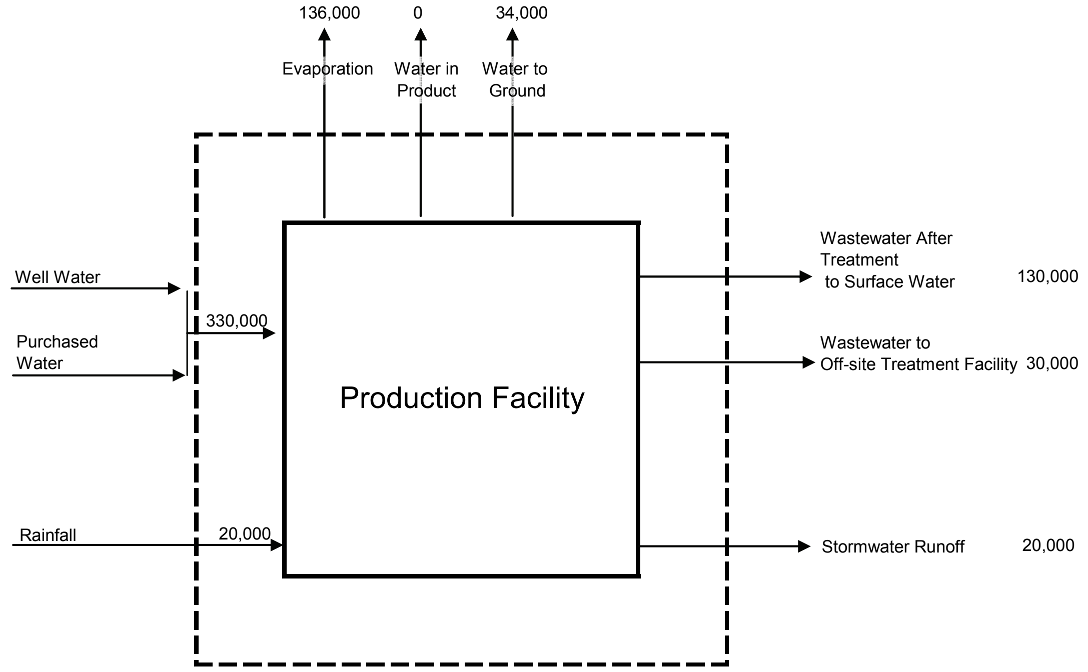
Case Example

Pfizer Inc: Use of a Water Balance to Reduce Water Usage

Introduction
A hypothetical example was developed to illustrate the use of a water balance to reduce water consumption at a production facility. Assume that the facility's objective is to reduce water usage by 10%.

Figure 1 shows the water inputs and outputs to and from a hypothetical production facility. Notice the imaginary dotted line around the production facility. In developing a water balance, the facility engineer shall identify and estimate the flow rate of all of the streams that contain water that cross the imaginary dotted line. It is noted that the GEMI tool refers to these input and output streams as inputs, losses and wastewater discharges.

Figure 1 : Site Wide Facility Water Balance
Note: All values are in the units of gallons per day



As shown in Figure 1, the facility uses water obtained from on-site wells and water purchased from the municipality. Rainfall is also an input to the facility because it crosses the imaginary dotted line around the production facility. The output streams include:

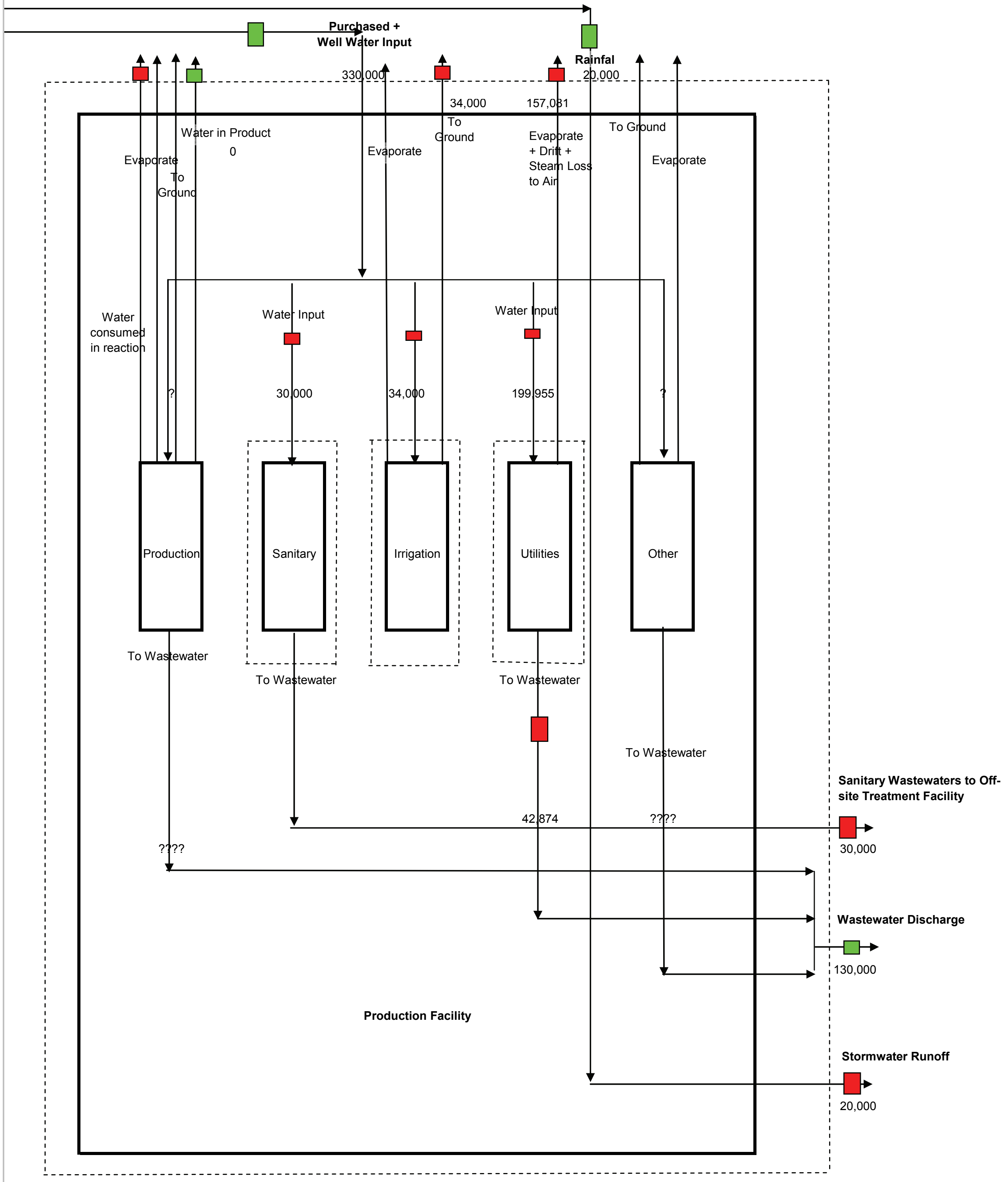
- water that is evaporated from the facility, for example from the cooling towers
- water that is contained in the facility's products, for example a beverage
- water that enters the ground, for example, from the facility's irrigation system and leaks from the facility's water distribution system (piping)
- the effluent from the facility's on-site wastewater treatment facility which is discharged to a surface water
- sanitary wastewaters which are sent to an off-site wastewater treatment facility operated by the municipality
- storm water runoff (following a rainfall event)

Figure 2, located on the following page, shows an expanded view of the same hypothetical facility. In Figure 2, separate water balances are shown for certain areas of water use in the facility including sanitary, irrigation, and utilities. There are other areas of use in this hypothetical facility including production and an other use category where water is used but does not fit into to one of the categories, e.g., quality assurance laboratories. Water balances for the production and the other use areas are not included in this example. Needless to say, the reader can establish different areas of use or for that matter develop a water balance around a building, a particular process, several processes or specific equipment. The choices are endless. The reader is reminded to follow the basic rule for developing a material balance, which is, drawing the imaginary dotted line about the area, process, building and or equipment and then identifying and quantifying the inputs and output streams.

In Figure 2, notice that the well water and purchased water are combined in one line and there is green box signifying for purposes of this example that the volume of purchased water and well water is measured, in this case via water meters. Rainfall (in inches) is also measured at a nearby airport via a rain gauge. By multiplying the inches of rainfall per year by the surface area of the production site, the volume of rainwater entering the site is estimated.

Pfizer Inc: Use of a Water Balance to Reduce Water Usage (Cont.)

Figure 2: Partial Site Wide Water Balance Broken Down by Area of Use.
All values are in the units of gallons per day (gpd)



🟥 Flow rate is estimated by process knowledge, engineering calculation and or judgment, factor or a combination thereof

🟩 Flow rate is measured. For example, water meter on purchased water, flow meter on wastewater, other measurement, e.g., the wastewater collection tank (volume of 3000 gallons) from building A fills up and is transferred twice per day.

The water outputs (other losses and wastewater discharges) from the different areas of use are determined via inspection and process knowledge. For example, the output of water used for sanitary purposes, including water used in toilets, showers, food preparation, dish washers and human consumption is primarily to the wastewater collection system. For sanitary usage, there is very little evaporation or loss to ground, except for leaks from the process waste lines or from the sewerage system. Similarly, the output for water used in irrigation, for example watering green areas in the facility, is principally to the ground via percolation into soil or leaks from the irrigation system piping and via evaporation. For uses in the irrigation area, there is no wastewater discharge. For production uses, the analysis of the out put streams is more complex as there are often multiple outputs from usage in production, for example:

- venting of steam or other water vapor to the air, for example, from product drying steps
- water that is contained in the product
- wastewater from cleaning of production areas, equipment and vessels that are discharged to wastewater collection system
- one pass, non-contact cooling water that is discharged to wastewater collection system. Note that the inputs and outputs of cooling water from the production area that are recirculated to the cooling towers are the same unless there is leak or blow down. The recirculated streams are netted out because the inputs and outputs of recirculated cooling water across the production area dotted line are equal.
- water that is consumed and or generated via chemical reaction
- wastewater that is generated in production area water treatment systems used to produce higher quality water for production purposes
- water that is included in a wastes that are sent off-site for disposal, for example, hazardous wastes that contain water

As indicated, there are numerous possibilities and combinations of water inputs and outputs. Table 1, shown on the following page, provides common inputs and losses and resulting discharge as wastewater.

Table 1: Description of Common Inputs, Losses and Wastewater Discharges

Plant Overall Balance

Common Inputs	*Common Losses*	*Wastewater*
Water used in production		
as a reactant in the process, e.g., water enters into chemical reaction or used to quench a reaction	Water can be consumed in a chemical reaction. For example, when calcium oxide reacts with water, calcium hydroxide is formed while the water is removed. A fraction of the water can also be evaporated from the process during the reaction.	Water used in production that does not enter the reaction is often discharged to the wastewater collection system less what is evaporated.
as a solvent, e.g., the reaction is carried out in water, as tablet coating solvent	Water can be evaporated from the process, e.g., spraying a tablet with an aqueous film coat with the water being evaporated.	Water can also be discharged as a wastewater from the production area
to clean equipment, work areas, raw material and product containers	If elevated temperatures are used for cleaning, some of the water can be evaporated	Most of the water that is used for cleaning goes to wastewater collection system.
as an ingredient in product, e.g., in a beverage, in food, in a pharmaceutical	Water which included in the product. For example, the water that is in the beverage or other product.	A fraction of the water that is incorporated in the product can be lost to wastewater via leaks from the process piping or during cleanup following a production run.
Water used as an input to a water treatment process to make higher quality water. For example, purchased water is used in water treatment process to produce a high quality water via distillation or reverse osmosis followed by a continuous deionizer for a pharmaceutical production process	While classified as a loss, the output water from the water treatment process is a loss.	There are several wastewater treatment processes. For filtration and carbon adsorption, there are backwash streams which are discharged to wastewater. For softeners, there are also backwash, regeneration streams, and fast and slow rinses. For reverse osmosis systems, there is a reject stream that commonly goes to wastewater. For continuous water demineralizers there are continuous blowdown streams. For distillation units, there is a blowdown stream and water blowdown from the condenser.
for cooling		
as one pass non-contact cooling water	Generally no losses	Generally non-contact cooling water is either discharged to a surface water, recharged into the ground or sent to an on-site or off-site wastewater treatment facility
to cool and lubricate pump seals	Generally no losses	Commonly this water is discharged to the site's wastewater system.
Water used for sanitary purposes		
Toilets		To wastewater
Showers		To wastewater
Food Preparation		To wastewater
Drinking Water	Consumed though a small amount	
Dishwasher		To wastewater
Area cleaning		To wastewater
Water used in utilities		
as an input to a water treatment process to produce softened water and or higher quality water for boiler feed water and or cooling tower makeup	See discussion for water used as an input to water treatment process.	See the above discussion covering water treatment processes that are used in production.
as makeup to the cooling towers	Water which evaporates from the cooling tower and drift losses from ID fans	Cooling tower blow down, side stream filter blow down
as boiler feed water	steam/water which is evaporated, water/condensate which is lost from steam traps	Boiler blowdown,
as once through cooling for compressors, chillers and other equipment	Generally no losses	Discharge to surface water or wastewater
as water to inject into gas turbines to reduce Nox emissions	Water is evaporated	Generally no wastewater discharge
Water used for Irrigation		
to irrigate the lawns, shrubs, plants, fields (the green areas)	Discharge to ground	Runoff can enter wastewater collection
Water used for other purposes		
Water to replace water which leaks from the water distribution system	Discharge to ground	Leak and or runoff can enter a wastewater collection system
Water used in Quality Assurance, Control and or Production Support Laboratories	Generally no losses	Generally to wastewater. Small amounts may be sent off site for waste disposal
Water used in pollution control equipment. For example, as makeup to a aqueous scrubber, as quench water in an incinerator, to wash filtration media	A fraction of the water can be evaporated,	Most of the water goes to wastewater
To clean other than production areas	Generally no losses	To wastewater

Calculations, Published Factors to Prepare a Balance

Sanitary Water Usage	10 -25 gallons per person per shift	The lower value is used where there are just toilets. A higher value is used where there are toilets, showers, full kitchen services, that is, food preparation and dish washing.
Irrigation Usage	Number of sprinkler heads x the flow capacity per head, e.g. 2.5 gpm x the duration (minutes) of water application	Inspect the irrigation system during operation to determine if there are leaks from broken sprinkler heads and from water distribution lines.
Wastewater Streams from Water Treatment Operations		
Reverse Osmosis Reject Flow	Reject stream generally ranges from 25 to 50% of the feed to the system	Reject flow can be higher than the indicated range. RO reject streams can be used as cooling tower makeup if the water is softened prior to the reverse osmosis system.
Backwash & Rinse Rates	Backwash, regeneration and rinse rates can be obtained from manufacturer's literature. The rates should be verified in the field.	
Cooling Tower Usage	Sum of Water lost via windage + water evaporated from the tower + blow down from the tower	Windage is the water driven from the tower due the tower fans. The windage loss decreases if the tower is provided with a mist eliminator.
Windage Rate	Commonly 0.1 to 0.3 % of the Recirculation Rate	The Tower recirculation rate can be obtained from the manufacturers literature and or head versus flow curve for the pump
Tower Evaporation Rate	$C \times \triangle T \times C_p / (H_v$	C is the tower recirculation rate in the units of lbs of water per minute , T is the temperature difference across the cooling tower in degrees Fahrenheit, Cp is the specific heat = 1 BTU/lb and Hv is the heat of vaporization = 1,000 Btu/lb of water evaporated
Cooling Tower Blow down Rate	(Windage Rate x (Cycles of Concentration -1) - Tower Evaporation Rate) / (1- Cycles of Concentration)	Cycles of Concentration = conductivity or chloride level in the cooling tower blowdown/ conductivity or chloride level in the cooling tower makeup water
Boiler Usage		
Boiler make up	Boiler Steam Rate - Condensate Return + Boiler Blow Down	
Boiler Blow down	Range of 4 to 8 % of boiler makeup	
Other Uses		
Pollution Control Equipment Usage	Obtain from manufacturer's literature	
One Pass Non-contact cooling water	Obtain via measurement and or calculate via heat balance or with discharge pressure via pump curve, that is, head versus discharge rate	
Water used for area cleaning	Obtain from standard charts of pressure and nozzle diameter or measure	
Equipment Cleaning	Obtain cleaning procedure from production personnel	

Again, the important concepts are drawing the imaginary dotted line about the process, building or area for the water balance followed by identifying and quantifying the inputs and outputs.

The water inputs to the production category are often not measured. The user can often obtain a preliminary understanding of the relative quantity used by walking through the production area looking for continuous water flows and more importantly reviewing the production and cleaning processes with production personnel. Where the inputs and output flows are not measured, estimates of water flow can be obtained by calculation, process knowledge and engineering judgment. Some of these techniques are discussed in a later section.

At many facilities, the utilities area is the largest user of water. For example, a facility in a warm climate which requires controlled humidity and temperatures in the production and packaging areas uses a significant amount of water in the cooling towers to remove heat from the sites chillers. Often, water is blown down from the cooling tower at a higher rate than is required to control corrosion, scaling and bio-fouling. Similarly, facilities that generate steam for production and heating or cooling purposes which have low rates of condensate return can use considerable amount of water. An often overlooked source of water usage in the utilities area is the water treatment system that produces higher quality makeup water for the cooling tower and boilers.

Water used in the other category includes activities which do not fit in the other areas of use, for example, production. Examples of these streams include water used in pollution control equipment and water used in quality assurance laboratories.

After identifying the inputs and outputs, the next step is to quantify these inputs and outputs. It is always important to remember that the goal of this example is to reduce water consumption by 10%. To achieve this objective, the facility engineer may develop a facility wide water balance to help prioritize his/her efforts to conserve water. For example, if is found that sanitary water usage is a very small fraction of total water usage , say 5% of total water input, then the facility engineer would not place high priority to installing low flow shower heads and low flow toilets to meet the sites 10% reduction goal. However, suppose that 65% of the facility's total water input is to the utilities area, then the facility engineer would probably focus on the utilities area to understand and determine whether there are opportunities the reducing the blow down from the cooling towers and from the water treatment systems that produce high quality water for the cooling towers and boilers. It is important to understand that end of the water balance is not achieving 100% closure of the water balance, that is, where the water inputs equal the water outputs. Rather the objective of the water balance is to understand where water is used, the quantity used and the quality requirements, e.g., dissolved solids, hardness, organic levels, so that the facility engineer can identify ways to meet the objective.

Estimating Water Flow Rates

Another important point is that lacking water meters there are other ways to estimate the water usage including calculations, published factors, engineering judgment and process knowledge. Let's review some of the techniques to estimate water consumption lacking meters.

Two of the more commonly used methods are described in the following section for estimating irrigation flows. An irrigation system generally consists of a multiple zones. Each zone contains sprinkler heads which may be of different size and capacity. The operation of each zone is individually controlled via a timer and a control valve. Each sprinkler head has a nominal capacity, for example 2.5 gallons per minute. The flow capacity (gpm) of each different sprinkler is obtained from the manufacturer of the sprinkler head. The timer actuates a solenoid valve which starts and stops the flow to a zone. For example, zone #1 may operate between 0500 and 0530 while zone 2 is operated from 0530 to 0550. To estimate water usage for a particular zone, the facility engineer counts the number of different sprinkler heads in a zone and multiplies the number of sprinkler heads by the hydraulic capacity of each head by the time that the zone is operated. The volume of water applied in each zone is summed to determine the total volume applied.

Based upon prior experience, it is important to periodically inspect the irrigation system while in service to look for broken heads and or breaks in water distribution line. Irrigation zone leaks are often a significant fraction of water used in an irrigation system.

Another technique to estimate irrigation system usage is to monitor the incoming water meter when the zones are in service. For example the base water usage may be 150 gpm. The flow increases to 225 gpm when zone 1 starts and 200 gpm when zone 2 is started. The incremental flow is the rate of flow that that is applied to the zone.

There are published factors to estimate sanitary water usage. These range from 10 to 25 gallons/ person/shift exclusive of industrial wastes. The lower value includes the flow from toilets and employee washing while the higher value includes estimated water usage if the facility has toilets and showers, food preparation and dishwashing equipment (a cafeteria).

With regard to the utilities areas, the water evaporated from a cooling tower can be estimated with the water temperature difference across the tower and cooling tower recirculation rate. With these data, the facility engineer can calculate the heat removal across the tower and the water evaporation rate using the latent heat of vaporization. The loss of water from tower by so called windage or drift is estimated as a factor (0.1 to 0.3%) multiplied by the tower recirculation rate. The facility engineer should contact the manufacturer of the cooling tower to obtain the appropriate factor. The blow down of the tower can be calculated with the following data: measurement of the concentration of chlorides or conductivity in the make up water to the tower and the concentration of chlorides or conductivity in the blow down from the tower, the calculated water evaporation rate and the estimated windage/drift losses. As indicated, estimates of water usage in a cooling tower can be made with relatively few measurements.

Water losses from the water treatment system that provides the makeup water to the boilers and or cooling tower is commonly estimated by referring to the water treatment system operating manual. For example, information obtained for the sand filter might indicate that the sand filter is backwashed on a daily basis at a rate of 15 gpm/ square foot for a duration of 10 minutes.

Boiler blow down can be calculated knowing the concentration of chlorides or conductivity in the boiler feed water, the concentration of chlorides or conductivity in the boiler blow down, the steam generation rate and the rate of condensate returned to the boiler. There are also published factors where the blow down rate from the boiler ranges for 5 to 10% of the stream generation rate. The condensate return can be measured and or estimated by the facility engineer.

In the other category water usage such as in pollution control equipment can often be obtained from information provided by the manufacturer of the system. For example, the amount of water required to clean the filter media is provided in the units operating manual. In certain cases it relatively straight forward to measure the instantaneous flow rate, for example, in the blow down from an aqueous scrubber. There are formulas to estimate the rate of water flow from hoses of different diameters and pressures.

In summary, flows can be estimated by a variety of methods, e.g., water meters, wastewater flow meters, process knowledge, for example, X gallons of water are used to clean a particular vessel, published factors, for example, the site sanitary water usage is estimated to 25 gallons per person per shift, engineering calculations, for example, calculation of evaporation rate from the cooling tower, and other forms or measurement, for example, using a bucket and stop watch or cross sectional area times the average velocity.

Water Balance Key Points

In summary, the important points for the reader relative to a water balance are listed below:

- Water balance can be applied in many ways, for a production facility, for a type of use, for example, irrigation, for a building, for a production process or for a piece of equipment.
- All of the inputs and outputs that cross an imaginary dotted line around the area selected for the balance should be identified and quantified.
- There are many ways to quantify the input and output flows including, but not limited to metering, engineering calculation, process knowledge and engineering judgment.
- The last point is achieving 100% closure of the water balance, that is, where the inputs equal the outputs is not the objective. Rather the objective of developing a water balance is to obtain sufficient information about water usage to make decisions to reduce, reuse or recycle water.

Water Balance Calculations

Returning to the hypothetical example, suppose we start off developing a water balance around the production facility shown in Figure 1. Assume that the well water and purchase water is metered and the average usage is 330,000 gallons per day (gpd). Assume that the total wastewater flow from onsite wastewater treatment facility is also metered and average 130,000 gpd. Assume that the sanitary sewage flow is not measured. Other outputs include the loss to air via evaporation, and loss to ground via irrigation and leaks. Assume that 5 acres of land are irrigated.

The first question is to try to understand what is happening to 200,000 gpd of water, the difference between the input water flow (330,000 gpd) and the wastewater treatment plant effluent flow (130,000 gpd). The facility engineer can begin to understand the reason(s) for the large difference by completing the facility wide water balance. As a first step, there are a total of 1200 full time and contract persons working at the facility and that the facility has showers and cafeteria. Using a factor of 25 gallons of water per person per shift and multiplying this by 1200 people yields an estimate of sanitary water usage of 30,000 gpd.

A survey of the irrigation system was conducted to determine the type and number of sprinkler heads in the various zones. The number of sprinkler heads was multiplied by the flow capacity of each head by the hours of sprinkler operation. The calculation showed that the irrigation system uses 29,000 gpd. It was also discovered in doing this analysis that water was being applied at the rate of 1.5 inches of water per week whereas the recommended irrigation rate for the area of the hypothetical facility is 1.0 inches of water per week. The irrigation system was also inspected during operation. Two leaks were observed during the inspection. The flow rate of the leak was estimated at 5,000 gpd.

It was assumed that there were no significant other leaks as evidenced by extremely low water usage rates during the annual shutdown for maintenance and repair.

For purposes of this example, assume that the runoff from rainfall (storm water) which falls on the site is not intermixed with other wastewater flows. Rather, the storm water is collected in a separate collection system. For purposes of the balance, the input and output streams are assumed equal. It is noted that there is some infiltration of rainfall into the ground but assume for purposes of this example that it is not significant.

In referring to Figure 1, the estimated evaporative loss by difference is 136,000 gpd (330,000-130,000-30,000-34,000). The facility wide balance pointed to evaporative loss being significant and an area for investigation. Similarly, there may be other opportunities for reduction of the water that ends up in the facility's wastewater stream. The facility wide balance points the facility engineer to the utilities area where there is a significant evaporative loss.

Remembering that the objective is to reduce water consumption by 10%, the water balance indicates that a reduction of 14,700 gallons (approximately 44% of the water conservation objective) can be achieved by repairing leaks and reducing the duration of the sprinkler heads to apply 1 inch per week.

Moving to Figure 2, an expanded representation of the facility, a water balance was developed around the utilities area. The principal water users in utilities area includes a water treatment system to produce boiler feed water and cooling tower make up, the cooling towers and boilers. The evaporative loss from the towers was estimated via engineering calculation. These calculations are presented in Table 2 (also found on the web site).

Table 2: Water Balance Example Calculations

1. Cooling Tower Makeup = Windage + Evaporation + Blowdow	**Existing**				**After Water Treatment Upgrade & Irrigation System Improvements**				**Water Reduction (gpd)**
Windage									
Tower Recirculation (from manufacturer's literature)	9,900	gpm			9,900	gpm			
Windage Rate (assumed from process knowledge)	0.1%	%			0.1%	%			
Windage (calculation)	14,256	gpd			14,256	gpd	-		0
Evaporation									
Change in Temperature across the Tower (measurement)	8	degrees F			8	degrees F			
Evaporation (calculation)	114,048	gpd			114,048	gpd	-		0
Blow down									
Cycles of Concentration (measured via conductivity measurements)	4	number			8	number			
Blowdown (calculation)	23,760	gpd			2,037	gpd			21,723
2. Boiler									
Steam Generation (measurement)	20,000	lbs/hour	57,554	gpd	20,000	lbs/hour	57,554	gpd	
Cycles of Concentration (Blowdown/ Boiler Makeup) (measured)	4				8				
Condensate Return (estimated)	10,000	lbs/hour	28,777	gpd	10,000	lbs/hour	28,777	gpd	
Blowdown (calculation)	3,333	lbs/hour	9,592	gpd	1,429	lbs/hour	4,111	gpd	
Boiler Feed water Makeup (calculation)	13,333	lbs/hour	38,369	gpd	11,429	lbs/hour	32,888	gpd	5,481
Evaporation (calculation)	10,000	lbs/hour	28,777	gpd	10,000	lbs/hour	28,777	gpd	
3. Cooling Tower & Boiler Inputs & Outputs			-						
Cooling Tower Makeup + Boiler Makeup	190,433	gpd			163,229	gpd			
Water Treatment Wastewaters (estimate from manufacturers operating instructions)	9,522	gpd			1,000	gpd			8,522
Total Inputs into Utilities	199,955	gpd			164,229	gpd			
Evaporation	157,081	gpd			157,081	gpd			
Utilities Wastewaters (boiler blowdown + cooling tower blowdown + water treatment wastewaters)	42,874	gpd			4,465	gpd			
4. Sanitary Wastewaters									
1200 people time 25 gallons/person/shift	30,000	gpd			30,000	gpd			0
5. Irrigation									
Count number of heads per zone multiply by rated capacity multiply by sprinkling time. Sum the flows for all zones	29,000	gpd			19,333	gpd			9,667
Estimated leaks based upon engineering judgment	5,000	gpd			0	gpd			5,000
6. Total Water Reduction									**50,393**

Cooling Tower Equations

Water Balance: Tower Makeup = Evaporation + Windage/drift+ Cooling Tower blowdown
Conductivity Balance: Water Makeup * Xm = Evaporation * 0+ Windage * Xb+ Blowdown * Xb
Water Blowdown = (Windage* (Xb/Xm-1)-Evaporation)/(1-Xb/Xm)

Boiler Equations

Boiler Makeup + Condensate Return = Boiler Output + Boiler Blowdown
Boiler Makeup = Boiler Blowdown * Cycles of Concentration
Plant Material Balance for Steam (assuming only loss of steam is via evaporation)
Boiler Makeup = Steam loss via evaporation + Boiler Blowdown

The average change in temperature across the cooling tower (8 degrees F) was based upon a series of measurements during the year. The average temperature difference was multiplied by the recirculation rate of 9,900 gpm. This recirculation rate was obtained from manufacturers literature supplied with the cooling towers. The product of the recirculation rate, the temperature difference across the tower and specific heat of water yields the heat removal (BTU/hour). This value was divided by the heat of vaporization of 1,000 BTU/pound yielding the rate of water evaporated in transferring the heat. The average water evaporation rate was calculated to equal114,000 gpd. The calculations are included in the spreadsheet which can be found through the link provided in Module 1. The drift or so called windage loss from the tower was based upon engineering judgment to be 14,200 gpd (0.1% multiplied by the recirculation rate). The combined loss of water to the air from the cooling towers (evaporation and drift) was estimated to be 128,300 gpd. The cooling tower blow down was estimated via engineering calculation. The cycle of concentration (conductivity of the blow down stream/ conductivity of the feed water) was equal to 4. It is noted that the evaporative loss also made sense with loading on the facility's chillers which are used to control the temperature and humidity in the working areas.

The facility's boilers produce 20,000 lbs/hour of steam. Based upon engineering judgment and calculations, the make up water to the boiler was estimated at 13,333 lbs/ hour to account for steam lost from the system and blow down from the boiler. The lost steam is believed primarily to be lost to the air.

The water treatment system consists of a sand filter, two resin based softeners to remove calcium and magnesium and dealkalyzer to remove carbonates and bicarbonates. The water treatment system was more than 20 years old and needed to be replaced. The system was regenerated on a timed basis, e.g. once per day, rather than regenerated after a specific volume had been treated. The softener backwash, regeneration, fast and slow rinse rates were obtained from the manufacturer's literature. These rates and resulting wastewaters were considerably larger than employed with new models of water treatment systems.

The facility replaced the existing water treatment system with system that included softening and reverse osmosis. With the improved water treatment system, the facility was able to reduce to provide higher quality water to the boilers and cooling towers. It is noted that softened water is used for cooling tower makeup while the reverse osmosis product water is used as boiler feed water. The reverse osmosis reject stream is also used for cooling tower makeup. By improving the quality of the feed water to the tower and boiler, the facility was able to increase the cycles of concentration from 4 to 8 in the cooling tower and boiler resulting in a reduction in the volume of the cooling tower and boiler blow downs. The wastewater discharges from the new water treatment system are also less than the discharges from the old treatment system. These changes resulted in a 35,700 gpd reduction in water usage in the utilities area.

The water balance showed the facility engineer that approximately 50% of the water used in the facility was as make up to the cooling towers. This led the facility engineer to look for clean wastewater streams that contain low levels of dissolved solids to use as cooling tower makeup.

Water balances were developed around high purity water systems that use reverse osmosis and distillation processes in the production areas. These balances which are not shown in Figure 2 showed that up15,000 gpd of reverse osmosis reject streams were being sent to the sewer system. Because the dissolved solids levels in these streams were low, these reject streams could be used for make up to the cooling towers. The site decided not to implement the project of capturing and diverting these streams to the cooling tower because of the high cost for a pump station and piping and because the water reduction objective was achieved with the other changes.

A water balance was developed around a scrubber showing fresh water make up 10,000 gpd. The site attempted to reduce the make up to the scrubber but there were performance issues. The site investigated replacing the aqueous one pass scrubber with dust collector/bag house system to remove particulates. The estimated capital costs were higher than could be justified. These later examples reinforce the principle that the water balance is tool to help the site make decisions.

In summary, the facility exceeded its objective of 10% reduction in water usage by making relatively simple low cost improvements to it irrigation system and by upgrading the water treatment system in the utilities area and by increasing the cycles of concentration in its cooling towers and boilers.