# Chapter 3

# BREWHOUSE

## 3.1 INTRODUCTION AND BACKGROUND

The Rosslyn brewery has two brewhouses for wort production, namely brewhouse 1 and 2, which operates simultaneously and will be referred to as the "brewhouse" for the remainder of this section. To provide the necessary conditions for fermentation, the initially insoluble components in the malt must be converted into soluble products, and in particular soluble fermentable sugars must be produced. The formation and dissolving of these compounds is the purpose of wort production. The brewhouse is capable of producing approximately 2 500 hl of wort per brew (of which 1 000 hl is produced by brewhouse 1, 1 500 hl is produced by brewhouse 2 and a brew refers to the combined outputs from brewhouses 1 and 2). The operations in a brewhouse are batch related and one brew takes approximately three hours (brewlength).

The brewhouse operations include milling, mashing, lautering, buffering in the underback, preheating, wort boiling and separation in the whirlpool (see Figure 3.1). The brewery brews high gravity wort (wort with a high concentration of fermentable sugars) for better equipment utilisation within the brewery. This also reduces the size of vessels needed during wort production and therefore also reduces the volumes of water required to clean the vessels per volume of wort brewed. Each brand of beer has its own unique recipe (based, *inter alia*, on the amount of process water added during production) to ensure a brand's unique characteristics. However, these differences in water consumption of the various brands are negligible and this investigation (thesis) is based on the most commonly brewed brand at the brewery, "Castle".

### 3.1.1 Malting

Malting does not occur on the brewery site itself and is therefore not considered in this investigation.

### 3.1.2 Mills

The brewhouse is equipped with five mills in parallel to service brewhouses 1 and 2. (However, only three mills are used to supply the brewhouse at a given time.) The malt is milled accurately to the correct particle size distribution. Water is used in the conditioning chamber of the mills to assist in the milling process and the mills also undergo a CIP clean two times per week.

### 3.1.3 Mash tuns

Before the process of mashing occurs, water is added to obtain the correct liquor to grist ratio. During the transfer of the mash from the mash tuns to the lauter tuns, water is used to transfer any mash, remaining within the pipelines, to the lauter tuns. After the mash has been transferred, the mash tuns are rinsed with water to remove any mash still remaining in the vessels. This water is discharged to the drains. The mash tuns undergo a CIP clean two times per week.

### 3.1.4 Lauter tuns

Before the transfer of mash from the mash tuns, underletting occurs where water is added to the lauter tuns to ensure an even distribution of mash within the vessels. After the majority of the wort has been separated from the husk fraction, water is sprayed over the bed in the lauter tuns to wash out any remaining extract. The separation of the mash liquor from the husk fraction is optimised to give the correct volume to the underbacks with minimal extract loss. The volume of mash liquor transferred to the underbacks is determined from analyses of the process. Any remaining mash liquor and water in the lauter tuns are discharged to the drains.

The spent grain, with a moisture content of approximately 80%, is transferred to the spent grain storage bins by air blowers and sold to farmers as animal feed. Once the spent grain is removed from the lauter tuns, the vessels are rinsed with water to remove any waste still residing within the vessels. The lauter tuns undergo a CIP clean two times per week.

### 3.1.5 Underbacks

The underbacks are utilised as buffer tanks prior to wort boiling. On completion of the transfer of the mash liquor to the wort kettles, a measured volume of water is utilised to transfer any mash liquor, remaining in the pipelines, to the wort kettles. The underbacks undergo a CIP clean two times per week.

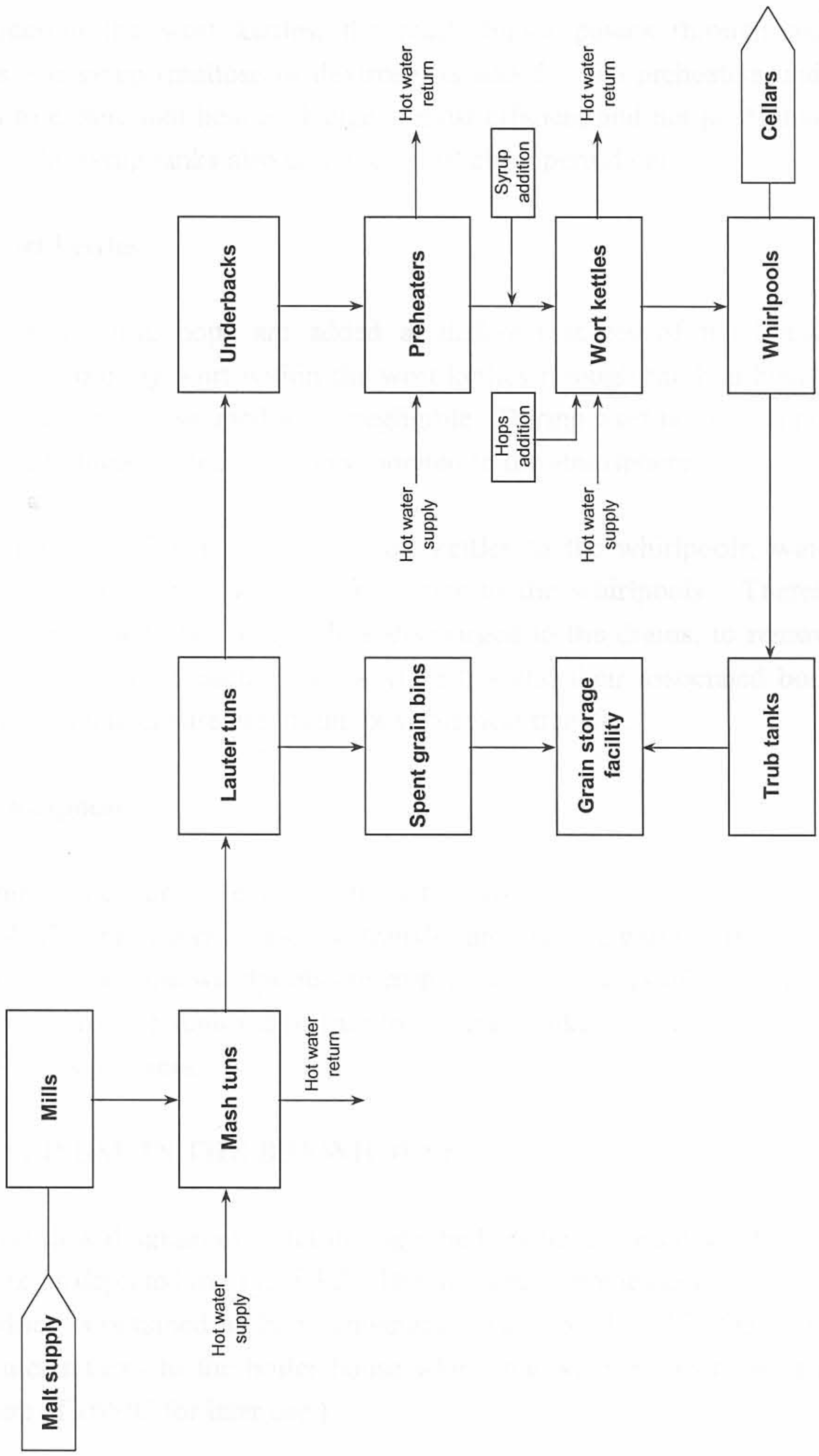



**Figure 3.1** Flow diagram of the brewhouse at the South African Breweries Rosslyn plant.

### 3.1.6 Preheaters and syrup addition

Before entering the wort kettles, the mash liquor passes through plate and frame preheaters and syrup (maltose or dextrose) is added. The preheaters undergo a regular CIP clean to ensure that heat exchange is most efficient and not prohibited by the build-up of dirt. The syrup tanks also undergo a CIP clean periodically.

### 3.1.7 Wort kettles

During wort boiling, hops are added at different stages of the boiling process by circulating the boiling wort within the wort kettles through the hop bins. The moisture content in the hops is assumed to be negligible. During wort boiling, approximately 6 to 8% (volume/volume) of the wort is evaporated to the atmosphere.

After the transfer of wort from the wort kettles to the whirlpools, water is added to transfer any wort remaining in the pipelines to the whirlpools. Thereafter, the wort kettles are rinsed with water, which is discharged to the drains, to remove any wort or trub remaining in the vessels. The wort kettles and their associated boilers undergo a regular CIP clean to ensure maximum possible heat transfer.

### 3.1.8 Whirlpools

In the whirlpools, trub is separated from the wort and the wort transferred to the wort coolers. Additional water is used to transfer any wort remaining in the pipelines to the wort coolers. Once the whirlpools are empty, large volumes of water is utilised to rinse the whirlpools for the removal of trub to the trub tanks. The whirlpools undergo a CIP clean two times per week.

## 3.2 WATER USE IN THE BREWHOUSE

The general flow diagram of water through the brewhouse, assuming the brewhouse to be a black box, is depicted in Figure 3.2. The mash tuns, preheaters and wort kettles require heating which is obtained by high temperature water produced in the boiler house. (The cooled water returns to the boiler house where the water is maintained at the required temperature of 165°C for later use.)

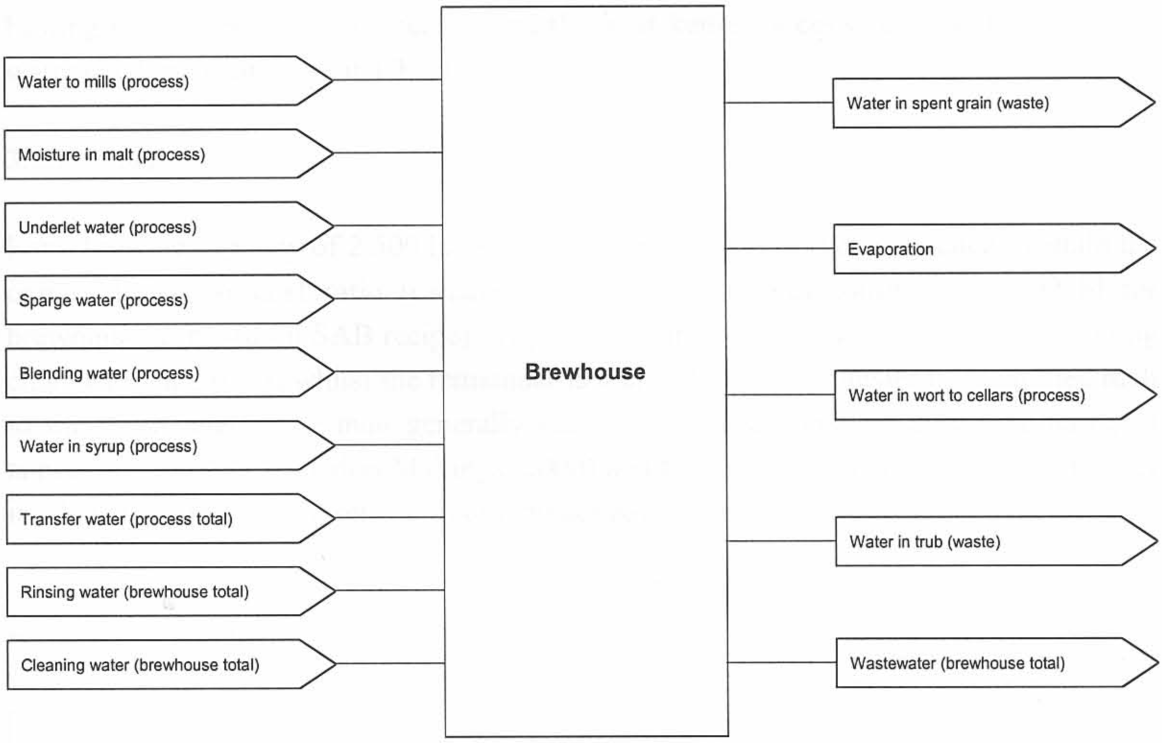


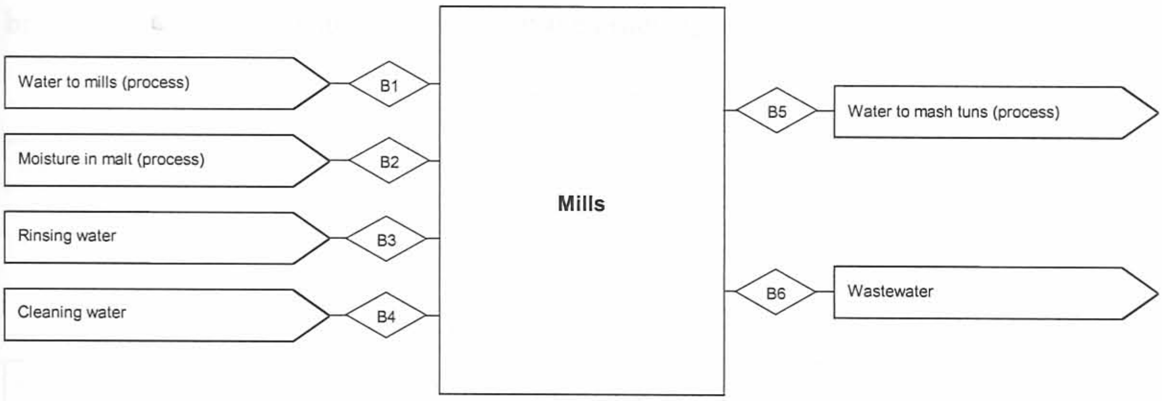

**Figure 3.2** Simplified water balance over the entire brewhouse.

To determine the quantity of water, measured in hl, used per hl of beer brewed, a mass balance over each unit process was completed. This analysis will use one brew from each brewhouse, with a total brewing capacity of 2 500 hl, as a basis to determine water use per week. Water in the brewhouse is either used as brewing (process) water, rinse water or cleaning water. The average volume of beer brewed per day, based on production figures and assuming a five day week and 24 hours production per day, is 15 950 hl (Naik, 2000). Therefore, approximately 6,4 brews per day (or 32 brews per week) are brewed in the brewhouse.

Except for transfer and underlet water, all process water (for the production of wort) is measured and controlled. Water used for transferring, underletting, rinsing and cleaning, over each of the unit processes within the brewhouse, is unmeasured and is supplied by one pump station consisting of five pumps operating in parallel. The pumps supply hot water into a common header which services the brewhouse, cellars and packaging sections. It is assumed that the pumps operate at 80% efficiency (total capacity 4 650 hl/h) and that equal amounts of water are transferred to the brewhouse, cellars and packaging sections. From the above, the flowrate of water used for rinsing, transfer and cleaning, under normal operating conditions, is calculated as 1 240 hl/h. Water used for heating of the mash tuns, preheaters and the wort kettles is considered with the general water used in the brewery in Chapter 6.

### 3.2.1 Mills

For a brewing capacity of 2 500 hl, approximately 1 330 hl of water is added to attain the correct liquor to grist ratio (calculated as 530 hl for brewhouse 1 and 800 hl for brewhouse 2, based on SAB recipe). A portion of this water is added in the conditioning chamber of the mills, whilst the remainder is added during the transfer of the milled malt to the mash tuns. The malt generally has a moisture content, on a volume basis, of approximately 4 % (Caledon Maltings, 2000) and therefore approximately 16 hl of water is added per brew (based on 406 hl of malt added).




| Stream | Volume [hl] | Frequency | Ave volume/week [hl/week] | Source ⊕ |
|---|---|---|---|---|
| B1 | 1 330 | per brew * | 42 560 | S1 |
| B2 | 16 | per brew | 512 | S2 |
| B3 | 83 | per brew | 2 656 | S3 |
| B4 | 1 860 | per week + | 1 860 | S3 |
| B5 | 1 346 | per brew | 43 072 | B1 + B2 |
| B6 | - | - | 4 516 | B3 + B4 |

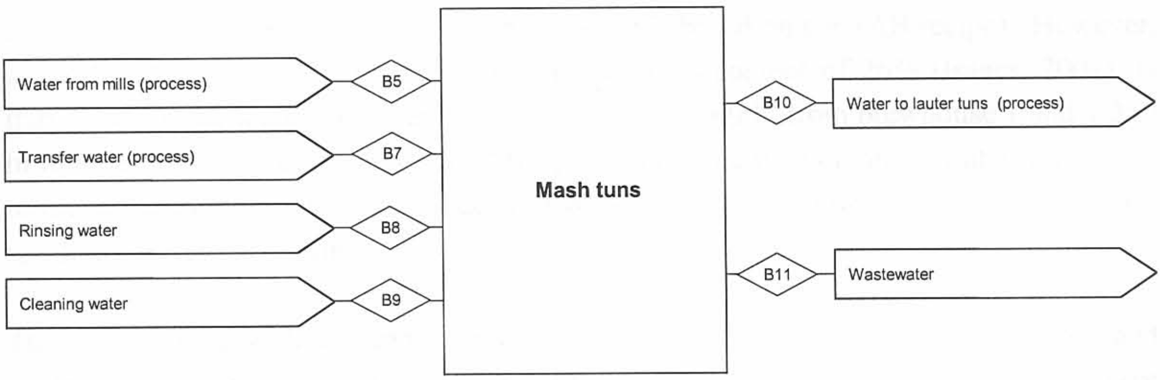
⊕ Sources, other than streams, are presented at the end of each chapter. * per brew means for both brewhouses. + per week indicates for both brewhouses per week.

**Figure 3.3** Water balance over the mills.

Water is used to rinse the mills, after the transfer of the milled malt to the mash tuns (therefore after each brew), at a rate of 1 240 hl/hour for 40 seconds (van der Merwe, 2000). Therefore, 83 hl of water (calculated as 41,5 hl of water for the three mills in brewhouse 1 and 41,5 hl of water for the three mills in brewhouse 2) is utilised for rinsing and discharged to the drains. Twice per week, three mills will undergo a CIP clean with an estimated total water use of 1 860 hl of water per week, which is discharged to the drains (van der Merwe, 2000).

### 3.2.2 Mash tuns

The water balance over the mash tuns is shown in Figure 3.4. After the transfer of the mashed malt to the lauter tuns, water is transferred through the pipelines, at a rate of 1 240 hl/h for 58 seconds per mash tun (van der Merwe, 2000), to transfer any remaining mash out of the pipelines to the lauter tuns. Therefore, the volume of water required to transfer the mash out of the pipelines per brew (for two mash tuns, one each from brewhouses 1 and 2), which forms part of the product, is 40 hl.




| Stream | Volume [hl] | Frequency | Ave volume/week [hl/week] | Source ⊕ |
|---|---|---|---|---|
| B5 | 1 346 | per brew | 43 072 | - |
| B7 | 40 | per brew | 1 280 | S3 |
| B8 | 17 | per brew | 544 | S3 |
| B9 | 1 200 | per week | 1 200 | S3 |
| B10 | 1 386 | per brew | 44 352 | B5 + B7 |
| B11 | - | - | 1 744 | B8 + B9 |

⊕ Sources, other than streams, are presented at the end of each chapter.

**Figure 3.4** Water balance over the mash tuns.

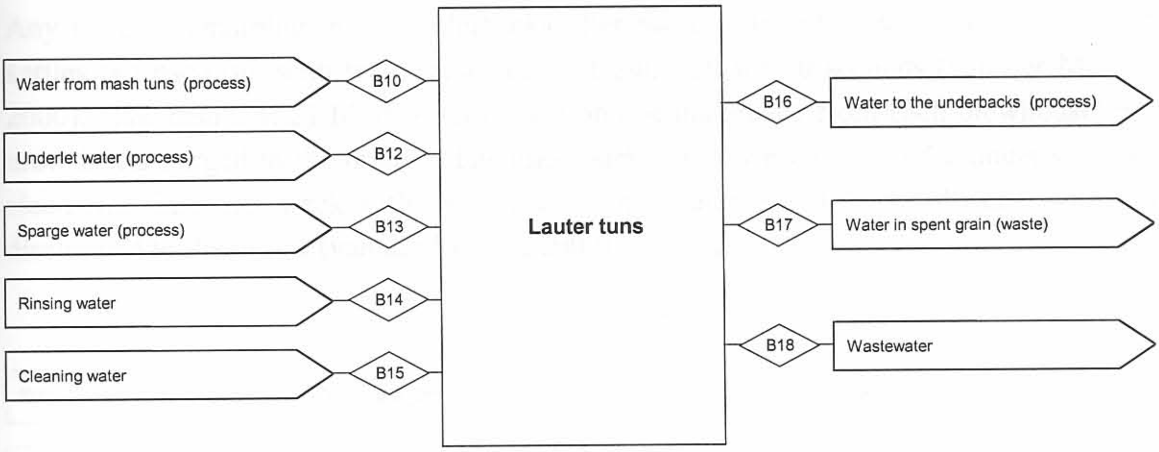
Once the transfer of mash is complete, water is utilised to rinse the vessels at a rate of 1 240 hl/h for 25 seconds per mash tun (van der Merwe, 2000), resulting in 17 hl of water used for rinsing per brew. The two mash tuns in the brewhouse (one each from brewhouses 1 and 2) undergo a CIP clean two times per week with an estimated total water use of 1 200 hl/week, which is discharged to the drains (van der Merwe, 2000).

### 3.2.3 Lauter tuns

The water balance over the lauter tuns is shown in Figure 3.5. Underlet water is added before the transfer of mash liquor from the mash tuns at a rate of 1 240 hl/h for 60 seconds (van der Merwe, 2000). Therefore approximately 41 hl of water is added per brew (for two lauter tuns, one each from brewhouses 1 and 2) for underletting, which also becomes part of the product.

After the majority of the mash liquor has been removed from the lauter tuns, sparge water is sprayed over the beds at a specific flowrate unique to the brand of beer being brewed. Approximately 1 305 hl of sparge water is added to the lauter tuns per brew (calculated as 570 hl for brewhouse 1 and 735 hl for brewhouse 2, based on the SAB recipe). However, in total only 2 250 hl of mash liquor, with a solids content of 26% (Isaacs, 2001), is transferred to the underbacks per brew (calculated as 900 hl from brewhouse 1 and 1 350 hl for brewhouse 2, based on the SAB recipe). Therefore the volume of water transferred to the underback with the mash liquor is 1 665 hl. The remaining mash liquor and water are discharged to the drains.

The spent grain with an approximate moisture content of 80% (Isaacs, 2000) and containing an estimated 75 hl of water per brew, is transferred to the spent grain storage bins. After all the spent grain is removed from the lauter tuns, each lauter tun is rinsed at a rate of 1 240 hl/h for 200 seconds to remove any remaining residue from the vessel (van der Merwe, 2000). Therefore 138 hl of water is utilised during each brew to rinse the lauter tuns and this water is discharged to the drains. The lauter tuns undergo a CIP clean two times per week with an estimated total water use of 2 000 hl/week (for two lauter tuns, one each from brewhouses 1 and 2), which is discharged to the drains (van der Merwe, 2000).




| Stream | Volume [hl] | Frequency | Ave volume/week [hl/week] | Source ⊕ |
|---|---|---|---|---|
| B10 | 1 386 | per brew | 44 352 | - |
| B12 | 41 | per brew | 1 312 | S3 |
| B13 | 1 305 | per brew | 41 760 | S1 |
| B14 | 138 | per brew | 4 416 | S3 |
| B15 | 2 000 | per week | 2 000 | S3 |
| B16 | 1 665 | per brew | 53 280 | S1 |
| B17 | 75 | per brew | 2 400 | S5 |
| B18 | - | - | 38 160 | B10 + B12 + B13 +B14 +B15 – B16 - B17 |

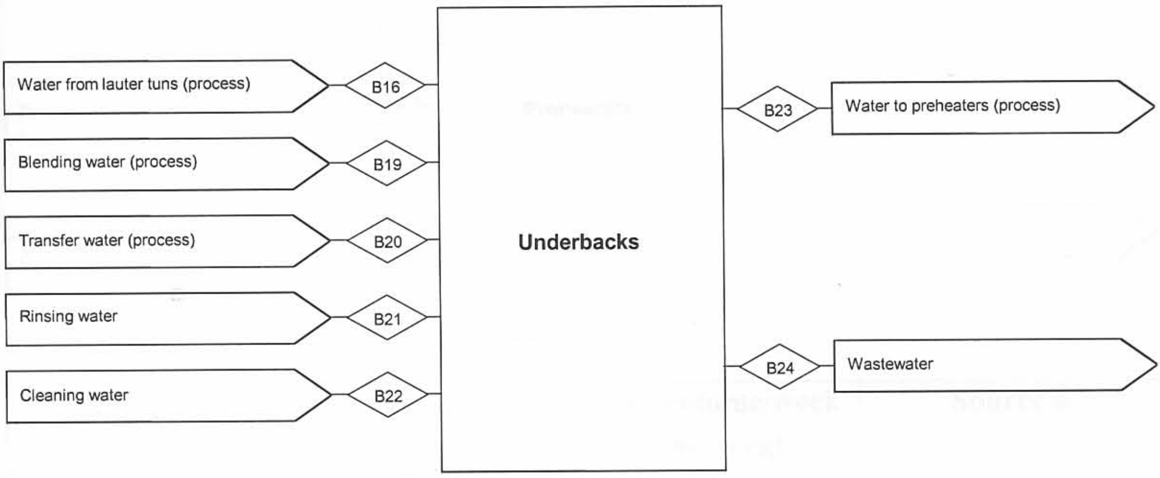
⊕ Sources, other than streams, are presented at the end of each chapter.

**Figure 3.5** Water balance over the lauter tuns.

### 3.2.4 Underbacks

The water balance over the underbacks is shown in Figure 3.6. Water is blended with the process liquor in the underbacks (prior to the transfer to the wort kettles) and amounts to a total volume added of 475 hl (calculated as 200 hl for brewhouse 1 and 275 hl for brewhouse 2, based on SAB recipe). On completion of the transfer of liquor to the wort kettles, 75 hl of water is added to transfer any liquor remaining in the lines to the wort kettles (calculated as 40 hl for brewhouse 1 and 35 hl for brewhouse 2) and this volume forms part of the product (Isaacs, 2001).

Any residue remaining in the underbacks after the transfer of mash liquor to the wort kettles is rinsed out with water at a rate of 1 240 hl/h for 30 seconds (van der Merwe, 2000). The resultant 21 hl of water (based on one underback from each brewhouse) per brew is discharged to the drains. The underbacks in brewhouses 1 and 2 undergo a CIP clean two times per week with an estimated total water use of 1 600 hl/week, which is discharged to the drains (van der Merwe, 2000).



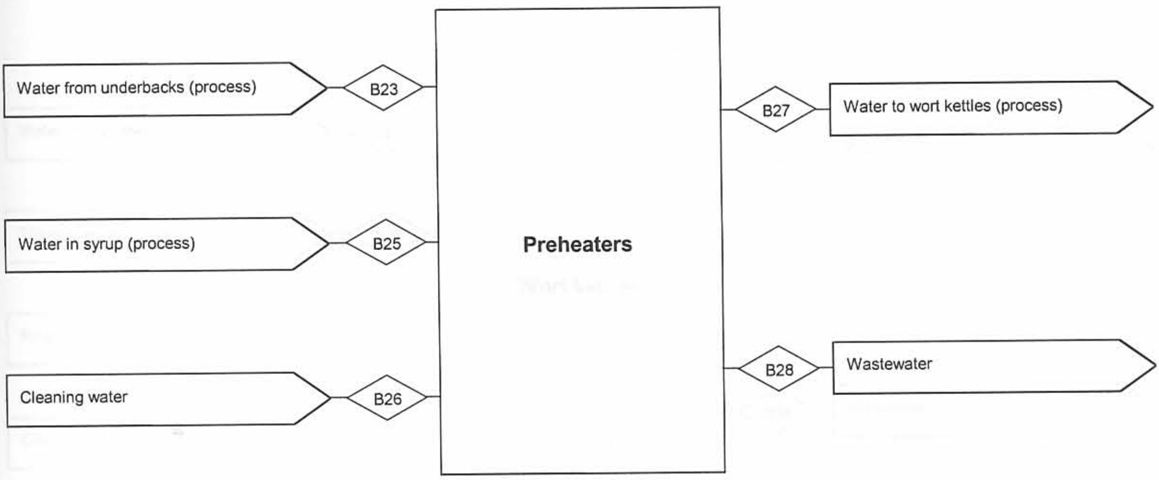

| Stream | Volume [hl] | Frequency | Ave volume/week [hl/week] | Source ⊕ |
|---|---|---|---|---|
| B16 | 1 665 | per brew | 53 280 | - |
| B19 | 475 | per brew | 15 200 | S1 |
| B20 | 75 | per brew | 2 400 | S5 |
| B21 | 21 | per brew | 672 | S3 |
| B22 | 1 600 | per week | 1 600 | S3 |
| B23 | 2 215 | per brew | 70 880 | B16 + B19 + B20 |
| B24 | - | - | 2 272 | B21 + B22 |

⊕ Sources, other than streams, are presented at the end of each chapter.

**Figure 3.6** Water balance over the underbacks.

### 3.2.5 Preheaters and syrup addition

The water balance over the preheaters, including syrup addition, is shown in Figure 3.7. 15 225 kg of syrup, with an estimated water content of 22 % and a density of 1 380 kg.m$^{-3}$, is added to the process liquor during the transfer of wort to the wort kettles (Isaacs, 2001). Therefore, 110 hl of syrup, with a water content of 24 hl, is added per brew. The preheaters undergo CIP cleaning after every brew with an estimated total water use of 100 hl per brewing cycle, which is discharged to the drains (van der Merwe, 2000).




| Stream | Volume [hl] | Frequency | Ave volume/week [hl/week] | Source ⊕ |
|---|---|---|---|---|
| B23 | 2 215 | per brew | 70 880 | - |
| B25 | 24 | per brew | 768 | S5 |
| B26 | 100 | per brew | 3 200 | S3 |
| B27 | 2 239 | per brew | 71 648 | B23 + B25 |
| B28 | 100 | per week | 3 200 | B26 |

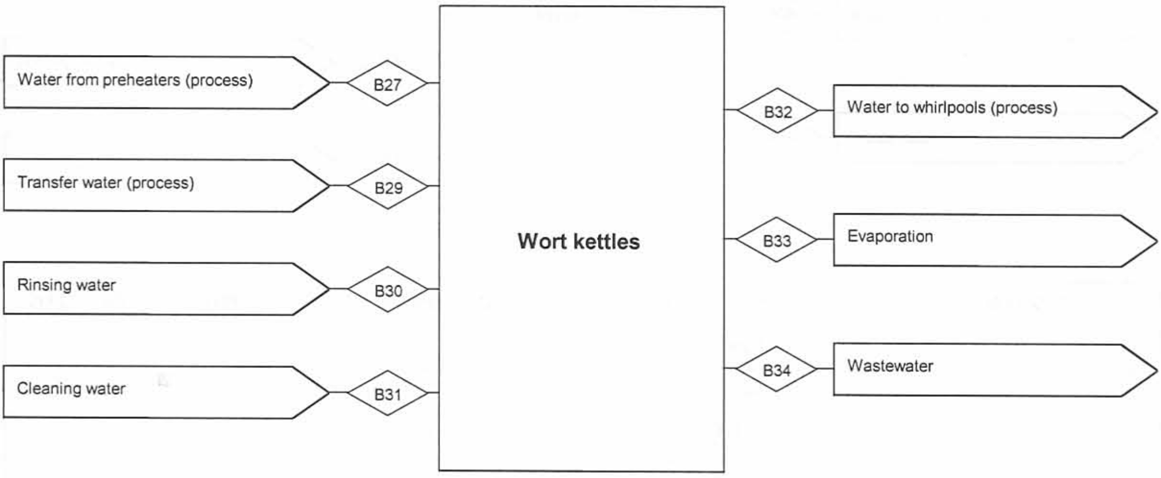
⊕ Sources, other than streams, are presented at the end of each chapter.

**Figure 3.7** Water balance over the preheaters (including syrup addition).

### 3.2.6 Wort kettles

The water balance over the wort kettles is shown in Figure 3.8. During the boiling of the mash liquor in the wort kettles, approximately 7 % of the liquor, on a volume basis, is lost to atmosphere (Isaacs, 2000). Therefore, approximately 157 hl of water is evaporated to the atmosphere per brew.

On completion of the transfer of wort to the whirlpools, water is used at a rate of 1 240 hl/h for 65 seconds to transfer any remaining wort in the pipeline to the whirlpools (van der Merwe, 2000). The resultant 45 hl of water (based on two wort kettles) forms part of the product. The wort kettles are also rinsed at a rate of 1 240 hl/h for 30 seconds after each brew to remove any remaining residue (van der Merwe, 2000). Therefore 21 hl of water is used for rinsing the vessels and is discharged to the drains. The wort kettles, including their internal boilers, undergo a CIP clean twice every 5 brews with an estimated total water use of 140 hl per cleaning (van der Merwe, 2000). Thus an additional 1 792 hl of water is discharged to the drains per week.



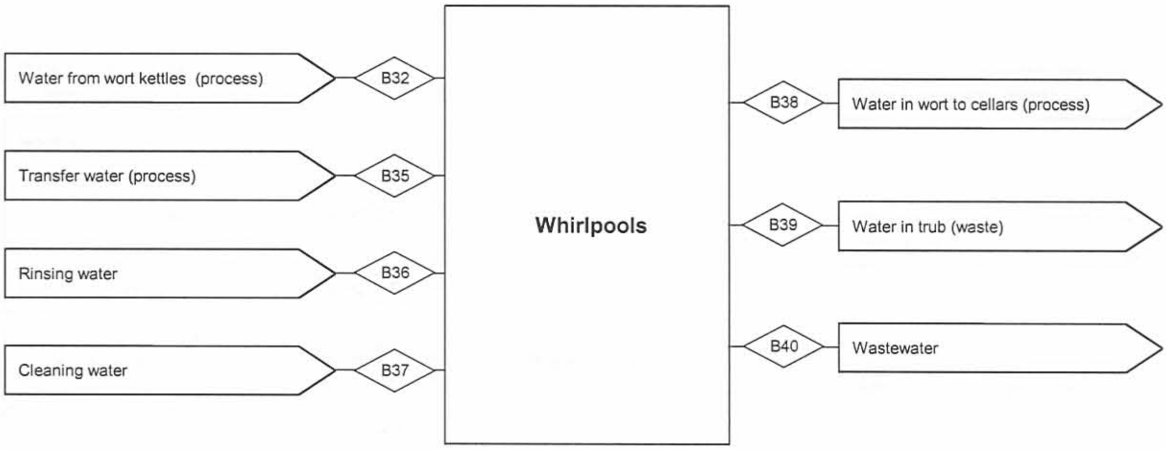

| Stream | Volume [hl] | Frequency | Ave volume/week [hl/week] | Source ⊕ |
|---|---|---|---|---|
| B27 | 2 239 | per brew | 71 648 | - |
| B29 | 45 | per brew | 1 440 | S3 |
| B30 | 21 | per brew | 672 | S3 |
| B31 | 1 792 | per week | 1 792 | S3 |
| B32 | 2 127 | per brew | 68 064 | B27 + B29 – B33 |
| B33 | 157 | per brew | 5 024 | S5 |
| B34 | - | - | 2 464 | B30 + B31 |

⊕ Sources, other than streams, are presented at the end of each chapter.

**Figure 3.8** Water balance over the wort kettles.

### 3.2.7 Whirlpools

The water balance over the whirlpools is shown in Figure 3.9. After the transfer of the wort to the wort coolers, water is added at a rate of 1 240 hl/h for 150 seconds to transfer any remaining wort in the line to the wort coolers (van der Merwe, 2000). Therefore, an additional 103 hl of water (for the two whirlpools) is added during every brew and forms part of the product.




| Stream | Volume [hl] | Frequency | Ave volume/week [hl/week] | Source ⊕ |
|---|---|---|---|---|
| B32 | 2 127 | per brew | 68 064 | - |
| B35 | 103 | per brew | 3 296 | S3 |
| B36 | 276 | per brew | 8 832 | S3 |
| B37 | 1 200 | per week | 1 200 | S3 |
| B38 | 2 205 | per brew | 70 560 | B32 + B35 – B39 |
| B39 | 25 | per brew | 800 | S5 |
| B40 | - | - | 10 032 | B36 + B37 |

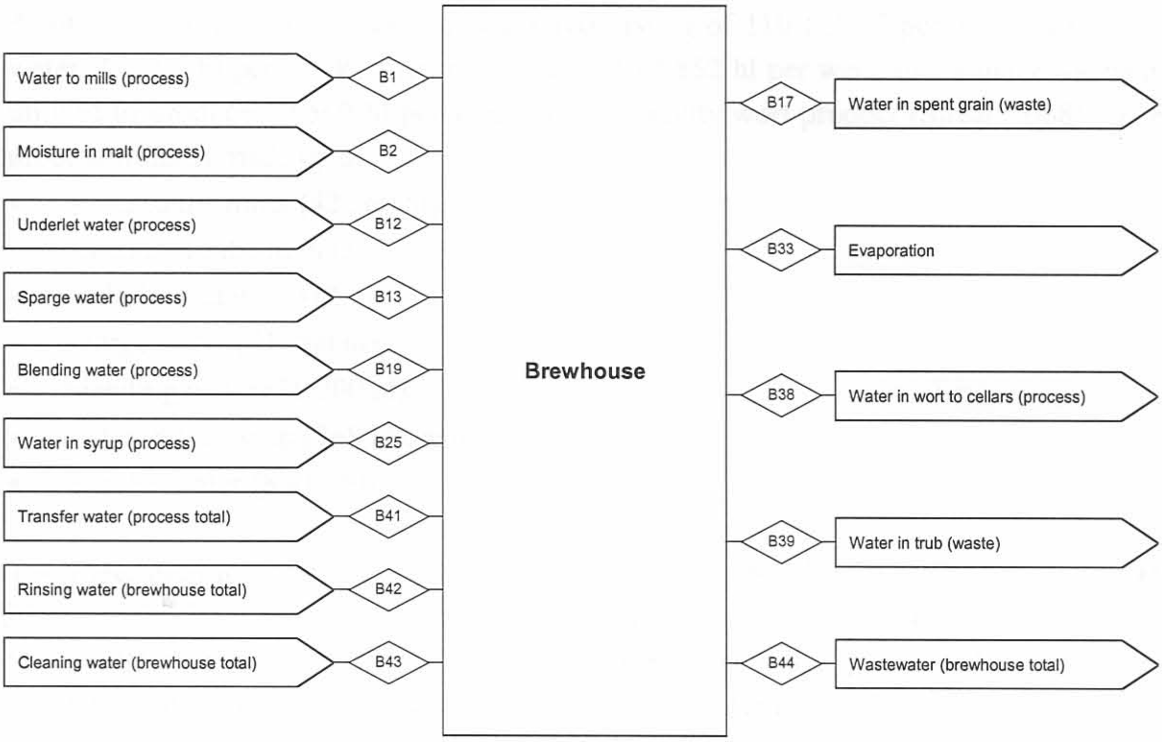
⊕ Sources, other than streams, are presented at the end of each chapter.

**Figure 3.9** Water balance over the whirlpools.

The whirlpools are rinsed to remove any trub still residing in the vessels at a rate of 1 240 hl/h for 400 seconds (van der Merwe, 2000). The resultant 276 hl of water used per brew for the two whirlpools is discharged to the drains. The trub remaining in the whirlpools (containing approximately 25 hl of water per brew) is sent to the trub tanks from where it is mixed with the spent grain and sold to farmers as animal feed (Isaacs, 2000). The whirlpool in each brewhouse is cleaned twice a week with an estimated total water use of 1 200 hl/week, which is discharged to the drains (van der Merwe, 2000).

## 3.3 OVERALL WATER BALANCE OVER THE BREWHOUSE

The overall water balance over the brewhouse is shown in Figure 3.10.




| Stream | Volume per week (hl/week) | Source |
|---|---|---|
| B1 | 42 560 | Section 3.2.1 |
| B2 | 512 | Section 3.2.1 |
| B12 | 1 312 | Section 3.2.3 |
| B13 | 41 760 | Section 3.2.3 |
| B17 | 2 400 | Section 3.2.3 |
| B19 | 15 200 | Section 3.2.4 |
| B25 | 768 | Section 3.2.5 |
| B33 | 5 024 | Section 3.2.6 |
| B38 | 70 560 | Section 3.2.7 |
| B39 | 800 | Section 3.2.7 |
| B41 | 8 416 | B7 + B20 + B29 + B35 |
| B42 | 17 792 | B3 + B8 + B14 + B21 + B30 + B36 |
| B43 | 12 852 | B4 + B9 + B15 + B22 + B26 + B31 + B37 |
| B44 | 62 388 | B6 + B11 + B18 + B24 + B28 + B34 + B40 |

**Figure 3.10** Overall water balance for the brewhouse at the Rosslyn plant.

A total of 141 172 hl of water per week (consisting of 110 528 hl per week of process water, 17 792 hl per week of rinsing water and 12 852 hl per week of cleaning water) is utilised to produce 70 560 hl per week of high gravity wort product (Stream B38). The process water is made up of:

- water to the mills (42 560 hl),
- moisture in the malt (512 hl),
- underlet water (1 312 hl),
- sparge water (41 760 hl),
- blending water (15 200 hl),
- water in the syrup (768 hl), and
- transfer water (8 416 hl).

The water used for cleaning (12 852 hl) and rinsing (17 792 hl) of vessels, in total 30 644 hl per week, forms part of the wastewater discharged to the drains. During the boiling of the mash liquor in the wort kettles, 5 024 hl of process water is lost to the atmosphere through evaporation. A further 3 200 hl of process water is lost through the disposal of spent grain and trub byproducts, which are sold to farmers as animal feed.

Finally, the Rosslyn plant brews high gravity wort for better equipment utilisation and water conservation. However, the ratio of hl of water used to hl of beer produced (a ratio commonly utilised by the brewing industry to depict water usage, Wainwright, 1998) is based on normal gravity wort. Since blending with water, to obtain normal gravity wort, only occurs in the cellars section, the high gravity wort volume is adjusted with the blending ratio (as utilised in the cellars section) to evaluate the water consumption within the brewhouse. A blending ratio of 0,44 parts of water to 1 part of wort is used at the Rosslyn brewery (SAB, 2000) and therefore 101 606 hl of normal gravity wort equivalent is prepared by the brewhouse. The ratio of water used to beer produced can therefore be calculated as:

$$(\text{Ratio of water used : beer produced})_{\text{brewhouse}} = \frac{141172}{101606} = 1{,}39 \ \ (\text{v/v})$$

The water balance in this chapter does not include water for washdown and other losses. These streams will be considered in Chapter 6.

## 3.4 SOURCES

The sources used within this chapter for calculating the different water balances over the brewhouse are presented below.

| Source | Reference |
|---|---|
| S1 | SAB (2000a) "Beer Division Brewing Manual", Johannesburg. |
| S2 | Caledon Maltings (2000) "Malt Analysis", supplied on delivery of malt at the Rosslyn brewery, George. |
| S3 | Van der Merwe, A.I. (2000) "Water Report for Brewhouse and Cellars" report to SAB Rosslyn plant, Pretoria. |
| S4 | SAB (2000b) "Process Best Operating Practices", SAB Rosslyn plant, Pretoria. |
| S5 | Isaacs, N. (2001) "Operation in the SAB Rosslyn Brewhouse", Personal Communication, Rosslyn Brewery, Pretoria. |