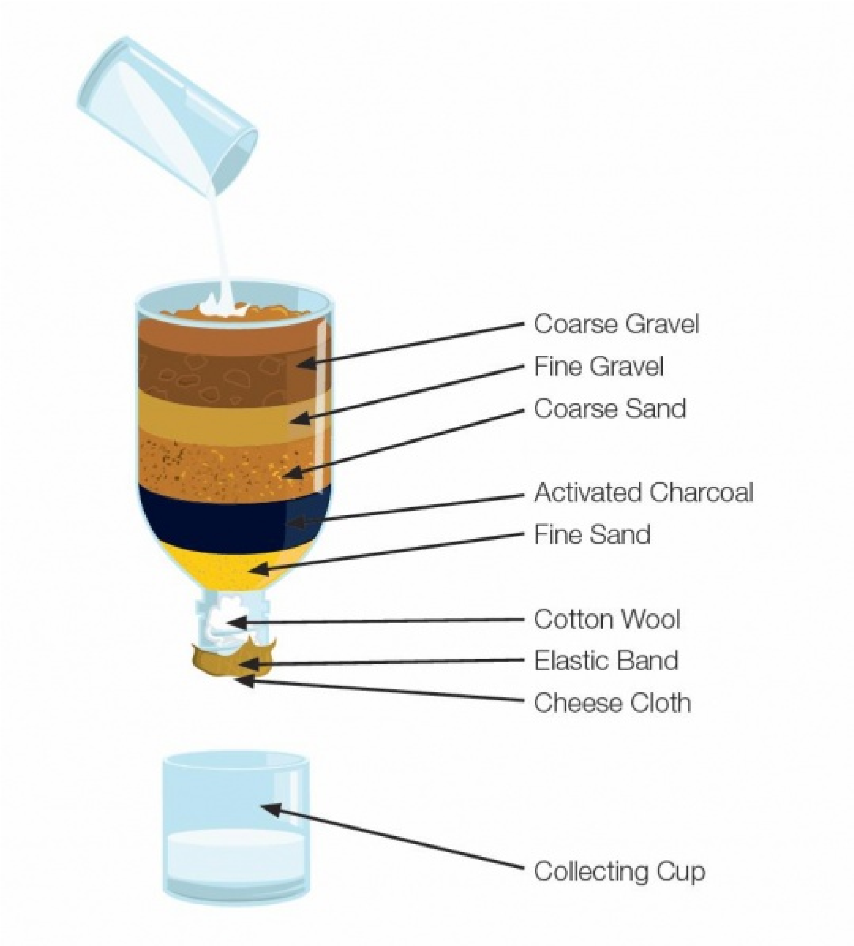
The following equipment would be required to run the session:

Description	Quantity
Clamp	4
White board markers	8
Adhesive Stick	4
Scissors	4
Access to sink and tap or bucket of water	-
10-14 litre bucket (if possible)	1

NB: Students are not required to use all the materials – some offer no advantage for filtering. Iron filing, sodium chloride, sawdust are not actually required to make the filter but should be provided so that the students have to make a choice of suitable materials. It is advisable to take surplus materials if available. The teams should use the bill of quantities provided to order their materials. Only one representative from each group may come to purchase materials, one group at a time.

Filter diagram (for teachers only)

The filter diagram below includes all the information regarding the filter composition. **Do not make this image available to the students.**



Further discussion topics

• How well did you work as a team?
• Would you have done anything differently?
• How effective were the filters?
• What needs to happen to materials before being used in filter (if not considered)?
• What might not have been removed by the filters – virus/bacteria
• How does this relate to the real world?
• Introduction to the design process and the role of the engineer
• Restrictions/consideration of an engineer: availability of water/resources/labour/money/durability of filter
• Consider other engineering issues – distribution of water to habitants and sewage systems/treatment
• what other solutions are there?

Notes of Experience

• Explain that design focuses on the function of each part and how they relate to each other. Show an example of an annotated design.
• Explain the steps in the activity and say what points we are assessing them on.
• Organizers need a sheet of points to score each group. It helps to give constructive feedback and for the students to know what to work on specifically.
• May need to hint that the bottle can be used upside-down.
• They need 15mins to make the filter.
• Instruct the students to run clean water through the filter to get it working. Then it can be used to filter dirty water.
• Clearing up time is necessary.
• 16 is a good number for this activity. May need a hall or a very big classroom if the activity is to be larger.

Design Brief (this sheet is meant to be printed for student use)

You are a team of engineers tasked with designing a water filter.
You must design and build a prototype water filter, and present your design to the client.

Execution

The timings are as follows:

- 5 minutes to design and cost (no hands on materials)
- 15 minutes to build filter and produce presentation
- 5 minutes to present idea

You will need to purchase the items needed for your water filter. Cost of each items are given below.
You have a budget of **80 credits**
Your presentation should include the following:

- A diagram
- Justification of cost and material selection
- Justification of design
- Potential for increase in scale
- Potential for mass market

Material	Description	Cost
2 litre bottle	-	10 credits
1 litre bottle	-	5 credits
Capture Cup	Collects water	2 credits
Rubber Band	-	2 credits each
Sellotape	-	2 credits/10cm
Iron filings	React over time with water and air to produce iron oxide. Dissolve at a faster rate in seawater due to dissolved ions.	15 credits/teaspoon
Activated charcoal	Highly porous carbon with large surface area. Carbon based compounds and chlorine adsorbed to the surface.	30 credits per 1/4 cup
Cheesecloth	Fine non-water resistant cloth	4 credits/square
Sugar	Crystallised organic molecule	5 credits/cup
Cotton wool	Fine wadding	2 credits/ball
Latex gloves	Clean hands	10 credits
Gravel - coarse	Acts as a sieve, allowing different particle sizes to pass through	5 credits/cup
Gravel - fine	"	5 credits/cup
Sand- coarse	"	10 credits/cup
Sand - fine	"	10 credits/cup
Sodium chloride	Inorganic compound. Dissolves in solution.	10 credits/cup
Sawdust	Fine particles of wood. Absorb and stick together when in contact with water.	5 credits/cup
Toilet paper	Absorbent plant fibre based sheet.	2 credits/sheet
A3 paper	Plant fibre based sheet.	2 credits/sheet

NB: Not all materials have to be used.

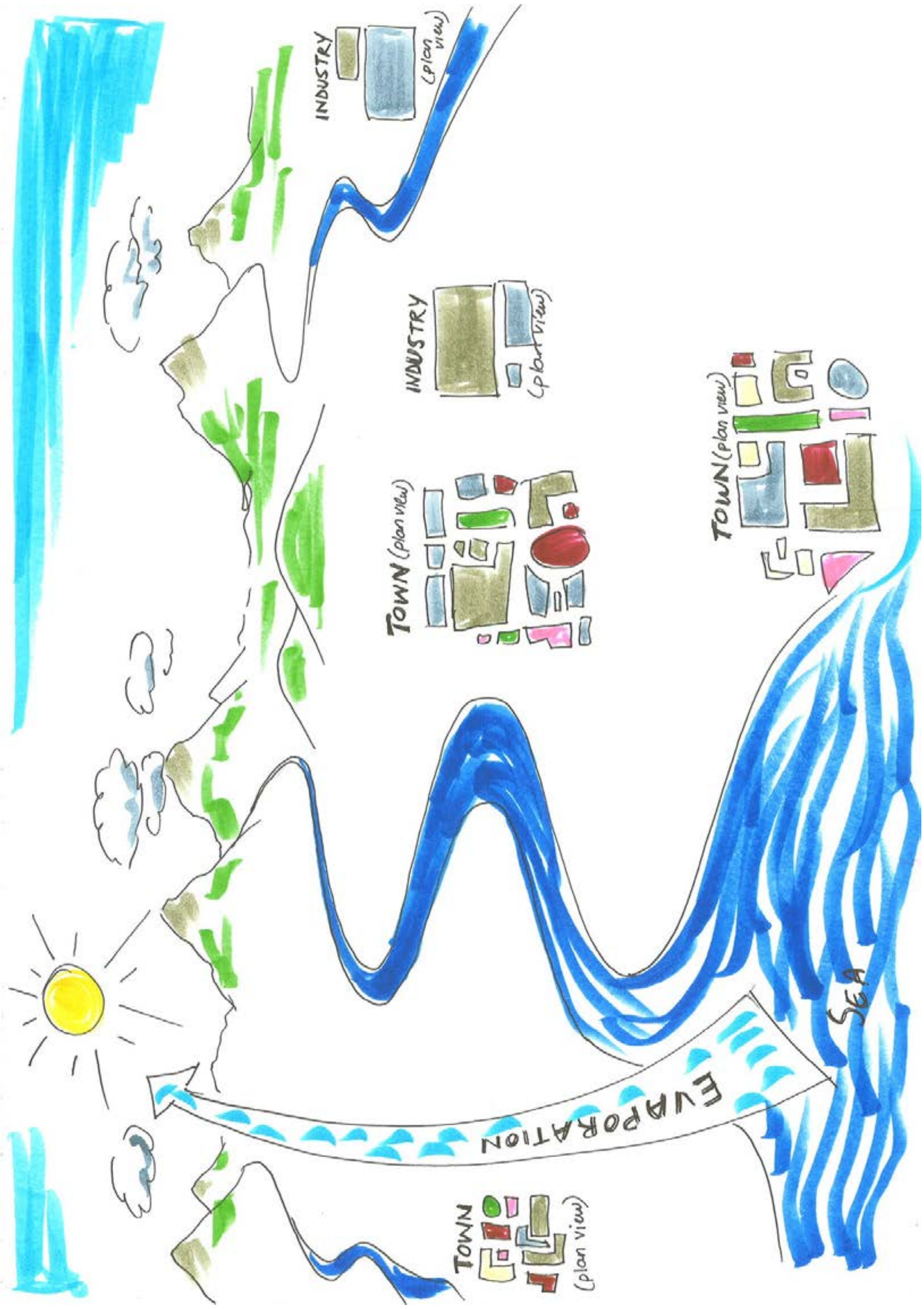
Bill of Quantities **(this sheet is meant to be printed for student use)**

Team: ________________________________

Total Budget = ________ credits

Material	Unit Cost	Quantity Required	Total Cost
2 litre bottle	10 credits		
1 litre bottle	5 credits		
Capture Cup	2 credits		
Rubber Band	2 credits each		
Sellotape	2 credits/10cm		
Iron filings	15 credits/teaspoon		
Activated charcoal	30 credits per 1/4 cup		
Cheesecloth	4 credits/square		
Sugar	5 credits/cup		
Cotton wool	2 credits/ball		
Latex gloves	10 credits		
Gravel - coarse	5 credits/cup		
Gravel - fine	5 credits/cup		
Sand- coarse	10 credits/cup		
Sand - fine	10 credits/cup		
Sodium chloride	10 credits/cup		
Sawdust	5 credits/cup		
Toilet paper	2 credits/sheet		
A3 paper	2 credits/sheet		
		Grand Total	=

Water Cycle Diagram



COMPONENTS OF THE WATER SERVICE INFRASTRUCTURE