Water demand and population growth

CF Schutte* and WA Pretorius
Water Utilisation Division, Department of Chemical Engineering, University of Pretoria

Abstract

The contribution of population growth in water demand projections is often obscured, since only the increase in domestic water demand is usually taken as an indication of the increase in water demand due to population growth. This paper aims to quantify direct (domestic) and indirect water requirements (e.g. for food production, energy etc.) to sustain an individual at a particular lifestyle level.

The average domestic water demand projected to the year 2015 accounts for only about 20% of the average full demand while the water demand for the production of food and consumer goods and for employment accounts for 80% of the full water demand to sustain an individual.

The full water demand of the 1995 increase in the South African population of about 1 million people, projected to the year 2015 when the newborns reach adulthood, is conservatively estimated at 638 M*ℓ*/d or about 23% of the current average daily water supply of Rand Water, indicating the tremendous pressure on water resources as a direct consequence of the high current levels of population growth.

Introduction

Water demand figures are typically given as the total of the water requirements for the domestic, industrial and agricultural sectors together with estimates on water needs to maintain ecosystems, estuaries, wetlands etc. Projections of future water demands given in this manner often obscure the actual relationship between population growth and water demand increases. The reason for this is that the increase in domestic demand is seen to account for population growth while increases in industrial and agricultural water demand are often regarded as related to economic growth and somewhat divorced from population growth.

The purpose of the study on which this paper is based, is firstly to estimate the "full water demand" for an individual taking into account water needs for domestic purposes, for food, for consumer goods, transport, housing and job-creation. The second objective is to project the full water demand figure for the 1995 increase in the population to the year 2015 when the newborns of 1995 will have reached adulthood. These figures should give a less obscured picture of the effect of population growth on water demand.

Estimates of the indirect water usage e.g. for food production are based on numerous assumptions since the factors which influence water demand may vary over extremely wide ranges and little specific information is available to quantify these variables. The motivation behind the paper is not to try to establish exact figures (this would be impossible) but rather to give a "ballpark" feeling for additional water requirements to sustain an individual at a particular lifestyle level.

Background

South Africa's 1995 population is estimated to be about 43.5 million, growing at an annual rate of 2.3% (Ministry for Welfare and Population Development, 1995). This means that 1995 will show a net increase of about 1 million in our population who will need to be accommodated in the allocation of resources, i.e. creation of 1 million jobs in due course, construction of 500 000 housing units, producing food, and supplying water for the additional people.

The current situation as far as water supply is concerned, is that a large fraction of the population do not have an adequate water supply and/or sanitation facilities of an acceptable level (Department of Water Affairs and Forestry, 1994). Projections of future water demands based on the current situation will not give a realistic picture and projections are therefore made for the year 2015 when the "1995 million" reach adulthood and the imbalances in water supply and sanitation will have been corrected.

General approach

The scope of the study is limited to a desk study comprising the collection and analysis of readily available data.

The approach followed in establishing the full water demand of a person was to develop a water balance for an individual by incorporating the most important facets of life in which water plays a role. In this process a number of assumptions had to be made. These were made in consultation with people knowledgeable in the particular field, and/or from information in the literature. Many of these assumptions are only estimates and open to debate since the many factors which influence water usage vary over extremely wide ranges.

The water balance was made for different levels of lifestyle or consumption in order that different population profiles could be evaluated to arrive at a figure for the predicted water demand for the additional 1 million people.

An important premise of the analysis is that the objectives of the Reconstruction and Development Programme (RDP) would be successful in improving the living conditions of the poor section of society to the level where water and sanitation services of acceptable level would be available to all.

Domestic water demand

Domestic water use comprises a number of components, including drinking, personal hygiene, sanitation, and gardening. Current levels of direct water use vary from 25 *ℓ*/c·d (the so-called lifeline level) to higher than 400 *ℓ*/c·d for the very high consumption

* To whom all correspondence should be addressed.
☎(012) 420-3571; fax (012) 436683; e-mail schu-cf@fanella.ee.up.ac.za
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TABLE 1
DOMESTIC WATER USE 1994

Level of living index	Water use (ℓ/c·d)								
	Drink/ cook	Dish wash	House wash	Clothes wash	Bath/ shower	Garden	Toilet	Pool	Total
Very low	3	2	1	3	15	0	0	0	24
Low	4	3	1	4	20	18	0	0	50
Moderate	4	4	2	4	40	26	0	0	80
High	4	10	3	6	92	100	30	5	250
Very high	4	15	5	8	163	200	40	15	450

group. According to the International Water Supply Association (IWSA, 1995) the average specific water consumption was 276 ℓ/c·d for people served by water reticulation systems in South Africa in 1993.

Table 1 gives figures for domestic water use for different levels of consumption for 1994, adapted from Van Schalkwyk (1996).

In order to estimate the domestic water demand for different levels of consumption in 2015 the following **assumptions** are made:

- Due to the limited availability of water, the awareness of water conservation will increase. Tariffs will increase on a sliding scale penalising high levels of consumption with the result that the size of stands for housing in the high and very high income groups will decrease. As a result the high and very high levels of consumption will decrease or remain stagnant, mainly due to smaller gardens and changes in gardening practices.
- On the other hand, water use will increase in the low and moderate consumption groups due to increased standards of living. The use of washing machines and dishwashers will increase, resulting in higher *per capita* water use.
- It is assumed that only the very low and rural levels of consumption will use on-site sanitation systems which could include VIP or Aqua Privy types of systems. The higher levels will be served by water-borne sewerage systems connected to sewage treatment works. However, the use of water for toilet flushing will decrease from the current 9 to 12 ℓ per flush to 2 to 8 ℓ per flush through the use of modifications to ensure effective flushing with small volumes of water.
- Water losses from the distribution system, i.e. actual leakage and other losses, must be taken into account and apportioned to individual usage. It is assumed that losses will not exceed 10%. Figures for unaccounted-for water (which includes unmetered usage and meter inaccuracies) can be as high as 20 to 30% but these are not taken into consideration.

Taking the above assumptions into account the following usage figures (Table 2) are projected for 2015.

In addition to the direct or domestic demand the indirect water demand to sustain a particular lifestyle must be determined. This consists of water for the production of food, energy, consumer goods and to develop employment opportunities.

Water requirements for food production

For the purposes of this study only the following major categories of food are considered. The list is certainly not exhaustive but the contribution of minor products to the water demand for food production would not make any material difference to the total.

Protein

- **Red meat**: The total amount of water required to produce 1 kg of meat consists of three main components, i.e. water consumed by the animal over its lifespan, the water used to produce food for the animal and water usage for slaughtering, packaging and transport.

  The drinking-water requirements and water usage for slaughtering are well documented but requirements for feed production vary over an extremely wide span, i.e. from only rainfall where cattle are raised on natural pastures to very high water demands where animals are kept in intensive feedlot systems. In order to arrive at a meaningful figure for this component a number of assumptions have to be made as discussed further on.

  - **Cattle drinking-water requirements**: From the figures of Ensminger et al. (1990), given in Table 3, the total water intake for cattle to reach a body mass of 350 kg is around 9 300 ℓ.

    Slaughtering yields a carcass of about 55% of live mass, offal 9% and the rest comprising skin, paunch contents, blood and other wastes (Water Research Commission, 1989a). A live mass of 350 kg will therefore yield carcass plus offal of 224 kg for 9 300 ℓ water consumed, or 42 ℓ/kg meat produced.

  - **Slaughtering**: The mean specific water intake of South African abattoirs is 1 360 ℓ per cattle unit for grade A abattoirs and 2 040 ℓ per cattle unit for other abattoirs (Water Research Commission, 1989a). Eighty per cent of the total volume of slaughtering is handled by grade A abattoirs which gives an average figure of 1 500 ℓ/cattle unit of 225 kg or 7 ℓ/kg meat produced.

  - **Feed production**: Feed can be produced on dry lands (no irrigation) or under irrigation, e.g. lucern. Total water requirements for feed production are about 500 ℓ/kg (Nel et al., 1985). Although only about 1% of South Africa's agricultural land is irrigated, it contributes between 25 to 30% of gross agricultural production (Backeberg and Klopper, 1991). Crops produced for livestock production account for the largest area under irrigation (Scotney and Van der Merwe, 1991). It seems therefore reasonable to

TABLE 2
PROJECTED DOMESTIC WATER USE FOR 2015

Level of living index	Water use (ℓ/c·d)									
	Drink/ cook	Dish wash	House wash	Clothes wash	Bath/ shower	Garden	Toilet	Pool	Total	Corrected for 10% loss
Very low	3	2	2	4	20	5	0	0	36	40
Low	4	5	3	6	35	20	20	0	93	102
Moderate	4	5	4	6	50	35	15	0	119	131
High	5	6	4	8	80	80	20	8	211	232
Very high	5	10	5	8	120	100	30	15	293	322

Very high: Very high income, very large house and stand with extensive gardening activity. Direct water use > 300 ℓ *per capita* per day (ℓ/c·d).
High: High income, large house or flat or cluster housing, moderate garden. Direct water use 200 to 300 ℓ/c·d.
Moderate: Moderate income. Small house or flat, small garden. Direct water use 100 to 250 ℓ/c·d.
Low: Low income. Very small house. Direct water use 50 to 150 ℓ/c·d.
Very low: Very low income. Shack type housing. Direct water use <50 ℓ/c·d. The majority of rural dwellers living in traditional dwellings are included in this group.

TABLE 3
AVERAGE DAILY WATER INTAKE FOR LIVESTOCK (ENSMINGER ET AL., 1990)

Weeks and years	Body mass(kg)	Condition	Water intake(ℓ/d)
4 weeks	51	growing	0.3 - 5.7
8 weeks	69	growing	5 - 7
12 week	93	growing	8 - 9
16 weeks	119	growing	11 - 13
20 weeks	148	growing	15 - 17
26 weeks	189	growing	17 - 23
60 weeks	354	growing	23 - 30
84 weeks	464	pregnant	30 - 38
1 - 2 years	464 - 545	fattening	30 - 34
2 - 8 years	545 - 726	lactating	38 - 95
2 - 8 years	545 - 726	grazing	17 - 34

assume that 10% of the total water requirements for feed production is derived from irrigation. If it is further assumed that the feed to carcass conversion ratio is 6, then the water requirements to produce feed for a carcass of 225 kg are : 225 kg x 6 (conversion) x 500 ℓ/kg x 0,10 = 67 500 ℓ per animal or 300 ℓ/kg meat.

Total water requirements to produce 1 kg of beef:

- on an extensive basis: 42 + 7 = 49 ℓ/kg
- on an intensive basis (assuming 10% water needs supplied through irrigation) 42 + 7 + 300 = 349 ℓ/kg.

In order to arrive at an average figure for beef production an assumption must be made as to the relative numbers of cattle from intensive and extensive farming. It can be expected that the number of cattle produced in feedlots will increase over the next 20 years so that a 50 : 50 assumption can be made, giving an average of 199 ℓ/kg beef or 20 ℓ/100 g portion.

- **White meat (poultry)**: Chickens consume about 10 ℓ of water and 3.5 kg of feed over a 50-d lifespan to reach a body mass of 1.8 kg and yield 1.2 kg meat plus offal. The specific water intake for slaughtering and packaging is 17 ℓ/bird for grade A abattoirs and 20 ℓ/bird for other grades (Water Research Commission, 1989b).

If the water requirement for feed production is again taken as 500 ℓ/kg feed and if it is assumed that 10% of the water requirement is supplied through irrigation, the water requirements for feed to produce a chicken of 1.8 kg are 500 x 3.5 x 0.10 = 175 ℓ/bird or 146 ℓ/kg.

Total water requirements: 10 + 146 + 17 = 173 ℓ/kg.

- **Fish**: The total freshwater requirement to process and package fish is about 8.5 ℓ/kg (Water Research Commission, 1983).

- **Milk**: The water intake of lactating cows varies from 38 to 95 ℓ/d (Ensminger et al., 1990) or conservatively taken as 4 ℓ water per litre of milk. Feed intake of lactating cows is about 2.5 kg per litre milk produced.

If it is again taken that the total water requirements are 500 ℓ/kg feed and that 10% of water needs is supplied through

irrigation, the water requirements for feed for milk production are 2.5 x 500 x 0.10 = 125 ℓ/ℓ of milk.

Processing and packaging require a further 2 ℓ/ℓ of milk (Water Research Commission, 1989c) giving a total of 4 + 125 + 2 = 131 ℓ water/ℓ of milk.

Carbohydrates

- **Bread**: An 800 g loaf of bread requires about 500 g of wheat and the water requirements for wheat production are about 600 ℓ/kg (Nel et al., 1985). If it is assumed that 25% of the water requirements for wheat production is supplied through irrigation the water supply required to produce one bread is therefore 0.5 kg x 600 ℓ/kg x 0.25 = 75 ℓ per bread.

- **Sugar**: Sugar cane production of 60 t/ha.a requires 750 mm of water (Department of Forestry, 1974) and this yields about 6 to 8 t of sugar per ha, or 1 070 ℓ/kg sugar. If it is assumed that 15% of the water requirements for sugar production is supplied through irrigation, the average figure is 161 ℓ/kg sugar produced. Water consumption during processing will add a relatively small amount of about 10 ℓ/kg (Water Research Commission, 1990a).

  Total water requirements : 161 + 10 = 171 ℓ/kg sugar.

- **Maize**: Total water requirements are 500 ℓ/kg (Nel et al., 1985) and if 5% of water needs is supplied through irrigation, the average irrigation demand is 25 ℓ/kg.

Vegetables

The water requirements for vegetable production vary widely, e.g. for cabbage it is 34 ℓ/kg, tomatoes 48 ℓ/kg and green beans 88 ℓ/kg (Nel et al., 1985), say 45 ℓ/kg on average.

Liquid beverages

- **Beer**: Beer production and packaging requires about 7 ℓ water per ℓ beer (Water Research Commission, 1987a), while malting adds a further 2 ℓ/ℓ beer. The corresponding figures for sorghum beer are 3.5 and 2.5 ℓ/ℓ beer (Water Research Commission, 1989d).

  The production of raw materials for beer brewing, i.e. barley, hops, sorghum, maize, sugar can be approached in the same way as for feed production as 500 ℓ water/kg product of which 15% is assumed to be supplied through irrigation. This gives for 0.2 kg solids per ℓ beer: 0.2 x 500 x 0.15 = 15 ℓ/ℓ beer. Total average water requirements for beer and sorghum beer production are 9 + 15 = 24 ℓ/ℓ beer.

- **Wine**: Wine produced on non-irrigated lands requires about 5 ℓ water per ℓ of wine for processing and packaging. On irrigated land the irrigation requirements are about 350 mm during the growing season (KWV, 1995). At a grape yield of 20 t/ha and a wine yield of 0.7 ℓ/kg grapes the water requirements to produce wine are 250 ℓ/ℓ wine.

  If it is assumed that 25% of the wine is produced under irrigation the average water requirement per 750 mℓ bottle of wine is 0.75 (250 x 0.25), i.e. 47 ℓ/bottle of wine.

- **Soft drinks**: Production and packaging of soft drinks require about 3 ℓ/ℓ product (Water Research Commission, 1987b). The raw material (mainly sugar) constitutes about 0.12 kg/ℓ product with a water requirement of 0.12 x 171 = 21 ℓ/ℓ giving a total of 24 ℓ/ℓ product.

Water requirements for consumer goods

- **Energy**: The main water usage in power generation is for evaporative cooling which accounts for the largest part of the average 1.8 ℓ per kWh of electricity generated (Department of Water Affairs, 1986).

- **Paper**: Paper is used in the form of newspapers, magazines, books, packaging, etc. One kg of paper requires about 3.2 kg of wood. Forests are not irrigated but they consume water which could otherwise have been used as water supply. At 5.1 t/ha.a wood production and 55 mm water retention a figure of 108 ℓ water/kg wood can be assumed which translates to about 346 ℓ/kg paper (Department of Forestry, 1974).

  Paper and paper products manufacturing adds a further 44 ℓ/kg (Water Research Commission, 1990b) giving a total of 390 ℓ/kg of paper.

- **Textiles and clothing**: Both the production of wool and textiles and the processing thereof require large volumes of water. For example, figures of around 2 000 ℓ/kg of cotton are quoted (Steyn, 1995). If it is assumed that 15% of these requirements come from irrigation, the overall requirements are 300 ℓ/kg.

  The production of wool (5 kg/a-sheep and a water consumption of 1 500 ℓ/a) also requires about 300 ℓ/kg (Ensminger et al., 1990).

  Textile processing consumes large volumes with figures of 80 to 600 ℓ/kg for cotton and 100 to 600 ℓ/kg for wool processing (Water Research Commission, undated).

  Total water requirements could therefore be taken as 300 + 300 = 600 ℓ per kg of textile produced.

- **Other products and services**: There are many other products and services used daily where water plays a role, e.g. transport, construction, provision of infrastructure and production of a variety of consumer goods. For the purpose of this study these are not further investigated since their contribution is expected to be relatively small. However, this means that the total water estimate will be underestimated.

Employment

The water needed to support economic and industrial activity to create one employment opportunity is extremely difficult to estimate and it can vary from very low in administrative jobs to very high in the mining and industrial sectors. Water requirements for employment in the administrative sector include water for personal use; support services, e.g. cleaning and electricity; consumables such as paper. A figure of 50 ℓ/job can be regarded as realistic on the conservative side (taking into account the 400 ℓ/kg paper needed).

On the other side of the spectrum an average figure of 267 ℓ/c·d for industrial use in 1993 in South Africa is given (IWSA, 1995). This is the average figure taken over a population of 40 million. The economically active population is only about 15 million (Ministry for Welfare and Population Development, 1995) and if it is assumed that 30% of the economically active population is employed in the industrial and mining sectors, the

TABLE 4
SUMMARY OF WATER REQUIREMENTS FOR THE PRODUCTION OF FOOD AND CONSUMER GOODS

	Red meat ℓ/kg	Poultry ℓ/kg	Fish ℓ/kg	Milk ℓ/ℓ	Bread ℓ/bread	Sugar ℓ/kg	Maize ℓ/kg	Fruit & vegetables ℓ/kg	Beer ℓ/ℓ	Wine ℓ/bottle	Soft drinks ℓ/ℓ	Energy ℓ/Kwh	Paper ℓ/kg	Textiles ℓ/kg
Direct consumption/ application	42	10	-	4	-	-	-	-	-	-	-	-	-	-
Feed production/ irrigation	300	146	-	125	75	161	25	45	15	47	21	-	346	300
Processing	7	17	8.5	2	-	10	-	-	9	4	3	2	44	300
Total	349	173	8.5	131	75	171	25	45	24	52	24	2	390	600

TABLE 5
PROJECTED EMPLOYMENT PROFILE OF ENTRANTS TO JOB MARKET, 2015

Category	% of population in category	Water demand ℓ/c·d for category	Weighted water demand ℓ/c·d
Formal sector industrial	12.5%	2373	297
Formal sector administrative	12.5%	50	6
Self-employed manufacturing	20%	150	30
Self-employed other	35%	50	18
Not employed	20%	-	-
		Total	351 ℓ/c·d

TABLE 6
PROJECTED CONSUMPTION OF FOOD AND CONSUMER GOODS AND USE OF SERVICES IN 2015

Level Item	Protein g/c·d	Milk mℓ/c·d	Sugar g/c·d	Bread and wheat products g/c·d	Maize g/c·d	Fruit and vegetables fresh and canned	Liquid beverages mℓ/c·d	Paper g/c·d	Energy kWh/c·d	Textiles and related products g/c·d
Very low	100	100	20	120	100	100	100	50	2	5
Low	120	120	30	140	100	120	120	100	4	10
Moderate	150	150	50	160	80	140	150	150	10	20
High	200	200	80	170	60	160	200	250	15	35
Very high	200	200	100	180	50	180	250	350	20	50

water consumption per job in these sectors increases to 2 373 ℓ/job·day.

In order to arrive at an average figure for jobs across the whole spectrum of formal and informal, industrial and administrative sectors, the composition of new jobs for the 1 million job seekers in 2015 is assumed to be as given in Table 5 giving a weighted water demand per job of 351 ℓ/c·d.

Projected total water demand

In order to determine the total water demand of an individual, assumptions have to be made regarding consumption of food and consumer goods, and use of commodities and services for the different levels of consumption in the year 2015. These assumptions are open to debate but it is believed that variations in these figures will not make any major difference to the total values. The projected consumption and water requirements are summarised in Tables 6 and 7.

The *per capita* water requirements in Table 7 have been calculated from the values in Tables 2, 4, 5 and 6 and are based on the following assumptions:

- It is assumed that both the quantity and composition of protein will vary with the level of consumption. The lower the level, the higher the proportion of cheaper protein, i.e. fish, poultry and canned protein.
- Energy requirements are projected on the assumption that electrification will proceed at such a rate that the use of coal and wood for domestic purposes will be relatively small by 2015.

TABLE 7
PROJECTED *PER CAPITA* WATER REQUIREMENTS BY THE YEAR 2015 IN ℓ/c·d

Level	Protein and milk	Carbo-hydrates	Fruit and vegetables and drinks	Consumer goods	Employment (Table 5)	Domestic (Table 2)	Total
Very Low	15	23	7	25	351	40	461
Low	25	30	14	50	351	102	572
Moderate	45	30	23	100	351	131	680
High	70	40	30	150	351	232	873
Very high	90	42	36	265	351	322	1106

TABLE 8
PROJECTED TOTAL WATER USE OF 1 MILLION PEOPLE IN 2015 (Mℓ/d)

Level	% of total population	Weighted domestic water demand		Weighted indirect water demand		Weighted full water demand	
		ℓ/c·d	weighted Mℓ/d	ℓ/c·d	weighted Mℓ/d	ℓ/c·d	Weighted Mℓ/d
Very low	25	40	10	421	105	461	115
Low	25	102	26	470	117	572	143
Moderate	35	131	46	549	192	680	238
High	10	232	23	641	64	868	87
Very high	5	322	16	784	39	1 106	55
Total	100	-	121	-	517	-	638

Projected water demand for 1 million people in 2015

The full water demand in 2015 of the 1 million people introduced into the population in 1995 will depend on the composition of this group in terms of level of consumption.

A likely scenario for the composition of this group in the view of the authors is given in Table 8, which gives a projected full water demand of 638 Mℓ/d.

Discussion

The average full water demand figures estimated in this paper are not meant to be absolute figures but rather as an indication of the volume of water required to sustain an individual at a certain lifestyle level. Many of the assumptions are open to debate but, in the view of the authors, the assumptions are on the conservative side. In addition, there are many areas where water is required which have not been taken into consideration because they are regarded as relatively small. This means that the actual figures would be higher than those estimated in this paper.

The figures given in Table 8 indicate that the projected domestic water demand (water supply to residences) accounts on average for only about 20% of the total water demand of an individual. The largest fraction, i.e. 80% of the total is required for the production of food and consumer goods and to provide employment (or self-employment) opportunities.

The total estimated water demand figure for the year 2015 of the 1 million people born in 1995 of 638 Mℓ/d or 233 x 10^6 m^3/a can be seen in perspective when compared with the average supply from Rand Water or with a scheme such as the Lesotho Highlands Scheme.

- The projected water demand for the 1 million people is 23% of the total average water supply of 2 832 Mℓ/d from Rand Water in 1994/1995 (Rand Water, 1995). This means that just for the population increase of over 4 years an additional supply equivalent to the total current supply of Rand Water is required.
- Phase 1A of the Lesotho Highlands Scheme will deliver 18 m^3/s or 1 555 Mℓ/d (Department of Water Affairs and Forestry 1995). This means that the water demand for the population increase over less than 2½ years is equivalent to the total delivery of the multi-billion Rand phase 1A of the Lesotho Highlands Scheme.

Conclusions

The projected full water demand to sustain an individual in the year 2015 ranges from 461 ℓ/c·d for people at a very low lifestyle level to 1106 ℓ/c·d for the very high level; giving a weighted average of 638 ℓ/c·d, conservatively estimated.

The projected full water demand of the 1 million people introduced into the population in 1995 will be 638 Mℓ/d in 2015 when they reach adulthood. This is equivalent to almost one quarter of the average daily water supply of Rand Water 1994/95 (Rand Water, 1995) which gives an indication of the tremendous pressure on our water resources as a direct consequence of the current levels of population growth.

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