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STAKEHOLDER ACCORD ON WATER CONSERVATION

Guideline for Baseline Water Use Determination and Target Setting in the Manufacturing Sector SAWC G3



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DOCUMENT INDEX

This is the third document in the following series of guidelines for the determination of Baseline Water Use and Target Setting for various economic sectors:

SAWC G1	Irrigation Sector
SAWC G2	Commercial Sector
SAWC G3	Manufacturing Sector
SAWC G4	Mining Sector

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GLOSSARY

Absolute water use	The amount of water used, in volume terms, over a defined period.
Aqueous phase	In margarine manufacture an emulsion is produced through high-shear mixing of an oil phase and an aqueous phase, the latter being a mixture of specific ingredients in water, or in some cases milk.
Baseline water use	Water consumption status at the beginning of a water conservation programme. Baseline measurements are used as a reference point for determination of a site's water savings as it completes its water conservation plan.
Benchmark	A quantitative measure of performance or qualitative practice against which other levels of performance or other practices may be compared.
Blow down	The discharge of concentrated cooling water from a cooling water loop. Concentration of salts occurs due to evaporation of water during the cooling process. Blow down is also carried out to remove other pollutants, such as organic matter for example.
Centrifuge	Device used to separate materials of differing density through the application of centrifugal force.
Centrifugal pump	A device used to increase the pressure of a fluid, thereby causing it to flow, through the use of a rotating impeller.
Cooling towers	Structures used to cool water through an evaporative process in which the water is exposed to air in counter-current flow.
Condensate	Steam that has been condensed into the liquid phase.
Condensate make-up	Water added to a steam production system to compensate for losses of condensate.
Condensate trap	A device installed to remove condensate from pipelines carrying steam.
Consumptive water use	Water use that removes water from the immediate environment and does not make it available to other users in the form of a liquid discharge. Consumptive use is generally a term applied to uses resulting in evaporation, evapotranspiration or incorporation into products.

GLOSSARY

Culinary steam	Steam that can be brought into contact with food products without impacting on their safety for human consumption.
Drift	Loss of water droplets through the top of a cooling tower as a result of the air draft. Can be reduced by installing drift eliminators.
Differential pressure cell	Also called a “d.p. cell”, this device is used to measure the liquid level in vessels or impoundments based on the difference in pressure between the pressure at the bottom of the liquid column and the pressure in the gases above the liquid surface, taking consideration of the density characteristics of the liquid.
Dust suppression	The process whereby the movement of dust is controlled/prevented, typically through the application of water sprays.
Energy balance	Calculations used to account for the flow of energy between materials, the fundamental basis of which is that energy is conserved.
Flash steam	Steam formed when high temperature, high pressure condensate experiences a drop in pressure e.g. when it is discharged into a vessel at atmospheric pressure.
Gas scrubbing	The process whereby gases are brought into contact with a fluid with the intent of removing solid, liquid or gaseous components from the gas stream through incorporating them into the fluid. In the context of this guide, the gas scrubbing referred to involves the use of water, though other fluids may be used.
Grey water	Water recycled from showers, sinks and wash basins.
Harvested rainwater	Rainwater that is not returned to the stormwater system but is collected for use on site.
Heat capacity	The amount of energy required to raise the temperature of a unit mass of a substance by one temperature unit without changing the phase of the substance.
Heat exchanger	A device used to exchange heat between two fluids, generally without the fluids being brought into direct contact.

GLOSSARY

Internal recycling	Water that is recycled on site after it has already been used. Internally recycled water should not be added to site water use, as it was already recorded as a water use when it was used for the first time.
Key performance indicators	The most important measures of water use performance, as chosen by users or other stakeholders.
Latent heat of vaporisation	The amount of energy required to convert a unit mass of a substance from the liquid phase to the vapour phase at constant temperature.
Lautering	In brewing, the filtration process whereby the liquid extract and malt husk components of a mash are separated, aided by the application of water sprays.
Load cells	Devices used to measure mass through measuring the amount of strain caused by the load. The strain is converted into a resistance value, which is ultimately converted to a mass reading.
Magnetic flow meter	Also called a “magflow”, this is a type of flow meter which measures the strength of the voltage generated by charged particles moving within a magnetic field generated by the meter. This voltage is proportional to the velocity of the particles, which is then related to the flow rate of the fluid being handled.
Malt mash	In brewing, a mixture of milled malt and water that is subjected to defined temperature and pH conditions in order to determine the sugar and (to a lesser extent) protein/amino acid spectrum of the resulting extract.
Mass flow meter	A device used to measure the mass flow rate of a fluid.
Mulching	The practice of covering soil (using natural or synthetic materials) in order to reduce moisture loss, prevent weed growth and prevent soil erosion.
Pasteurisation	The process of rendering a food product free of bacteria through the application of heat.
Potable water	Water of high enough quality to be used for human consumption without any short or long-term health effects. In the context of this guideline, this is treated water supplied by water service providers.

GLOSSARY

Pinch Technology	An approach used to minimise water or energy consumption through integrating the various process on a site, and matching water or energy sources to water or energy sinks, reducing the need for “fresh” water or energy sources by reusing available sources that would otherwise be wasted.
Preventive maintenance	Maintenance that is carried out to prevent failures from occurring (as opposed to maintenance carried out to correct failures that have occurred).
Point-of-use conservation	With reference to water conservation, this refers to techniques employed to reduce the amount of water used by individual processes at the point where the water is used.
Pulp	In papermaking, a suspension of fibres in water.
Raw water	Water from boreholes or surface water resources that is in an untreated form.
Saturated steam	Steam in which the liquid and vapour phases are in equilibrium, and for which pressure is a function of temperature. Removing energy from saturated steam causes it to start to condense.
Stormwater	Rain water diverted into drainage systems for transport to surface water resources.
Superheated steam	Steam for which pressure is independent of temperature. Removing energy from superheated steam will not cause it to condense unless sufficient energy is removed to cause the steam to become saturated, after which it will start to condense should additional energy be removed.
Thermal pollution	The increase in temperature, with consequent environmental degradation, of a water body, resulting from the discharge of water/effluents of higher temperature than that of the water body into the water body.
Unit operation	An individual process step within a bigger manufacturing process.
Viability	A viable conservation initiative is one which meets criteria that justify its implementation. These criteria are at the discretion of the implementing organisation.
Water audit	A process whereby all water on a site is accounted for, with the object of identifying losses and sources of inefficiency.

GLOSSARY

Water balance	A calculation/assessment technique in which all water into and out of a site is accounted for, using the principle that the amount of water entering the site (in solid, liquid or gaseous form) should be equal to the amount of water leaving the site. It is also possible to account for water retained on the site, a useful approach should inventories be large or where the balance is conducted over short time intervals.
Water conservation	The process whereby the amount of water used for an activity is reduced without impacting on the outcomes of the activity.
Water efficiency	The accomplishment of a function, task, process, or result with the minimal amount of water feasible. Water efficiency aims to reduce the waste of water and not restrict the use thereof.
Water intensity	Water use per unit of economic activity. In the case of the manufacturing sector, this is expressed as the amount of water used per unit of production. The lower the water intensity of a manufacturing operation, the more efficient it is.
Weigh bridge	A platform onto which vehicles may be driven in order to determine their mass. Vehicles are typically weighed before and after product is delivered or loaded, with the difference being the mass of product supplied to or by the site.
Work practices	The practices and procedures followed on a manufacturing site.

ABBREVIATIONS

CIP	Clean in place
hl	Hectolitre = 100 litres
IISI	International Iron and Steel Institute
KL	Kilolitre
KPI	Key performance indicator
L	Litres
m	Metre
mm	Millimetre
UNEP	United Nations Environment Programme
YOY	Year on year
WSP	Water Services Provider

1 INTRODUCTION

1.1 Overview

This is one of a series of guidelines outlining the steps to follow at site-level for the:

- i. Determination of baseline water use levels and;
- ii. Setting of water use targets, within the context of a water conservation programme.

In particular, this guideline supports the objectives of the Stakeholder Accord on Water Conservation, and the chosen water use performance indicators are aligned to those required for reporting as agreed by Accord stakeholders.

This guideline applies to the MANUFACTURING sector, which comprises those sites that convert raw materials into items of value, generally through the use of equipment and controlled processes. Included in this sector would be sites that conduct assembly operations.

1.2 Guideline objectives

The objectives of this guideline are to ensure that participants in the Stakeholder Accord on Water Conservation within the manufacturing sector receive guidance on:

- How to categorise the key water-using processes for their individual sites;
- What the water use and water intensity measures appropriate to the manufacturing sector are in terms of the requirements of the Stakeholder Accord on Water Conservation;
- How to determine baseline water use;
- How to identify opportunities for water conservation and;
- How to translate identified conservation opportunities into short and long-term water use and water intensity targets.

1.3 When to use this guideline

This guideline has been developed specifically to support the Stakeholder Accord on Water Conservation. It is however also of use in the following general circumstances:

- When developing a water conservation plan;
- As input to planning and budgeting processes.

1.4 Principles adhered to in this guideline

This guideline is based on the principles governing the Stakeholder Accord on Water Conservation and assumes that baseline determination and target setting would be undertaken at site level on a voluntary basis. The use of this guideline is not mandatory, but it is rather a tool aimed at supporting water users in the sector in their water conservation efforts. It is assumed that this guideline is implemented within the regulatory framework governing water use, taking cognisance of all environmental impacts related to the implementation of water conservation projects.

1.5 Structure of this guideline

This guideline is based on the concepts of water auditing. The approach followed in this guideline is comprised of the following steps:

- Determination of the absolute water use and water intensity baselines for the site;
- Identification of potential water conservation initiatives;
- Quantification of water savings expected from implementation of these water conservation initiatives;
- Determination of expected absolute water use targets for future years by subtracting water savings from viable conservation initiatives from the baseline. Both savings and the baseline may also be related to the level of production projected for the manufacturing entity;
- Repetition of this process annually for a rolling five-year period.

The guideline briefly discusses the nature of water use in the manufacturing sector and then defines a generic water balance for the manufacturing site. Thereafter the guideline describes key performance indicators (KPI's) relevant to the sector, to be used as a basis for determining absolute water use and water intensity baselines. Once the process to be used for determination of these baselines has been described, a methodology for the incorporation of water savings into the target setting process is described.

2 WATER USE IN THE SECTOR

2.1 Overview

For the purposes of this document, the manufacturing water-use sector is defined as comprising enterprises in which the primary assets employed in the conducting of business are plant and equipment and their surrounds (i.e. raw material storage areas, parking areas, gardens and outdoor amenities), typically delineated by a physical boundary. These assets are used to convert raw materials into products of higher value. The manufacturing sector would also include industries that assemble components into finished goods. While this guideline applies to any sub-sector in manufacturing, the type of water used, the quantity of water used and the patterns of water use (volume and seasonality) in the manufacturing sector can vary markedly between users based on the nature of their operations. Examples of water use sub-sectors that could use this guideline successfully to determine water use baselines and set water use targets are:

- Food and beverage processors;
- The iron and steel industry;
- The pulp and paper industry;
- The chemical manufacturing industry;
- Agro-processors.

It is also possible to use this guideline for the mineral processing operations of the mining industry, though it is preferable that the guideline: “Guideline for Baseline Water Use Determination and Target Setting in the Mining Sector” is consulted first in this regard.

Manufacturers, both between and within sub-sectors, typically have different water use characteristics, depending on a range of factors such as technology footprint, product mix, processing technique, scale of operations and raw materials used. The idea of this guide is to enable users in the manufacturing sector, regardless of their unique circumstances, to be able to baseline their water use and set meaningful water use targets.

2.2 Typical Water Uses in the Manufacturing Sector

2.2.1 Process water

Process water is defined as water that comes into direct contact with the product being manufactured, and in many cases is incorporated into the product. Some process water may be evaporated or discharged with waste materials during processing. Water incorporated into products is considered to be consumptively used. Examples of the types of operations in which process water is used in South African industry are:

- Slurrying of phosphate rock in phosphoric acid manufacture;
- Lautering of malt mash in the brewing industry;
- Pulp washing in pulp and paper manufacturing;
- Production of the aqueous phase in margarine manufacturing;

- In-package pasteurisation in the dairy industry;
- Washing of reusable containers in the soft drink industry.

2.2.2 Water used for steam production

Most manufacturing sites employ saturated or superheated steam (or both) in their operations, generally for heating purposes. In the food industry, culinary steam is sometimes used for sterilising of vessels or for direct incorporation into products. The steam is produced in boilers, using coal, gas, fuel oil or electricity as an energy source. Where steam is not brought into direct contact with product, or is not used in a consumptive manner on site, it is typically condensed and returned to the boilers as condensate, which is reused to produce steam in a closed cycle.

Despite the condensing of steam, with subsequent reuse of the condensate, it is usual to experience losses from the steam circulation system. As a pressurised system, it is prone to leaks, and there are typically some processes that use live steam, meaning that this steam is lost from the closed loop. Condensate traps upstream of process equipment such as heat exchangers also discharge condensate which, if not recovered, represents a loss of water. In addition losses due to flash steam may also occur where atmospheric pressure condensate recovery tanks are employed. In order to make up for these losses, additional water (commonly called “condensate make-up”) has to be introduced into the steam production system.

2.2.3 Water used for cooling

Water has certain characteristics such as its high heat capacity and high latent heat of vaporisation that make it excellent as a cooling medium. Where water is used for cooling through direct contact, such as in metal casting and iron and steel processing, some water is typically lost through evaporation. Water is also extensively used for cooling through indirect contact, for example through the use of heat exchangers to cool liquids, or jackets in the case of equipment cooling. In these instances the temperature of the water increases, and has to be reduced again before the water can be reused as cooling water. This is typically accomplished through the use of cooling towers, leading to some loss of water through evaporation, drift and windage losses. Dry cooling systems in which the water is cooled with air in a heat exchanger (much like a car radiator system) are also used, preventing evaporative losses, but making the cooling process more dependent on atmospheric conditions. Once-through cooling, in which the warm water returned from the cooling process is directly discharged to surface water resources, is also practised in some industries. This practice can lead to thermal pollution, particularly where the cooling water flows are large relative to the flow of the receiving water body.

2.2.4 Water used for gas scrubbing

Water is commonly used for gas scrubbing in industries such as mineral processing, the chemical manufacturing industry, the sugar industry and power generation, either on its own or as a carrier for chemicals involved in gas scrubbing processes. The water is typically disposed of as an effluent after use

in scrubbing processes, but there are generally opportunities available to recycle some of this water to the scrubber.

2.2.5 Water used for dust suppression

On sites in which the generation of dust is potentially excessive, water is often sprayed onto fine materials to limit dust formation. Chemicals are available to aid in dust suppression, thereby reducing water use for this application, but these should be carefully investigated before use in order to understand any potentially harmful impacts arising from their use.

2.2.6 Water used for cleaning

In food and beverage processing, water is used extensively for cleaning of the surfaces that come into contact with product, such as pipelines and the insides of vessels and equipment. This type of cleaning is called “cleaning in place” or “CIP”. This is typically carried out through the use of specially designed cleaning equipment and the use of cleaning chemicals. Water is used, both to constitute the chemical solutions used for removal of contaminants and for rinsing.

Recycling is a common means of reducing water use for cleaning applications. A typical CIP cycle would entail a preliminary rinse to remove gross solids and remaining liquids, followed by a chemical clean and then a final rinse to remove traces of cleaning chemicals. Through, for example, use of the final rinse water from a cleaning cycle as the preliminary rinse water for subsequent cycles, recycling can be achieved. The reused water is then disposed of along with other site effluents, or treated to allow further reuse, possibly in other process areas.

Besides CIP, water is also used to clean the manufacturing environment i.e. for on-site housekeeping. The amounts used here are typically small relative to other water uses, and would vary depending on the housekeeping and hygiene standards demanded by the sub-sector concerned.

2.2.7 Water used as a carrier for waste materials

Water is used as a carrier for waste materials in some industries, such as in mineral processing and power generation, chemical manufacturing and some sub-sectors of the food industry. Some water may be recovered for reuse where these waste materials are stored on site and systems such as leachate and/or seepage recovery systems are in place.

2.2.8 Water used to operate equipment

Certain specialised pieces of equipment require water for their operation e.g. centrifuges in the food industry, which use water to operate hydraulic pistons, or centrifugal pumps, which use water for sealing purposes. This is different to process water as defined above, since this water is not in direct contact with the product being manufactured. It is however not unusual for the water used here to be aggregated with overall process water use from a water accounting perspective, since it is typically a very small volume

and need not necessarily be accounted for separately. It is also uncommon for this water to be metered, again due to the small volumes involved.

2.2.9 Water used for staff and customer amenities

This refers to water used for drinking and ablutions i.e. by sanitary fixtures such as toilets, urinals and sinks. This is generally a small portion of total water use on a manufacturing site, but may present opportunities for water conservation. Please consult the guide: “Guideline for Baseline Water Use Determination and Target Setting in the Commercial Sector” should you require more information.

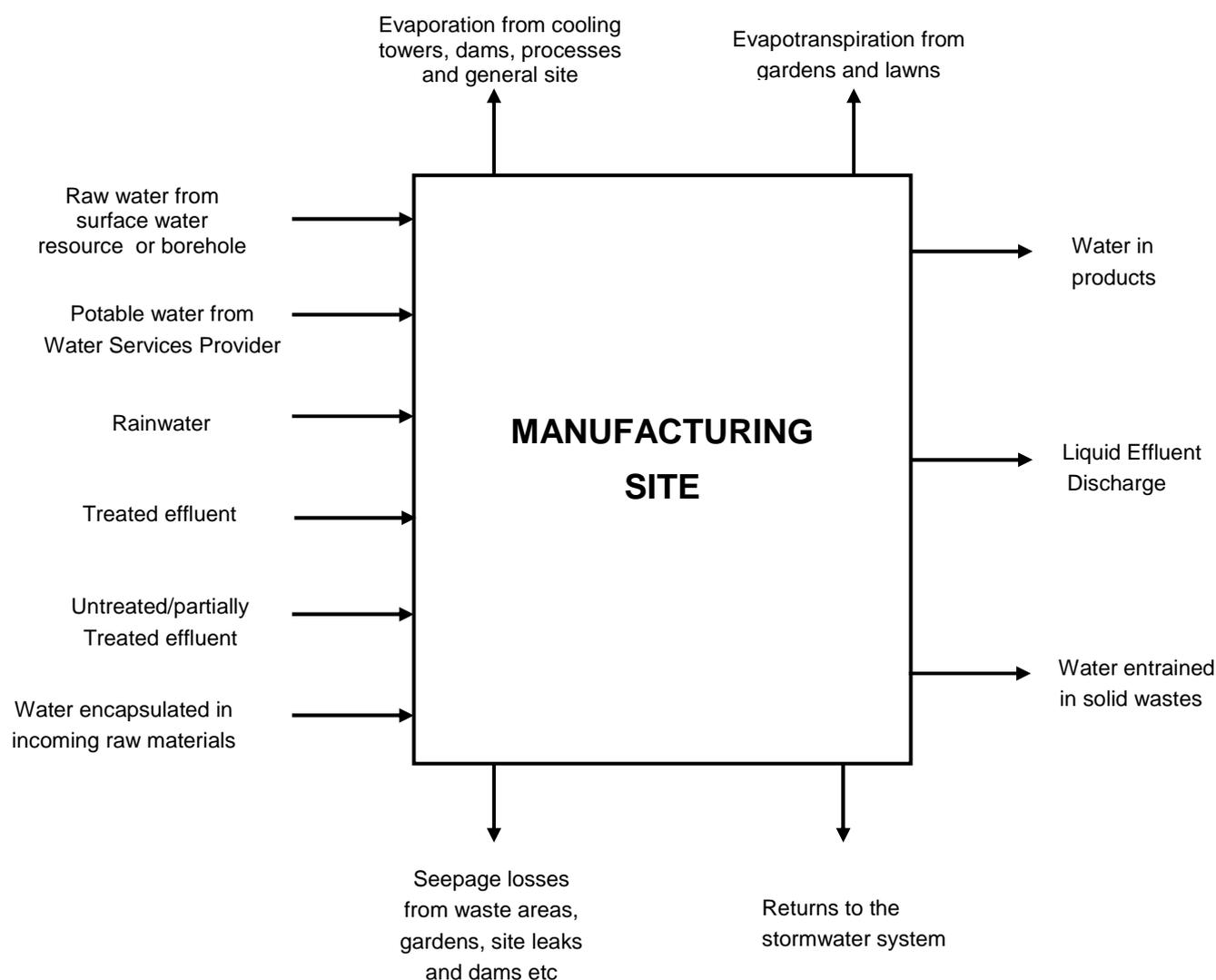
2.2.10 Water used for garden maintenance

This refers to the water used to irrigate gardens within the site boundary and for related uses such as water features. Potable water is often used, but it is possible to use raw water, recycled water or harvested rainwater for this purpose. Please consult the guide: “Guideline for Baseline Water Use Determination and Target Setting in the Commercial Sector” should you require more information.

3 DEFINITION OF THE SITE

In order to define the key performance indicators (KPI's) to be used for baseline water use performance determination and the setting of water use and water use efficiency targets, it is necessary to define the water management system at a typical manufacturing site. Figure 1 below outlines the key components of this system.

Figure 1: Water Management System on a Manufacturing Site



The following are general notes applicable to Figure 1:

- i. "Raw water" refers to untreated water from surface water resources such as rivers or impoundments or water that is sourced from boreholes, either on the site or outside of the site boundary. Some sites may have their own purification plants which may be used to convert some or all of this water to potable water before it is used on site;

- ii. "Potable water" refers to the treated drinking-quality water supplied by WSPs;
- iii. "Water encapsulated in incoming raw materials" refers to water contained in materials that are to be used on site e.g. the moisture content of maize used in industrial starch manufacturing or in the sugar cane used for sugar production;
- iv. "Rainwater" may be directed to on-site stormwater drains, from which it will be diverted to surface water resources, and/or be harvested for use on site, provided this is permitted by the relevant authorities;
- v. "Treated effluent" refers to effluent supplied by others that has been treated and may be used on site without further treatment.
- vi. "Untreated/partially treated effluent" refers to discharges from users outside the site boundary that may either be used without further treatment or treated further before use. A number of untreated/partially treated effluent streams of varying quality may be used on a single site;
- vii. The extent of seepage losses depends on individual geo-hydrological considerations for each site and considerations such as whether dams are lined or not, and if not, the nature of the underlying geology. Many sites employ seepage recovery systems, allowing the water to be captured and reused;
- viii. "Liquid effluent discharge" could comprise treated or untreated process effluents discharged to surface waters and/or to sewer, which would include process as well as domestic effluents generated on the site;
- ix. "Returns to the stormwater system" comprise that portion of rainwater that is not harvested for reuse;
- x. "Evaporation from cooling towers, dams, processes and general site" encompasses all evaporation on site that is not directly recovered, *excluding water evaporated from solid waste materials*;
- xi. "Evapotranspiration from gardens and lawns" refers to evaporation of applied water as well as rainwater from land and plant surfaces, as well as the loss of this water through the stomata of plants. This would include evapotranspiration from planted crops where irrigation water is part of the manufacturing site's water balance;
- xii. "Water entrained in solid wastes" refers to the portion of water discharged with waste materials that is not recovered for reuse on site, and *includes the water that may ultimately be evaporated from solid waste materials*. Examples of waste materials are the brine discharged from a reverse osmosis plant or the water contained in the ash from coal-fired boilers and;
- xiii. "Water in products" refers to the water contained in the products produced on the site, which would be in the form of moisture in the case of solid products or liquid in the case of products such as beverages.

Figure 1 represents the overall water balance for a manufacturing site. It should be clear that by reducing the amount of water leaving the site boundary through evaporation, evapotranspiration, discharges and

entrainment in waste materials, the amount of water that has to be transported across the site boundary for use on site is reduced. The two key ways to achieve this on a manufacturing site are to reduce the amount of water used by individual processes (i.e. "point-of-use" water use reduction) and/or to recycle as much water as possible.

4 KEY PERFORMANCE INDICATORS (KPI's)

4.1 Why Key Performance Indicators are Necessary

KPI's can be established at a number of levels, for example to measure the performance of the entire manufacturing site or to measure the performance of an individual process within a site. Hence KPI's may be established to measure water use for an entire dairy as well for an individual water-using process such as pasteurisation.

Process-level KPI's are considered to be outside of the scope of this document, which considers only site-level performance. More detailed KPI's would have to be developed by users at each site based on the structure of water-demanding processes on that site. These lower-level KPI's would permit improved management of water use efficiency at the site level, as they would typically address the drivers of overall site performance.

The use of standardised quantitative measures of water use performance allows individual sites to track performance over time as well as to benchmark performance against that of other sites.

4.2 Site-level Key Performance Indicators

The two key measures regarding water use at site-level in the manufacturing sector that have been agreed within the context of the Stakeholder Accord on Water Conservation are the following:

- i. The absolute volume of water used, which is an indicator of the demand that a site places on freshwater resources and;
- ii. Water intensity, which is an indicator of the sustainability of the site's water use.

4.2.1 Absolute Water Use

Absolute water use is simply the total volume of water used by a site over a defined time period. The units of absolute water use in the manufacturing environment are m³/annum (which is equivalent to kL/annum). For any particular manufacturing site, the calculation of absolute water use, using Figure 1 as a basis would be:

Equation 1: Absolute Water Use

$$\begin{aligned} \text{Absolute Water Use} = & \text{potable water use / annum} + \text{raw water use / annum} \\ & + \text{harvested rainwater / annum} + \text{treated effluent / annum} \\ & + \text{untreated or partially treated effluent / annum} \end{aligned}$$

Note that the water encapsulated in incoming raw materials is excluded from this figure, in line with the approach used by the Global Reporting Initiative. This water remains an important consideration when conducting a site water balance, which is an important problem-solving tool in the management of water use efficiency at site level.

Example 1:

A chemical manufacturing plant uses 900,000 m³/annum of potable water, 300,000 m³/annum of raw water, 30,000 m³/annum of harvested rainwater and 450,000 m³/annum of untreated effluent from a neighbouring steel mill. What is the absolute water use of the site?

$$\begin{aligned} \text{Absolute water use} &= 900,000 \text{ m}^3/\text{annum} + 300,000 \text{ m}^3/\text{annum} + 30,000 \text{ m}^3/\text{annum} + \\ &\quad 450,000 \text{ m}^3/\text{annum} \\ &= \underline{1,680\,000 \text{ m}^3/\text{annum}} \end{aligned}$$

4.2.2 Water Intensity

An efficient water user uses the minimal amount of water feasible to achieve a given outcome or result. The measurement of water use efficiency therefore requires an indication of absolute water use as well as a measure of the level of economic activity associated with that level of water use.

For manufacturing sites, the measure of water use efficiency generally used is that of “water intensity”, which relates water use over a defined time period to the mass or volume of production over that same period.

Equation 2: Water Use Intensity

$$\text{Water Use Intensity} = \text{Absolute Water Use} / \text{Production Activity (Quantity Produced)}$$

Example 2:

The chemical plant in example 1 produces 3,360 tons of product per annum. What is the water intensity of the site?

$$\begin{aligned} \text{Water intensity} &= 1,680,000 \text{ m}^3/\text{annum} \div 3,360 \text{ tons/annum} \\ &= \underline{500 \text{ m}^3/\text{ton}} \end{aligned}$$

Water intensity values alone do not provide complete information on how efficient the site is. For a more complete view on how efficient a site is, comparison to appropriate benchmark values would be required. Water intensity values do however provide a measurement that can be used to monitor trends in water use efficiency at a site. Figure 2 below outlines how trends of water intensity may be interpreted as regards water use efficiency at an individual manufacturing site.

Figure 2 examines the water intensity trend at a manufacturing site over a period of 4 years. The dashed line represents the minimum feasible water intensity at the site, which is the water intensity level the site could achieve if all feasible water conservation initiatives were implemented. The site is seen to experience an increase in water intensity (and hence a decline in water use efficiency) between Year 1 and Year 2, after which water intensity decreases. By year 4, a steady decrease in water intensity is apparent, indicating increasing levels of water use efficiency.

Figure 2: Example of a Water Intensity Trend at a Manufacturing Site

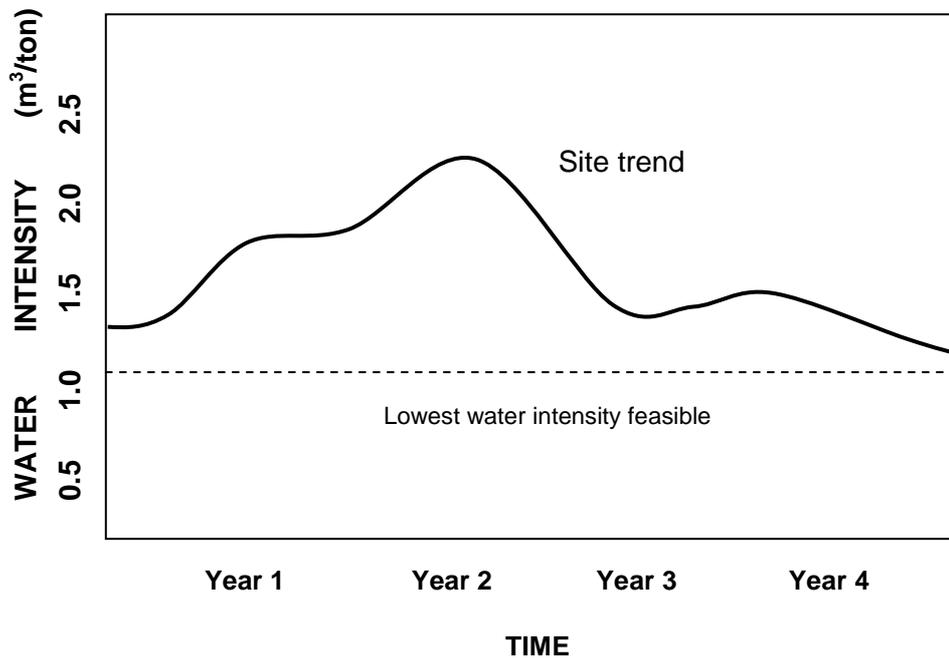


Table 1 below contains the raw data for this site, measured for each of the four years in question. The table also contains the year on year percentage change in water intensity.

For any year, Year_n followed by a year, Year_{n+1}, the percentage change year on year is:

Equation 3: % Change Year on Year

$$\% \text{ Change YOY} = (\text{Water intensity in Year}_{n+1} - \text{Water intensity in Year}_n) \times 100 / \text{Water intensity in Year}_n$$

To calculate performance in any year, Year_n relative to the base year, Year_b:

Equation 4: % Change Relative to Base Year

$$\% \text{ Change} = (\text{Water intensity in Year}_n - \text{Water intensity in Year}_b) \times 100 / \text{Water intensity in Year}_b$$

Table 1 shows the ongoing annual decrease in water intensity (and hence improvement in water use efficiency) at the site, leading to a cumulative decrease in water intensity of 18.67% by year 4.

Table 1: Water Use Efficiency Example

	YEAR 1	YEAR 2	YEAR 3	YEAR 4
WATER INTENSITY (m ³ /ton)	1.50	2.00	1.25	1.22
% CHANGE YOY	0.00	33.33	-37.50	-2.40
% CHANGE RELATIVE TO BASE YEAR (YEAR 1)	0.00	33.33	-16.67	-18.67

Absolute water use and water intensity should be examined together when considering the performance of a manufacturing site. It may happen that absolute water use may increase, but that water intensity may decrease, indicating increased levels of water use efficiency. An example may be when a site increases production levels, increasing absolute water use but becoming more efficient due to the introduction of water-efficient technologies, or through economies of scale.

5 DETERMINATION OF BASELINE WATER USE

5.1 The Need for Baseline Water Use Determination

Determination of the baseline is the process of establishing the status of absolute water use and water intensity for a manufacturing site at a defined point in time. When this baseline has been established, it serves as a benchmark against which water use performance improvements may be judged.

5.2 Pre-requisites for Baseline Water Use Determination

In order to determine the baseline water use for a manufacturing site, the following are the minimum pre-requisites necessary.

5.2.1 Measurement of site Water Use

Determination of baseline water use requires that the volume of all water that enters the site from outside the site boundary (or from water sources located inside the site boundary such as boreholes or on-site impoundments that receive un-metered flow from across the site boundary, and are not considered part of the site's water inventory) be measured. This implies that metering systems be in place to measure the volumes of potable water, treated and untreated/partially treated effluent (from external sources), harvested rainwater and raw water on a routine basis. Alternatively, the site needs to have a means of estimating these water volumes to an acceptable degree of accuracy.

The metering systems must be capable of measuring the cumulative volume of water used for the period of interest. Meters that have counters that cannot be reset are preferred, since the volume used between measuring periods can then simply be found by subtracting the most current reading from the reading before it. Meters that can be reset can result in lost information, since they could be reset in the middle of the month for example. Water use would in this case be under-stated, since the full month's data would not be contained in the cumulative value used. Water supplied by Water Services Providers is metered for billing purposes and hence should be available by default.

Highly automated manufacturing sites typically have the infrastructure to enable storage of water measurement data in a database, and the facility to examine water use trends. Local reading of meters (i.e. physical recording through readings taken at the site of the meter) in such environments is not necessary, since each incoming water stream is typically metered by a flow meter that is wired to an automatic recording device, or to a programmable logic controller (PLC). Using local area networks and technologies such as the internet, the data can be accessed from remote locations.

5.2.2 Measurement of Production Levels

Production levels are indicated either as the mass of production or the volume of production, depending on the industry concerned. In the beverage industry, volume is typically used, while in most other industries mass is used, often even in industries producing liquid products. There are various methods of

measuring production levels, examples of which are shown in Table 2 below. Measurement is typically automated.

Table 2: Methods of Measuring Production

UNIT OF MEASUREMENT	MEANS OF MEASUREMENT
MASS	<ul style="list-style-type: none"> i. Mass flow meter (liquids); ii. Tip scale (solids); iii. Load cells (liquids or solids); iv. Weighbridge (liquids or solids).
VOLUME	<ul style="list-style-type: none"> v. Mass flow meter with conversion to volume; vi. Flow meter e.g. magnetic flow meter; vii. Bottle count combined with standard volume or statistically determined volume; viii. Level measurement (e.g. using differential pressure cells or a sight-glass) converted to production volume through a calculation.

It is also possible to measure production levels in terms of the number of units produced e.g. number of vehicles in a car manufacturing plant.

5.3 Determination of Baseline Water Use in a Constant Throughput Scenario

Manufacturing plants seldom produce the same mass or volume of product each year. The constant throughput scenario will nevertheless be considered here, since it serves to illustrate some of the core concepts of baseline determination and target setting well. The more realistic scenario of changes in annual throughput is considered in the next section.

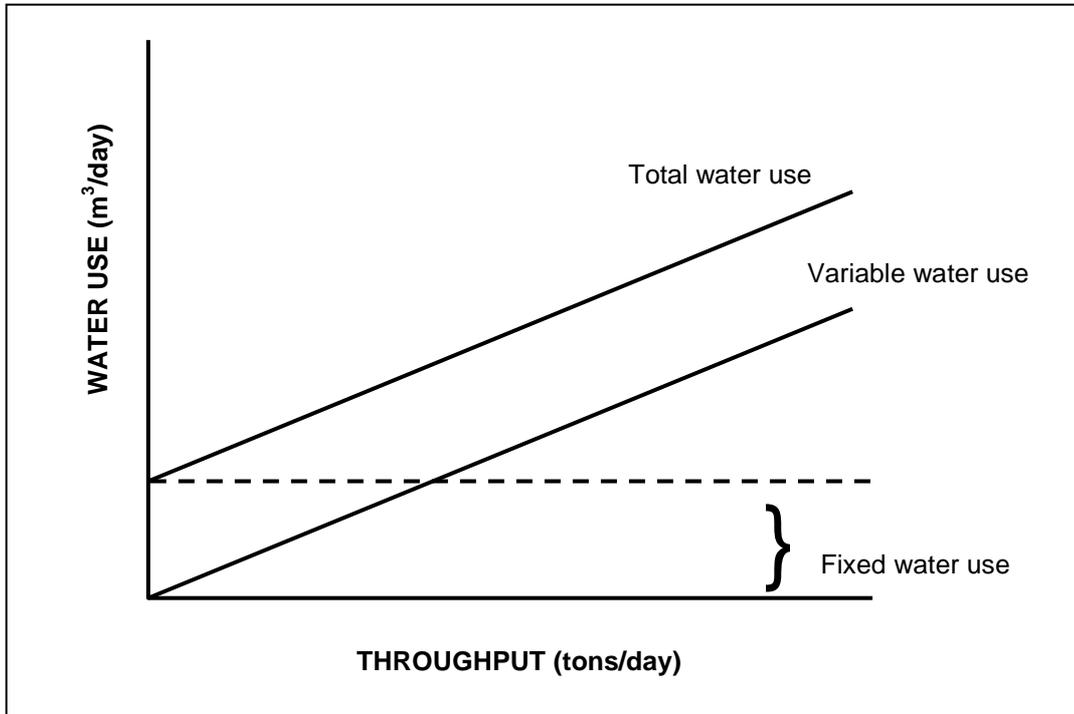
Even in plants where annual production levels are relatively constant, there are often significant seasonal variations in throughput, driven by changes in demand. This is more often the case where manufacturers make product to order (e.g. where products are perishable), since in these circumstances production levels are directly proportional to demand. The higher production levels are at a given manufacturing site over a defined period, the lower water intensity tends to be.

The drivers of the relationship between water intensity and throughput are partially related to specific design characteristics of equipment and processes. For example, process equipment is generally designed with an optimal throughput range in mind, and straying from this range could lead to the inefficient use of water. In general however, the phenomenon is best explained by considering that manufacturing sites have two primary components of water use: fixed water use and variable water use.

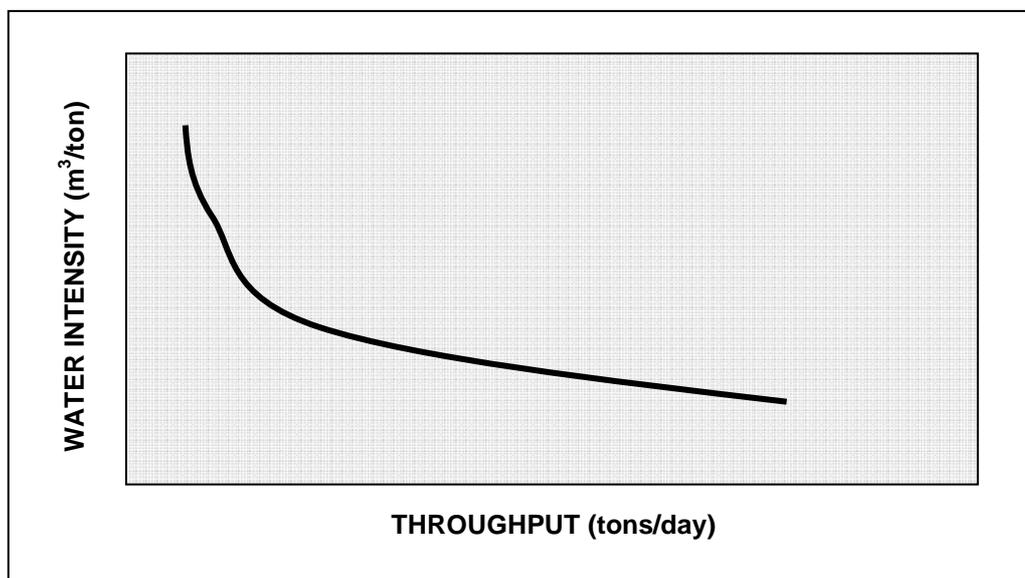
Fixed water use is independent of throughput. In times of low throughput, it therefore becomes a larger component of overall water use, and hence water intensity is increased. Variable water use changes with

the level of production. The cumulative variable water use hence increases as production levels increase and decreases as production levels decrease. If this relationship is considered to be linear, then overall water use also follows a linear relationship to production levels as illustrated in Figure 3 below.

Figure 3: The Relationship of Fixed and Variable Water Use to Total water Use



If we consider that water intensity is the ratio of absolute water use to throughput, it is clear that as total production levels increase, water intensity can be expected to decrease. As fixed water use becomes a smaller and smaller portion of total water use i.e. at high throughput levels, the reduction in water intensity with increasing throughput becomes less and less pronounced. This general relationship is described graphically in Figure 4 below.

Figure 4: Typical Relationship between Throughput and Water Intensity

Taking these considerations into account, it is clear that if water intensity is considered over too short a time frame at a site at which production levels fluctuate significantly over time, baseline water intensity could be either under or over-stated, depending on production levels at the time. As a minimum therefore, at least a full year's data must be used to determine the baseline water use for a manufacturing site, even at sites at which annual throughput levels are relatively constant from year to year. The only exception would be in the case for which monthly production volumes remain relatively constant, in which case monthly data could be used to approximate the annual situation.

The baseline water use for the year must be ascertained using equation one:

$$\begin{aligned} \text{Absolute Water Use} = & \text{potable water use / annum} + \text{raw water use / annum} \\ & + \text{harvested rainwater / annum} + \text{treated effluent / annum} \\ & + \text{untreated or partially treated effluent / annum} \end{aligned}$$

Recall that this applies to water crossing the site boundary or drawn from surface and/or groundwater resources located within the site boundary that are not considered part of the site's water inventory. Water that is recycled within the site boundary must NOT be added to absolute water use, as this would result in over-statement of water use.

The baseline Water Intensity must then be determined using equation two:

$$\text{Water Intensity} = \text{Absolute Water Use} / \text{Production Activity (Quantity Produced)}$$

“Quantity produced” would be the mass or volume of production *for the same 12 month period selected for determination of absolute water use.*

Some discretion is required in selecting the year to be used for baseline determination. It is preferable to select a baseline year in which no extraordinary business activity occurred on the site. If data for such a year is not available, then as far as possible the collected data should be corrected to accommodate anomalies. Hence if production was curtailed due to implementation of capital projects or problems associated with raw material supply, or if an unusually high level of production occurred due to a once-off order from a large client, the absolute water use and water intensity figures used for baseline determination may be corrected.

It is not necessary to use a calendar year for baseline water use determination since the use of data from any 12- month period during which operations proceeded as normal would address seasonal fluctuations in water demand.

Should water use targets be agreed at some time in the future for the purposes of the Stakeholder Accord on Water Conservation, a baseline year common to all Accord participants may be specified. In this instance, should the chosen year be one in which unusual water use activity may have occurred, it is recommended that either the production level or the water volume used be corrected to reflect a more average situation. These corrections must be rigorously related to the specific issues driving unusual water use performance.

This guideline deals with the determination of baseline absolute water use and baseline water intensity at the site level. It is however possible to carry out baseline determination using the principles above for specific areas of a manufacturing site, provided that the data as regards water measurement and the characteristics of the areas concerned are available. Hence if a site contains numerous manufacturing plants, each of which has its own metered water supplies and means of measuring production, absolute water use and water intensity can be calculated at the plant level, and hence a baseline can be determined for each area. The principles of carrying out such a determination are the same as those used at the site level. Individual users may wish to determine these more focused baseline determinations in the interest of area-specific water management. This area-based approach is outside the scope of this document.

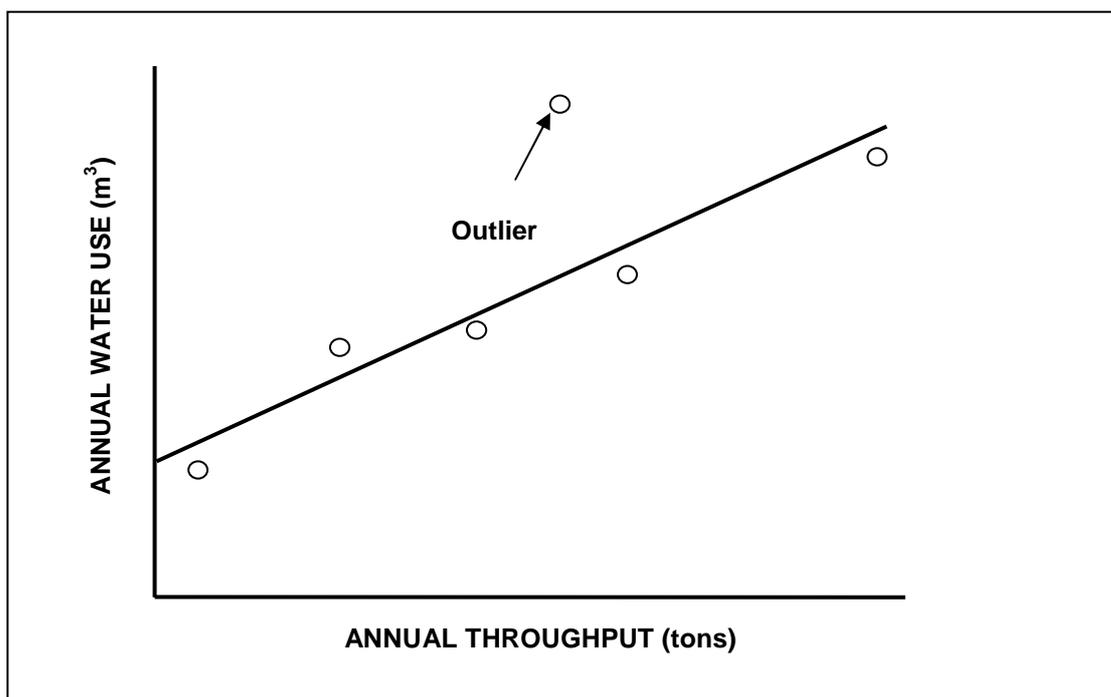
5.4 Determination of Baseline Water Use in a Varying Throughput Scenario

The motivation for the determination of baseline water use is the need to establish the level of water use at a site prior to implementation of water conservation. When conservation initiatives are implemented, it then becomes possible to ascertain the impact of these initiatives through comparison of observed water use to the baseline.

As discussed above, water intensity at manufacturing sites is generally a function of throughput levels. Hence, if throughput levels change significantly from year to year, use of a baseline water use value that does not take this impact into account would be of little value. It is therefore necessary to be able to correct the baseline that is determined at the start of a conservation programme for changes in throughput.

In order to be able to correct baseline water use for throughput, the relationship between annual water use and annual throughput for the manufacturing site has to be established. Figure 5 below outlines this process.

Figure 5: Throughput versus Absolute Water Use Graph at a Manufacturing Site



The time intervals of interest are annual intervals, and for sites that have the requisite historical data, the process would entail plotting a graph of annual water use versus annual production levels and then determining the mathematical relationship that defines that graph.

The graph in Figure 5 is based on the data from 6 separate years of production. Five of the points are shown to lie roughly on a straight line, while one of the points is an outlier. In that particular year, there may have been unique circumstances that increased water use disproportionately e.g. problems with the commissioning of a new production line. Provided there is evidence of unusual circumstances, such outliers should be ignored and excluded from the data used to determine the relationship between throughput and water use. Note that this process is aimed at understanding how a site behaves before the implementation of water conservation initiatives, or rather, at the time that has been chosen for baseline determination.

The determination of the relationship between annual throughput and annual water use can be carried out using spreadsheet applications such as EXCEL. Such applications can even be used to define non-linear relationships through fitting a trend line to the data and then using the application to define the relationship mathematically. It is in fact often better to use a polynomial to express the relationship, since polynomials tend to yield relationships with higher R^2 values where the observed relationship is not perfectly linear (a mathematical expression that perfectly described the relationship would have an R^2 value of 1).

Once the relationship is known mathematically, it becomes possible to determine a baseline value of performance for different throughput levels (this is shown in more detail in the example below). For sites that do not have historical annual water use and throughput data, it is possible to use monthly data as an approximation, multiplying both throughput and water use by 12 to gain a sense of what the relationship could look like annually.

It must be said that this process is by no means an exact science. Consider that an individual site could in practice have different water use levels for the same annual throughput level based on how that annual throughput was achieved i.e. the cumulative daily throughput levels that led to that annual throughput level. Note also that we can only truly talk of a baseline water use when a facility operates at a baseline performance level, and in reality, manufacturing sites deal with variables such as changing raw material quality, the impacts of human intervention, wear and tear of equipment and the like. There is hence always some level of flux inherent in manufacturing operations. These variations are however considered small in relation to the impact of changes in throughput, and throughput is hence a factor that must be included in baseline determination where annual throughput levels change significantly at a site.

Example 3:

The relationship between throughput and absolute water use was determined, by fitting a polynomial trend line to raw data, to be as follows at a beverage manufacturing site:

$$\text{Annual Absolute Water Use (m}^3\text{)} = -0.00000004 \times (\text{Throughput (hl)})^2 + 0.41 \times \text{Throughput (hl)} + 9.156$$

Site management wished to institute a water conservation programme, and wanted to establish what the baseline water use would be for each of the next 5 years, considering that throughput levels were expected to vary significantly over this period.

Throughput in the current year was expected to be 2,000,000 hl, and hence absolute water use was expected to be:

$$\begin{aligned}\text{Absolute water use} &= 0.00000004 \times 2,000,000^2 + 0.41 \times 2,000,000 + 9.156 \\ &= 660,009 \text{ m}^3/\text{annum}\end{aligned}$$

Table 3 outlines projected water use baseline values for each of the next five years, based on expected throughput levels.

Table 3 : Projected Water Use Baselines for Different Throughput Levels

YEAR	EXPECTED THROUGHPUT (hl)	PROJECTED WATER USE BASELINE (m ³ /annum)
0	2,000,000	660,009
1	1,850,000	621,609
2	2,100,000	684,609
3	2,300,000	731,409
4	2,160,000	698,985
5	2,400,000	753,609

The relevance of this approach is that for each of these years, it is possible to compare water use achieved (including the impacts of implemented conservation initiatives) to baseline water use, but corrected for the influence of changes in throughput. It is clear that neglecting to account for throughput could lead to use of a baseline that may be meaningless in terms of evaluating the impacts of conservation, since the savings expected or realised may be insignificant relative to the error inherent in the use of a baseline that does not account for throughput changes.

6 IDENTIFICATION AND QUANTIFICATION OF WATER CONSERVATION OPPORTUNITIES

6.1 Overview

This guideline describes the technical approach to be used in determining water use baselines and setting water use targets. This technical approach is complemented by certain strategic considerations e.g. business priorities or problems with water scarcity in specific locations. The detail of these considerations is considered outside the scope of this guideline, since they are unique to each organisation. They are however an important input to decisions regarding the viability of each water conservation initiative that is identified, which will ultimately determine whether individual initiatives are implemented or not. The assessment of viability is a matter that is left to the discretion of individual organisations as far as this guideline is concerned.

6.2 Quantification of Water Use in Priority Areas

6.2.1 Determination of a detailed water use breakdown

In order to determine water use targets, it is necessary to first identify each of the water-saving opportunities on the site, and to quantify the amount of water that could be saved through implementation of these. The first step in doing this is to determine how much water is used in various areas of the site. The example of a generic manufacturing facility will be used to illustrate this concept. It is important to appreciate however that each site is unique, and that even sites within the same manufacturing sub-sector may exhibit vastly different water use breakdowns.

The site should first be divided into major water-use areas. For a typical manufacturing site these would be:

- i. Core manufacturing areas – these are those areas on the site in which raw materials and products at various stages of manufacture are handled, processed and stored;
- ii. Site utility areas – these are areas that house site services, such as steam production, refrigeration, compressed air generation and cooling water circuits;
- iii. Staff amenities, such as toilets and washrooms;
- iv. Gardens and lawns, including water features;
- v. Cleaning / carwash and;
- vi. Staff canteen/kitchen.

6.2.2 Quantification of water use in core manufacturing areas

The detail with which the water use in core manufacturing areas may be assessed depends in part on the metering capabilities of the manufacturing site in question, with more extensive metering networks enabling more extensive assessment. Total core manufacturing water use is the amount of water used in all core manufacturing areas on a site, excluding water that is internally recycled.

Where flow meters are in place, quantification is simply a matter of reading the volumes used in individual areas over a given time period and adding these to ascertain total core manufacturing water use for the site over that period. Where flow meters are not available, it is possible in some cases to calculate the volumes of water used, based on engineering data such as pipeline pressures, pump running hours, pump characteristics, piping characteristics and the like. It is also possible to use energy balances to estimate the amount of water used, and to use information such as the moisture levels in waste materials and the mass of waste produced over the period of interest to assess the amount of water used in process areas that generate waste streams.

6.2.3 Quantification of water use in site utility areas

The approach used for the assessment of absolute water use in utility areas is similar to that used for core manufacturing areas. The water used for individual utilities/services (excluding water that is internally recycled) is added up to yield the total site utility water use.

6.2.4 Quantification of water use in staff amenity areas

Staff amenity areas in manufacturing facilities use plumbing fixtures and fittings such as taps, showerheads, toilets, mixers and the like.

There are three components to water use in these areas:

- i. The frequency with which each fitting is used;
- ii. The duration for which each fitting is used and;
- iii. The flow rate of water over the duration of each use.

These last two issues may be grouped into a single item, which would be the average volume of water used with each use.

Amenity areas are often not individually metered, and are typically widely dispersed across manufacturing sites. They may comprise kitchenettes, changing rooms, toilet facilities and the like. At labour intensive sites, staff changing rooms can consume large amounts of water. In order to assess water use due to amenities, it is therefore necessary to estimate frequency of use, duration of use and flow rate during use (or volume with each use) for all plumbing fittings. The data on flow rate or volume used could be obtained from manufacturer's specifications. These may not be readily available, and in this instance physical measurements may have to be made. For example, the volume of a washbasin may be determined from physical measurements, and the time taken to fill it could be divided into this volume to ascertain the flow rates of taps. It is the typical flow rate used rather than the maximum flow rate possible that is of interest when assessing taps.

Example 4:

The showers at a staff changing room at a steel plant operating on a 3-shift system with 300 workers on site for each shift and 90% of staff using the facilities, are operated for 2 minutes at a time and at a flow rate of 15 litres per minute. Calculate the average daily water use due to the showers.

$$\begin{aligned} \text{Water use} &= \text{frequency of use} \times \text{duration per use} \times \text{flow rate} \\ &= 0.9 \times 300 \times 3 \text{ uses/day} \times 2 \text{ min/use} \times 15 \text{ L/min} = 24,300 \text{ L/day.} \end{aligned}$$

Table 4 below outlines what the breakdown of staff amenity water use at a manufacturing site could look like after such an assessment has been conducted

Table 4: Quantification of Water Used for Amenities

Area	Fitting	Flow Rate (L/min)	Duration Per Use (min)	Volume Per Use (L)	No. of Uses Per Day	Volume Per Day (L)	Volume Per Annum (L)
Kitchenette 1	Tap 1	12	0.5	6	30	180	65,700
	Tap 2	10	0.5	5	56	280	102,200
	Tap 3	9	0.5	4.5	45	202.5	739,12.5
Kitchenette 2	Tap 1	15	1	15	67	1005	366,825
	Tap 2	15	0.8	12	43	516	188,340
Kitchenette 3	Tap 1	15	0.4	6	54	324	118,260
	Tap 2	15	0.5	7.5	32	240	87,600
Change rooms	Tap 1	14	1	14	30	420	153,300
	Tap 2	14	1	14	30	420	153,300
	Tap 3	14	1	14	30	420	153,300
	Toilet 1			8	200	1600	584,000
	Toilet 2			8	230	1840	671,600
	Showers	16	2	32	810	25920	9,460,800
TOTALS						33367.5	12,179,138

This site is shown to use approximately 12,000 KL per annum for staff amenities. More detail on assessing water use in this area may be found in the guide: “Guideline for Baseline Water Use Determination and Target Setting in the Commercial Sector”.

6.2.5 Quantification of water use by gardens and lawns

Where metering is not in place, water use can be estimated from the frequency of irrigation, its duration and the flow rate of water delivered to the irrigation system or via a garden hose. The flow rate can be determined by discharging water into a receptacle of known volume and then determining the time required to fill it, with the volume divided by the time being the calculated flow rate. The total time used for irrigation over the year can then be used together with this flow rate to estimate the volume of water used for irrigation. This element of water use is typically very small at a typical manufacturing site. Impacts of

seasonality must be accounted for by assessing water use at various times in the year. Changes in the types of plants being irrigated should also be accounted for.

At some manufacturing sites, irrigation with effluent is practised, in some instances over large areas such as pastures or crop fields. The water used must only be considered part of site water use where the effluent was supplied by another party. Effluent generated on the site that is subsequently used for irrigation must not be considered part of site water use, as this is an example of internal recycling.

6.2.6 Quantification of water use for cleaning/carwash

This refers to cleaning outside of the buildings on the manufacturing site (cleaning of the building interior should be factored into the water use ascertained when assessing staff amenities except in instances where non-potable water is used). Determination of water use can be carried out in much the same way as for the assessment of water use by gardens and lawns in the case where sub-metering is not in place.

6.2.7 Quantification of water use for the staff canteen/kitchen

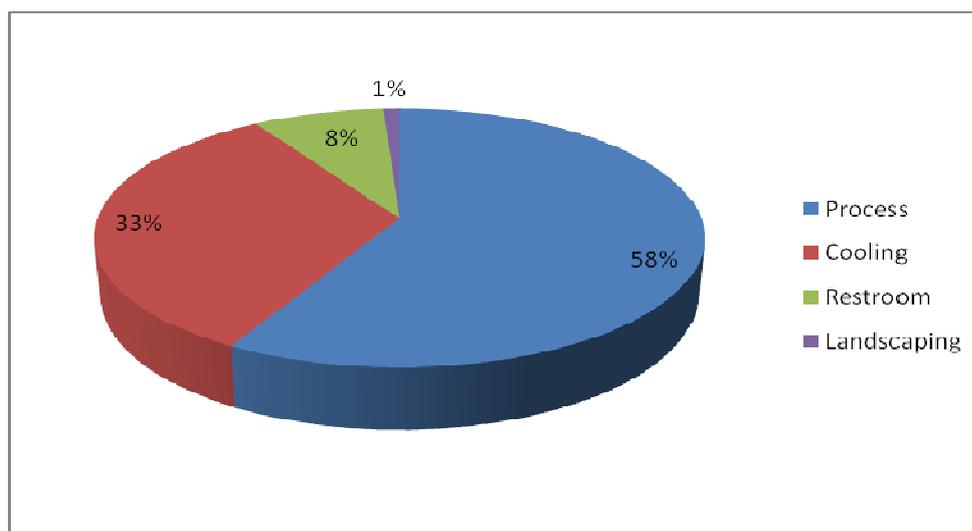
Note that this is different to the water use due to kitchenettes, which are smaller facilities generally used to prepare hot beverages and to microwave food. Staff canteens/kitchens tend to be larger and designed to serve large groups of people. They may have numerous specialised appliances, some of which may consume significant quantities of water e.g. dishwashers. The approach used is similar to that used to assess water use by staff amenities, with engagements with equipment suppliers being an important means of obtaining water use information for specific appliances.

6.2.8 Accommodating water recycling

Issues regarding water recycling have been mentioned previously, but bear repeating for the sake of clarity. The recycling of water is a common water conservation strategy in the manufacturing sector. When determining baseline water use, it is however the amount of water that crosses the site boundary and water that is sourced from surface and groundwater resources on site that is of interest. Water that is internally recycled on a manufacturing site should therefore not be included in baseline water use. Water that is recycled from another facility should however be included, as this water crosses the site boundary.

6.2.9 Compiling a site water use overview

The aim of gathering the information on individual water use areas is to be able to construct a breakdown of water use on the site, which would assist in pointing out where the biggest opportunities for conservation are. Figure 4 below outlines an example of such a breakdown, based on audits carried out on meat processing plants in California, USA.

Figure 6: Typical Breakdown of Water Use in Meat Processing

Source: *The Pacific Institute*

It is clear from Figure 6 that Process Water (i.e. “water use in core manufacturing areas”) and Cooling Water (which would fall into the “site utilities” category) are the biggest users, followed by Restroom Water, which would fall into the “site amenities” category. Water used for landscaping (irrigation and possibly water features) is a small portion of the total. While the relative size of individual use categories may not necessarily imply the biggest opportunities for conservation, it makes sense to investigate opportunities in these areas first, particularly if the site exhibits high water intensity relative to other sites in the same sector.

6.3 Assessment of Individual Water Conservation Opportunities

In order to set meaningful water use targets, the size of individual water conservation opportunities has to be determined. Each opportunity can then be evaluated in terms of its viability, and those found to be viable can then be planned for implementation. Implementation timelines will determine when the savings expected from planned conservation interventions will be realised and can hence be built into targets. A water conservation opportunity may be defined as a viable intervention which, when implemented, results in a reduced consumption of water relative to baseline water use.

The viability of individual water conservation interventions should be ascertained using the standard methodologies used by individual organisations when justifying any project. While the details are outside the scope of this guideline, and will depend in part on the approach of individual organisations, the following are important considerations:

- The capability of the organisation and/or external service providers to sustain the intervention. For example, should new equipment be required, are the spares and skills required for routine maintenance available locally and at short notice?
- The financial viability of the intervention i.e. will savings in water, energy, chemicals etc. justify the capital and operating costs arising from the intervention?

- Risks arising from the intervention – a full risk assessment should be carried out on all proposed plant and work practice modifications to ensure that unintended consequences of implementation are avoided. For example, reducing the frequency with which cleaning solutions are refreshed could lead to microbiological contamination in food processing plants. Ill-considered conservation projects can lead to unanticipated problems.
- The risks of not implementing an intervention also bear consideration. In water-scarce regions, sites may be subjected to water restrictions, significantly increasing the costs of failing to conserve water.

There are two broad categories into which water conservation initiatives in the commercial sector may be divided:

- i. Operational initiatives and;
- ii. Capital projects

Operational initiatives are those which yield water savings through the modification of work practices and behaviour, or through the use of different materials/consumables. For example, implementation of a preventive maintenance programme could reduce leaks and hence conserve water.

Capital projects are those in which changes to equipment or plant are made. An example here would be the introduction of a water treatment plant to allow increased recycling of treated effluents, thereby reducing fresh water requirements.

What follows are brief examples of how opportunities may be assessed in the various water-use areas of a manufacturing site.

6.3.1 Assessment of water conservation opportunities in core manufacturing areas

Core manufacturing areas differ significantly in different manufacturing sub-sectors, and it is not uncommon to find organisations within the same sub-sector using very different equipment and processing techniques. Core manufacturing areas are an important source of competitive advantage for manufacturers, and have an impact on important considerations such as production capacity, product quality, process yields and operational flexibility. The identification of water conservation opportunities in core manufacturing areas therefore demands a deep understanding of local site conditions.

Water conservation opportunities in the core manufacturing area generally comprise opportunities to reduce “point-of-use” consumption and opportunities to recycle water. A holistic review of potential conservation opportunities would typically result in the identification of opportunities in both of these areas. “Point-of-use” reductions in water use involve reducing the amount of water required by individual unit operations. An example would be replacement of the spray balls used for vessel cleaning in the food industry with more efficient alternatives that use less water yet achieve the same level of hygiene.

Recycling opportunities involve replacing all or part of the water requirements for a process with recycled water. The recycled water could be obtained as an effluent from other processes on site and used in unaltered form if possible, or treated before reuse. It is generally best to assess these opportunities in an integrated manner rather than in a piece-meal fashion. There are techniques such as Pinch Technology available that may assist in the selection of streams to be recycled and the matching of water-demanding and water-consuming processes on a manufacturing site.

6.3.2 Assessment of water conservation opportunities in site utility areas

The approach to be followed here is similar in some ways to that followed for core manufacturing areas. Site utilities generally employ generic technologies supplied by a larger number of vendors than what is typically found in the case of core manufacturing equipment. Special care should be taken to consider how site utilities interface with core manufacturing areas i.e. there are typically a number of links between the performance of site utilities and the performance of core manufacturing unit operations. Hence it is possible to compromise product quality or employee safety by implementing ill-considered water conservation initiatives in the site utilities area, and such risks should be carefully evaluated.

6.3.3 Assessment of water conservation opportunities in staff amenity areas

Efficient plumbing devices and fittings are available in South Africa, as are efficient appliances. In order to ascertain potential water saving opportunities, the expected water consumption due to the installation of alternative devices must be compared to the water use due the devices currently installed. The difference is then the magnitude of the saving. Opportunities may also exist to recycle grey water from washbasins and the like. More detail on this topic is available in the guide: "Guideline for Baseline Water Use Determination and Target Setting in the Commercial Sector".

6.3.4 Assessment of water conservation opportunities in garden and lawn irrigation

It is useful to benchmark site water use for irrigation in mm, as this allows horticultural specialists to compare the water use of a site to a projected water use for a given mix of plants, taking the local environment (in terms of rainfall and evaporation) into account. To convert the volume required for irrigation from KL to mm, use the following relationship:

Equation 5: Irrigation Water Use

$$\text{Irrigation Water use (mm)} = \text{Irrigation Water Use (KL)} \times 1000 / \text{Garden area (m}^2\text{)}$$

It is best to use an annual figure for this assessment in order to account for seasonality.

From an operational point of view, the types of measures that could be taken to reduce irrigation water use include:

- i. Watering only during cool periods;
- ii. Watering no more than once a week;
- iii. Ensuring that water is directed only at plants and not paved areas;

- iv. Changing watering patterns based on seasonal variations;
- v. Mulching of flower beds;
- vi. Removal of weeds/invading vegetation and;
- vii. Control of mowing height for lawn areas.

The types of capital investment opportunities that could be pursued in order to reduce irrigation water use include:

- i. Installation of efficient irrigation systems;
- ii. Rain sensors to shut off irrigation systems;
- iii. Wind sensors to shut off irrigation systems;
- iv. Soil moisture sensors and;
- v. Use of indigenous plants and plants that use minimal amounts of water e.g. groundcover tends to use less water than lawn does.

The savings associated with each of these initiatives should be documented for possible inclusion in a water conservation plan, dependent on viability.

6.3.5 Assessment of water conservation opportunities in cleaning/carwash

Work practice changes typically present a significant opportunity for savings in this regard e.g. the use of brooms instead of hoses for cleaning of walkways and paved areas. Since manufacturing sites typically also experience significant traffic due to the delivery of raw materials and the dispatch of product, housekeeping issues regarding vehicles are important e.g. leaks from tankers should be actively managed.

6.3.6 Assessment of water conservation opportunities at canteens / staff kitchens

This assessment is very similar to that for amenity areas. Extensive consultation with specialist suppliers is necessary to ascertain specific savings associated with particular appliances. From an operational point of view, the work practices of kitchen staff could potentially be changed to save water.

6.3.7 Assessment of water conservation opportunities due to rainwater harvesting

Rainwater harvesting is typically carried out by collecting rainwater from rooftops as well as from ground-level stormwater collection areas in manufacturing installations. The water is typically diverted to a tank (or on large sites, a dam), from which it is either pumped or fed by gravity to point-of-use, depending on the elevation of the tank or impoundment relative to the elevation at the point-of-use. Some treatment may be required depending on user requirements, but for uses such as garden irrigation, the water may typically be used without treatment. It is of course important to ensure that the stormwater is not contaminated during collection, as this could limit options for its use in untreated form.

The amount of water that can potentially be harvested may be estimated from the average annual rainfall and measured area of the rooftops and/or paved/concreted areas to be used from the relationship.

Equation 6: Potential Rainwater Harvest

$$\text{Potential Rainwater Harvest} = \text{Annual rainfall (mm)} \times \text{Collection area (m}^2\text{)} / 1000$$

Example 5

What is the annual potential volume of rainwater that could be harvested at a manufacturing installation with a roof area of 1300 m² and paved stormwater collection areas of 115,000 m² in a town with an average annual rainfall of 500 mm?

$$\text{Potential rainfall harvest} = 500 \times (1,300 + 115,500) / 1000 = \underline{58,400 \text{ m}^3/\text{annum}}$$

The actual tank or impoundment size required would depend on shorter-term fluctuations in rainfall patterns and the matching of rainwater supply to the demands of the processes in which harvested rainwater is to be used.

6.3.8 The need for an integrated approach to the identification of conservation opportunities

The preceding sections of this guideline have examined individual water conservation opportunities. However, it is important that once these individual areas have each been examined, the entire site is evaluated as a single integrated system. This ensures that any changes made in one area which could have impacts for other areas are considered with these impacts in mind. This integrated approach can also assist in the prioritisation of the implementation of individual water conservation initiatives. Several iterations would typically be required before the overall plan can be finalised.

For example, consider the case of the implementation of an effluent treatment system that would allow increased recycling. The system's design capacity may be based on a given volume of effluent, which may change significantly should "point-of-use" conservation initiatives be implemented. It is therefore prudent to consider the entire basket of options and the implications of each option for the basket as a whole before implementing any single option.

7 SETTING WATER USE TARGETS

7.1 Timeframes for water use targets

Water use targets should be reviewed at least annually, with a target determined for each year over a five year time horizon. Hence at any one time an organisation should have five targets, one for each of the next five years. The target for the next year may be viewed as a short term target, and the target in five years time as a long-term target. Repeating the process each year allows for current approaches in water conservation as well as current business strategy and/or stakeholder priorities, to be incorporated into the process.

Continuous improvement is one of the drivers of target setting and performance monitoring, and hence the target for each year should demonstrate a progressive planned reduction in water intensity i.e. a progressive improvement in water use efficiency. These planned improvements should be based on opportunities that have been evaluated as described above. Over time however, it does become more and more difficult to continue to improve without significant capital investment. This is the law of diminishing returns as applied to water conservation. Organisations that achieve their lowest feasible water use level should shift their focus to the maintenance of performance, while continuing to scan the environment for new technologies that may enable yet further improvement.

7.2 The role of water use benchmarks

The use of water intensity trends as a means of reviewing water use efficiency performance has been discussed earlier, and is a means for an individual organisation to determine whether water use efficiency performance is improving or declining over time. An organisation's absolute water use efficiency performance may in addition be compared to other users in a sector through the use of benchmarks. In addition to benchmarks that merely document the performance of users in a sector, a number of "best-practice" water use benchmarks are available for various industries, some examples of which are outlined together with other more general benchmarks in Table 5 below.

Table 5: Selected Water Intensity Benchmarks in Manufacturing

INDUSTRY	BENCHMARK DETAIL	BENCHMARK VALUE	SOURCE
Iron and Steel	Typical integrated mill with extensive recirculation	2.4 – 4.8 m ³ /ton crude steel	International Iron and Steel Institute
Brewing	Average global brewery water use	6.5 hl/hl packaged beer	UNEP
	Best practice	4 hl/hl packaged beer	UNEP
Dairy	Average of 27 UK dairies	1.3 litres/litre packaged milk	Envirowise
Power generation	Best practice for wet-cooled, coal-fired power stations, derived from statistical analysis of US data	1.5 litres/kWh power to grid	Illinois University

It is not suggested that such benchmarks be directly used to set targets, since individual water users each have their own context within which water use has to be managed. Benchmarks do however provide an important reference point against which targets may be reviewed. If a water use target deviates significantly from a benchmark value, this may indicate that the target should be modified, specifically in cases where the water use target is at a far lower level of efficiency than the benchmark value. It is however critically important that the detail as to how individual benchmarks were derived is appreciated, since some benchmarks could be misleading. As a case in point, of the examples above, the incoming water quality at the power stations used to derive the best practice benchmark could be significantly better than what is experienced locally, and similar levels of performance may not be achievable in South Africa. Benchmarks may not be available in some instances, and may need to be developed, particularly for specialised manufacturing operations.

7.3 Development of a site water conservation plan and associated targets

Once potential opportunities have been identified and the volumes of potential water savings associated with each have been quantified, each of these opportunities now has to be analysed to a level of detail that will permit management within the organisation to be able to make well-considered business decisions regarding implementation.

Ideally, the assessment of opportunities on the site should yield a wide suite of potential water saving options. Each of these options would have to be evaluated with respect to specific criteria that determine viability, within each organisation's unique context. Of all the possible options, a number of viable options could then be identified. The viable options could be earmarked for implementation at specific times over the five-year period following each, annual iteration of target setting. By subtracting the water savings expected from the baseline water use level and taking the timing of implementation of individual initiatives into account, annual targets can then be set. It is recommended that since targets are set annually, initiatives planned for implementation in any one year be used to set the target for the following year. This is illustrated by the following example.

Example 6:

A carbonated soft drink plant with annual production of 2 million hectolitres uses 660,009 m³ of potable water annually. This water is split between the various uses on the site as per Table 6 below:

Table 6: Water Use by Area at a Soft Drinks Plant

Area	Water Use (m ³)	% of Total
Process	560,009	84.85%
Cooling towers	34,000	5.15%
Steam production	46,500	7.05%
Amenities	10,000	1.52%
Irrigation	4,800	0.73%
Canteen	2,600	0.39%
Cleaning/carwash	2,100	0.32%

1 hl = 100 litres and the water intensity of the plant was therefore:

$$\begin{aligned} \text{Water intensity} &= \text{volume of water} / \text{volume of product} \\ &= 660,009 \text{ m}^3 / (2,000,000 \times 100/1000) \text{ m}^3 \\ &= \underline{3.30 \text{ m}^3/\text{m}^3 \text{ OR } 3.30 \text{ hl/hl}} \end{aligned}$$

The Plant Manager noted that the company's 3 other plants had an average water intensity of 2.6 hl/hl, and that the best practice for the industry, according to independent research was 2.1 hl/hl. It was therefore clear that improvements in water use efficiency were possible, and hence a water conservation project was launched.

It was clear from the site water use breakdown that Core Manufacturing areas and Site Utilities should be the focus of any conservation projects, since these areas used 97% of the total amount of water used on site. This did not mean that there were no opportunities in other areas, but simply that that biggest opportunities were most likely in these areas and that they therefore should be prioritised for action.

Water conservation opportunities were identified and rough water savings were quantified for each opportunity. Detailed investigations by engineering staff located on the site supported by specialist contractors yielded a number of viable conservation projects based on savings in water (among other benefits) relative to implementation costs and the risks associated with implementation. The initial focus was placed on operational improvements. These comprised water conservation education and awareness programmes for plant operators and an improved preventive maintenance programme to restore equipment functioning to OEM specifications. In addition, opportunities to optimise the existing plant were

investigated. This involved an examination of work practices at the shop floor, and a review of all process conditions.

Next the focus moved to capital projects that could reduce water use. The bottle washer was found to be consuming far more water than at other sites in the organisation, and was prioritised for action. The supplier of the equipment was requested to propose water conservation options aimed at reducing water consumption while achieving the same level of bottle washing effectiveness. A number of phased options for modification of the bottle washer were proposed. Solutions were also found for reducing cooling water make-up through improved automation of blow down, and an audit of the entire steam reticulation system yielded opportunities to improve condensate recovery.

The suite of options identified was assessed, and those options found to be viable were planned for implementation. Table 7 outlines how these individual options were located within the five-year target-setting period.

Table 7: Projected Annual Savings from Water Conservation Projects

Area of Site	Baseline	% of Total Consumption	Expected annual savings of projects implemented in Year 1	Expected annual savings of projects implemented in Year 2	Expected annual savings of projects implemented in Year 3	Expected annual savings of projects implemented in Year 4	Expected annual savings of projects implemented in Year 5
Process	560009	84.85	80000	40000	15000	5000	0
Cooling Towers	34000	5.15	0	6000	0	2500	2900
Steam production	46500	7.05	3500	15000	0	0	0
Amenities	10000	1.52	0	0	0	0	0
Irrigation	4800	0.73	0	0	0	0	0
Canteen	2600	0.39	0	0	0	0	0
Carwash	2100	0.30	0	0	0	0	0
Future annual savings expected from implemented projects			83500	61000	15000	7500	2900
Expected Absolute Water Use in following year if no further action is taken (m³/annum)*			576,509	515,509	500,509	493,009	490,109
Expected water intensity in following year if no further action is taken (hl/hl)*			2.88	2.58	2.50	2.47	2.45

*Assumes the initiatives are successfully implemented and achieve the expected savings

Table 7 outlines the essence of the target-setting process. The philosophy followed is to build any water savings planned for implementation in a particular year into the target **for the following year**. Initiatives planned for implementation within any given year are not built into that year’s target. This approach is slightly conservative, since it would be possible to include initiatives implemented in any given year into that year’s target by performing pro-rata calculations of savings and including these into the target. This latter approach is not recommended for the following reasons:

- There is no guarantee that a conservation project would be implemented in the month it is planned. Pro-rata approaches could therefore lead to penal targets;
- The approach proposed provides more certainty to the target-setting process.

Table 8 below outlines in more detail how this process, which follows from table 7, is used to set targets. Note that the target for each year is the level of water use that the site would like to achieve over the course of that full year. The target is set at the beginning of the year and water use would then be monitored over the course of that year. The water use at the end of the year is then compared to the target to assess performance.

Table 8: Annual Water Use Targets Example

Year	Target (m ³)	Target (m ³ /m ³)	Comment
Baseline	660,009	3.30	Determined at “Year 0”
Year 1	660,009	3.30	Target = baseline
Year 2	576,509	2.88	Target = baseline – expected annual savings in year 1.
Year 3	515,509	2.58	Target = baseline – (expected annual savings in year 1 + expected annual savings in year 2)
Year 4	500,509	2.50	Target = baseline – (expected annual savings in year 1 + expected annual savings in year 2 + expected annual savings in year 3)
Year 5	493,009	2.47	Target = baseline – (expected annual savings in year 1 + expected annual savings in year 2 + expected annual savings in year 3 + expected annual savings in year 4)

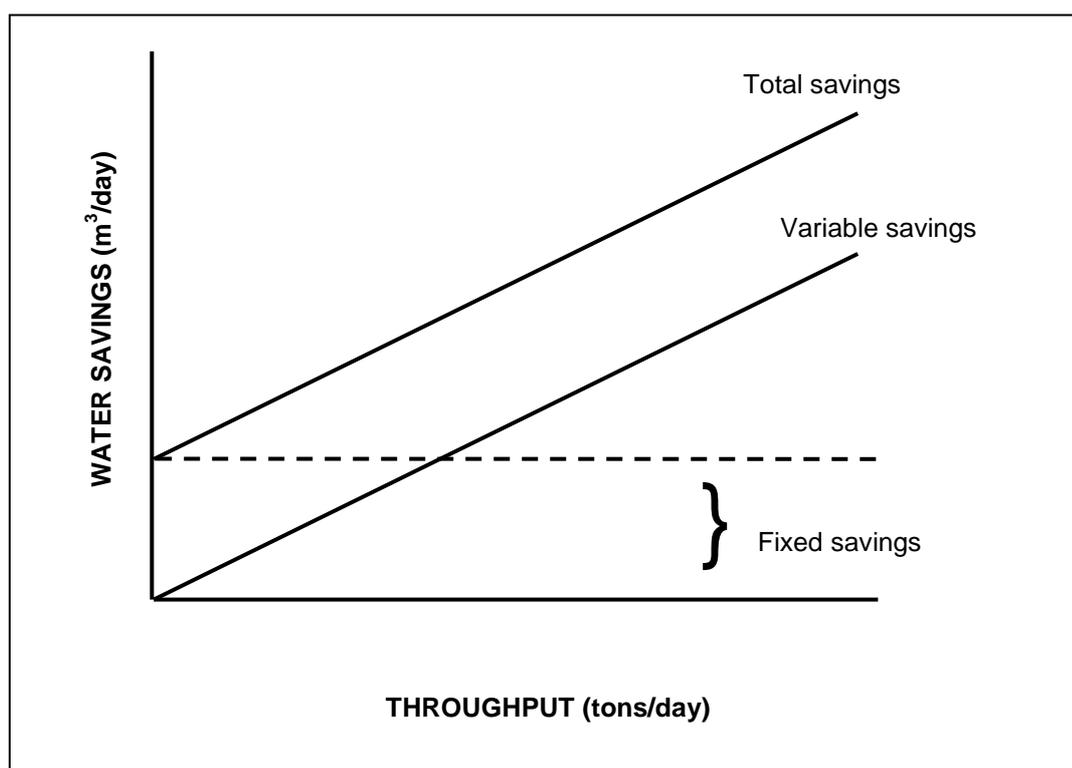
Year 1, which is the year after which the baseline is determined, is considered to be the year in which the first iteration of opportunity identification and assessment is carried out. It is therefore expected that minimal implementation would happen in this year as this would be a year of intensive planning. For this reason, the target for year 1 is taken as the benchmark water use level. Thereafter targets are made increasingly challenging as conservation projects are implemented.

7.4 Dealing with significant throughput changes

The preceding calculations and examples made an important assumption that requires further consideration – the throughput at the manufacturing site was assumed to be constant from one year to the next at 2,000,000 hl/annum. In practice this is often not the case, and hence it is worthwhile to examine the implications of significant changes in annual throughput. The issue of accounting for the impact of changes in throughput on baseline water use was handled earlier in this guideline (see section 5.4).

An additional and important consideration when including the impact of changes in throughput into the baseline and target-setting process, is that the magnitude of expected savings from individual interventions are in many cases themselves a function of throughput. This applies specifically to initiatives that deal with the variable element of water usage, as would be the case with conservation initiatives involving core manufacturing water use, for example. Figure 7 below illustrates the two fundamental types of water savings initiatives on the basis of their relationship to throughput.

Figure 7: Fixed and Variable Water Savings from Implemented Conservation Initiatives



Fixed savings arise from initiatives that are independent of production processes, or from processes within production that use water in quantities that are independent of throughput. Variable savings typically arise from initiatives within core manufacturing processes, and the quantity of water saved by these initiatives tends to increase as the level of production increases. Total savings at a site as a result of implementation of a number fixed and variable water use initiatives will therefore, as a group, typically be a function of throughput, as outlined in the graph. The magnitude of the savings and their relationship

to throughput depends on the specific nature of each initiative, and are typically quantified when each initiative is investigated for feasibility. This information is therefore generally available for use in target setting. For the variable savings in particular, it is necessary to calculate what these savings would be for each throughput level expected in each of the years over which targets are to be set.

This brings us to the fundamental difference between setting targets in an environment in which throughput is constant and in an environment in which throughput changes significantly from year to year. In the former situation, the target for any year is simply the baseline less the expected volumes of water saved in preceding years. These savings do not change since the throughput does not change. When annual throughput changes, the annual savings from each initiative (except for those involving fixed savings) change as well. For any given year, the target then becomes the baseline (corrected for throughput) less the savings due to initiatives implemented in preceding years, ***all corrected to reflect the throughput level of the year for which the target is being set.*** Table 9 below outlines how targets are calculated using this approach.

Table 9 : Baseline Water Use and Target-Setting with Changes in Throughput

YEAR		BASELINE YEAR	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
THROUGHPUT (hl)		2,000,000	1,850,000	2,100,000	2,300,000	2,160,000	2,400,000
CORRECTED BASELINE (m³/annum)		660,009	621,609	684,609	731,409	698,985	753,609
SAVINGS CORRECTED FOR THROUGHPUT (m³)	Process 1	0	80,000	91,000	97,000	91,500	98,500
	Process 2	0	0	40,000	43,000	40,500	44,000
	Process 3	0	0	0	15,000	14,000	16,000
	Process 4	0	0	0	0	5,000	6,500
	Cooling Towers 1	0	0	6,000	6,500	6,050	7,000
	Cooling Towers 2	0	0	0	0	2,500	2,750
	Cooling Towers 3	0	0	0	0	0	2,900
	Steam Production 1	0	3,500	4,000	4,300	4,050	4,500
	Steam Production 2	0	0	15,000	16,500	15,250	16,860
TOTAL ANNUAL SAVINGS EXPECTED BY END OF YEAR		0	83,500	156,000	182,300	178,850	199,010
TOTAL SAVINGS FROM PREVIOUS YEARS' INITIATIVES AT CURRENT THROUGHPUT		0	0	95,000	167,300	171,350	196,110
ABSOLUTE WATER USE TARGETS (m³/annum)		660,009	621,609	589,609	564,109	527,635	557,499
WATER INTENSITY TARGET (hl/hl)		3.30	3.36	2.81	2.45	2.44	2.32

In order to be able to perform the necessary calculations, it is first necessary to document the expected savings from each initiative at the various throughput levels expected over the target-setting period. This is illustrated in Table 9 above, again using the example of the soft drink plant from SECTION 5.4. Refer to Table 7 for a view of these initiatives in the “constant throughput” scenario. The savings in the year of implementation are assumed to be the same as those in the “constant throughput” scenario, with savings expected in subsequent years corrected to reflect the expected throughput level in those years.

Targets are then determined using the same philosophy outlined for the constant throughput scenario, which is to incorporate savings made in previous years into any individual year's target, but not to include savings expected in any one year into that same year's target. The key differences between this approach and that used in the case of constant throughput are:

- The baseline is adjusted for expected throughput in each year;
- The water savings are adjusted for expected throughput in each year;
- It is not a case of adding expected savings from prior years, but of evaluating cumulative savings from initiatives implemented in prior years ***at the throughput level of the year for which the target is being set.***

In terms of the first iteration of target-setting, the above process is adequate. However, by the end of the first year in which conservation initiatives have been implemented, changes may be required based on the savings that have actually been achieved. Where these savings differ from what was expected, the actual savings realised must be built into target-setting for future years, even for the case in which savings exceed expectations. Where savings are less than expected, it is of course necessary to understand why this is so and attempt to correct the problem before changing expected savings for future years.

8 CONCLUSIONS

Water use baseline determination and target-setting in the manufacturing environment can be complex, particularly when the impacts of changing throughput are incorporated into the process. The principles to be employed are however basically the same, regardless of whether throughput is fixed or whether it changes.

The potential impacts that changes in product mix can have on baseline determination and target setting have been purposefully omitted in the interests of simplicity, but could be incorporated into future revisions of this guideline.

This guideline represents a point of departure for baseline determination and water use target-setting in the manufacturing sector. Over time, it is expected that this guideline be improved, possibly incorporating details on specific sub-sectors within the manufacturing sector. In its current format, it can however be applied to any sub-sector within the manufacturing sector, provided that the principles illustrated here are adapted to account for any unique sub-sector characteristics.

As a final point, this guideline is for the benefit of users, and its ongoing improvement and development is welcome. Comments and suggestions for improvement of this guideline should be communicated to your sector representative.

9 REFERENCES

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