Water Footprint calculation

1. Data provided by a utilities company show that the distribution 1 ML of water to end users in a typical city setting will result in the emission of approximately 370 kg of CO_2. The current average water consumption in Wollongong is 80 ML per day. Calculate the ecological footprint of water distribution for Wollongong. The following background data may be needed for your calculation.

Table 1: Equivalence factors

Component	Equivalence factor
Primary cropland	2.17
Forest	1.35
Permanent pasture	0.47
Built-up land	2.17
Energy land	1.84
Marine	0.06

From "Ecological footprint calculators: technical background paper" by EPA Victoria, 2005.
Note: a definition of equivalence factors could be taken as:
Average Earth Biocapacity = (Total Earth Biocapacity)/(Total Earth Surface Area)
Equivalence Factor = (Biocapacity of a particular land type)/(Average Earth Biocapacity)
From second table uptake rate of C for Australian forests = 1.3 t C/ha.
Atomic mass of Carbon=12g/mol, Oxygen 16g/mol.

CO_2 emission from 80 ML of water transmission:
= 80 x 370 kg CO_2 = 29,600 kg-CO_2/day = 10804t-CO_2/yr
C emission rate = 10804 x [12/44] t-C/y = 2946.5 t-C/yr
Forest land required = 2946.5 t-C/y / (1.3 t/ha) = 2267 ha/yr
Ecological footprint: = 2267 x **1.84** = **4171 gha/yr**

2. The following table is obtained from Chapagain et al (2006) detailing consumptive water use at field level for the production of cotton in the major cotton producing countries. The total areas of cotton farming in Australia and China are 480,000 ha and 4,305,000 ha, respectively. Seed cotton productions in Australia and China are 1,777,240 ton/year and 13,604,100 ton/year, respectively.

Table 3 – Consumptive water use at field level for cotton production in the major cotton producing countries

	Crop water requirement (mm)	Effective rainfall (mm)	Blue water requirement (mm)	Irrigated share of area* (%)	Consumptive water use		
					Blue water (mm)	Green water (mm)	Total (mm)
Argentina	877	615	263	100	263	615	877
Australia	901	322	579	90	521	322	843
Brazil	606	542	65	15	10	542	551
China	718	397	320	75	240	397	638
Egypt	1009	0	1009	100	1009	0	1009
Greece	707	160	547	100	547	160	707
India	810	405	405	33	134	405	538
Mali	993	387	606	25	151	387	538
Mexico	771	253	518	95	492	253	746
Pakistan	850	182	668	100	668	182	850
Syria	1309	34	1275	100	1275	34	1309
Turkey	963	90	874	100	874	90	963
Turkmenistan	1025	69	956	100	956	69	1025
USA	516	311	205	52	107	311	419
Uzbekistan	999	19	981	100	981	19	999

* Sources: Gillham et al. (1995), FAO (1999), Cotton Australia (2005), CCI (2005), WWF (1999).

a. Calculate the green and blue water footprint of per ton of seed cotton produced in Australia and in China.

For Australia - Green water footprint/ton
Farm area = 480000 ha
Seed cotton produced = 1777240 ton/year
From table 3 blue water (mm) = 521 mm
$\therefore$ total blue water = 0.521m X 480000 ha X 10000 m^2/ha = 2.5Gm^3
$\therefore$ blue water footprint /ton= 2.5 Gm^3/1777240 t/year = **1407 m^3/ton**
From table 3 green water (mm) = 322 mm
$\therefore$ total green water = 0.322 X 480,000 X 10,000 = 1.5 Gm^3
$\therefore$ green water footprint /ton = 1.5 Gm^3/1777240 t/year = **870 m^3/ton**

For China:
Farm area =4305000 ha
Seed cotton produced = 13604100 ton/year
From table 3 blue water (mm) = 240 mm
$\therefore$ total blue water = 0.240m X 4,305,000 ha X 10,000 m^2/ha = 10.3 Gm^3
$\therefore$ blue water footprint /ton= 10.3 Gm^3/13604100 t/year = **759 m^3/ton**
From table 3 green water (mm) = 397 mm
$\therefore$ total green water = 0. 397 X 4305000 X 1000 = 17.1 Gm^3
$\therefore$ green water

b. The average fertilizer application rates in Australia and China are 121 kg/ha and 120 kg/ha (as nitrogen), respectively. Assume that 10% of the fertilizer will leach into the environmental water bodies. The water quality guideline value for nitrogen is 10 mg/L (adapted from the US-EPA). Calculate the grey water footprint component per ton of cotton seed.

For Australia:
Nitrogen leached into rivers =1/10 X 121kg/ha X 480,000 ha = 5808 ton/yr Water required to dilute to 10 mg/L = $\frac{5808 \text{ X } 1000 \text{ X } 1{,}000{,}000 \text{ mg/kg}}{10\text{mg/kg X } 1000 \text{ kg/m}^3}$
Grey water/yr = 581 10^6 m^3/year
Grey water m^3/ton = $\frac{581\ 10^6\ m^3/\text{year}}{1{,}777{,}240 \text{ ton/year}}$ = **327 m^3/to**

For China:
Nitrogen leached into rivers =1/10 X 120kg/ha X 4,305,000 ha = 51660 ton/yr Water required to dilute to 10 mg/L = 51660 $\frac{\text{X } 1000 \text{ X } 1{,}000{,}000 \text{ mg/kg}}{10\text{mg/kg X } 1000 \text{ kg/m}^3}$
Grey water/ha = 5166 10^6 m^3/year
Grey water m^3/ton = $\frac{5166\ 10^6\ m^3/\text{year}}{13{,}604{,}100 \text{ ton/year}}$ = **380m^3/ton**

c. Calculate the total water footprint per ton of cotton seed produced in Australia and China.

Total water footprint for Australia = 1407 + 870 + 327 m^3/ton= **2604 m^3/ton**

Total water footprint for China = 759 + 1256 + 380 m^3/ton = **2395 m^3/ton**

3. The table below describes typical wastewater characteristics at different stages of processing cotton textiles and permissible limits to discharge into environmental water.

Table 7 – Waste water characteristics at different stages of processing cotton textiles and permissible limits to discharge into water bodies

Process	Waste water volume* (m^3/ton)	Pollutants** (kg/ton)			
		BOD	COD	TSS	TDS
Wet processing	360	32	123	25	243
Bleaching	30	5	13		28
Dying	142	6	24		180
Printing	188	21	86	25	35
Finishing	136	6	25	12	17
Total	496	38	148	37	260
Permissible limits (mg/l) ***		50	250	50	

* Source: USEPA (1996).
** Source: UNEP IE (1996).
*** Source: WB (1999).

COD (Chemical Oxygen Demand) is determined by direct UV reading.
BOD (Biochemical Oxygen Demand) is determined by direct fluorimetric measurement.
TSS (Total Suspended Solids) is measured as per ISO 7027 with calibration against a formazine standard.

a. Calculate the grey water footprint per ton of processed cotton for each step.
Example:
Wet processing - water required to dilute 32 kg to 50 mg/kg = $\frac{32\ \text{kg}}{50\ \text{mg} / 1000{,}000\ \text{mg/kg}}$
= 640,000 kg/ton = 640 m^3/ton

b. If wastewater is treated on-site to satisfy the discharge limit prior to disposal, what would be the grey water footprint?

	Vol water required to dilute m^3/ton			Relevant dilution water volume (highest) m^3/ton
	BOD	COD	TSS	
Wet processing	640	492	500	640
Bleaching	100	52		100
Dying	120	96		120
Printing	420	344		420
Finishing	120	100	240	240
Total finishing and wet processing	760	592	740	**880**

A. **880 m^3/ton** (see table above)

c. If a pollution prevention measure is adapted resulting in 50% reduction of all four pollutants, recalculate the grey water footprint.

A.

	Vol water required to dilute m^3/ton			Relevant dilution water volume (highest) m^3/ton
	BOD	COD	TSS	
Wet processing	320	246	250	320
Bleaching	50	26		50
Dying	60	48		60
Printing	210	172		210
Finishing	60	50	120	120
Total finishing and wet processing	380	296	370	**440**

4. Use data obtained from Problems 2 and 3 to calculate the total water footprint of:
   a. A pair of jeans made from 1 kg of cotton.
   b. A baby nappy made from 75 g of cotton.
   (Note: you can assume that the water footprints of other materials of the above products are negligible)

A.

Total cotton water footprint/ton = 2603 m^3 + 760 m^3/ton = 3363 m^3/ton

Total cotton water footprint/kg = 3363 m^3/1000 = 3.36 m^3

∴ for jeans with 1 kg cotton footprint is 3360 L water

for nappy with 0.075 kg cotton footprint is 252 L water