# Manitoba Operations Water Flow

## Technical Report

Belo Horizonte, 2012-12-14

CRONO ENGENHARIA LTDA.
Rua Bernardo Guimarães, 895/508, 30140-081 Belo Horizonte, MG, Brazil – Phone +55-31-3261-9209
cronoengenharia@crono.eng.br

# Manitoba Operations Water Flow

**CONTENTS**

## FIGURES



## TABLES



## APPENDICES

# 1 FOREWORD

This report summarizes the studies developed by Crono Engenharia Ltda. (Crono Consulting Engineers) under the terms of the contract 1604471 signed with Vale-DIAM. The objectives of the contract are: (i) to develop a diagram of Vale's Manitoba Operations industrial water flow; (ii) to calculatethe Global Reporting Initiative – **GRI** environment performance indicators **EN8**, **EN10** and **EN21**; and (iii) to identify water reuse and recycling opportunities.

Performance indicators values were calculated based on Vale-DIAM adopted concepts, further referenced on the directives set out by **GRI**. The indicators are:

**EN8** – total water withdrawal by source;

**EN10** – percentage and total volume of recycled and reused water; and

**EN21** – total water discharge by quality and destination.

Data and other information used in these studies were previously provided by the Operations technical team **[1]**[1]. These were complemented by data and information obtained during a technical visit to Manitoba Operations site, which took place in the period 2012-05-28 to 2012-06-01.

# 2 INTRODUCTION

Terms <u>water reuse</u> and <u>water recycling</u> normally refer to projects whose associated technologies aim at the strengthening of the natural water cycle. According to the *United Nations Secretariat* (2001), total urban population in the year 2000 amounted to 2.85 billion, for a world population of 6.06 billion. It is estimated that by the year 2030, almost 5 billion people shall be living in urban areas. This significant increase in urban population may lead to a

[1] Consulted bibliography and other references are cited wherever applicable.

consequent increase in water-scarce areas and areas under hydric stress, relatively to what is nowadays observed (**Figure 2.1**).

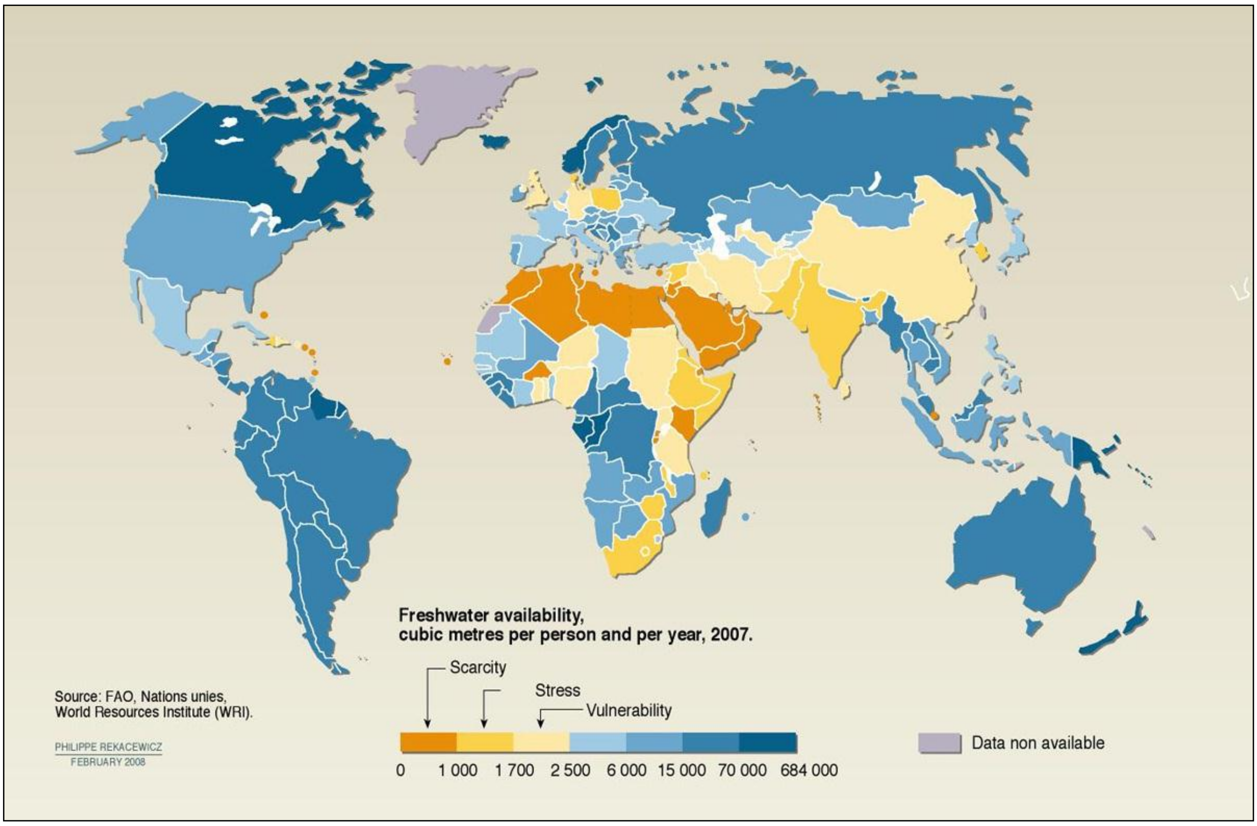


**Figure 2.1: Freshwater availability (2007)**

A counteraction to such a trend demands new technological and managerial processes able to reduce water use and increase reuse. Therefore, every action towards the maintenance or the enlargement of the productive basis faces new challenges regarding the use of water resources. First, water demand management must be considered as a priority, in such a way as to increase the sustainability of the productive processes and thus increase water availability for human consumption, which takes precedence in cases of scarcity. Second, but not less important, reuse and recycling may supply demands of several types, given an adequate treatment to make water suitable for purposes where potability is not of prime concern.

In addition to contributing to the safety and continuity of water supply, reuse and recycling result in significant environmental benefits especially due to the fact that they are locally controllable. Water reuse minimizes withdrawals thus reducing impacts, especially on sensitive environments. Water reuse also reduces effluent discharges and the contamination of receiving water-bodies. Living organisms depend on water quality and quantity to survive and reproduce in their habitats. The deterioration of an aquatic system may seriously degrade the associated ecosystem and its bio-diversity.

Mining operations may cause changes in water-bodies in their areas of influence. They may alter hydrological and topographical characteristics of the mined area and subsequently change run-off patterns, soil humidity rates, evapotranspiration rates and underground water behavior, thus posing danger to water quality, flow regime and available volumes.

Therefore, effective management directed to minimizing changes on the quality and quantity of available water resources is important to render sustainability to mining operations. Water resource management is also important in reaching satisfactory agreements with the affected communities and government authorities regarding existing and planned mining operations.

Water use reduction, as well as water reuse and recycling in productive processes, and the development of new technologies which employ lower water volumes, are objectives to be pursued by mining companies. In most occasions, especially for mining operations, water use reduction entails lower energy consumption rates, with lower production costs, higher competitiveness and higher sustainability patterns.

Companies worldwide, Vale included, have no alternative but minimize negative influences on their businesses originating from inadequate use of water resources, by incorporating higher knowledge levels and innovative solutions to managerial and productive processes. Advances observed thus result from: (i) new legal restrictions; (ii) the perspective of extinction of natural resources; and also (iii) an increasing market demand for products of environmentally sustainable processes.

In line with the directives laid out by its Sustainable Development Policy, Vale invests in the improvement of water resource management actions and technological innovations, aiming at the reduction of new-water withdrawal volumes and the increase of reuse rates.

Vale develops studies in its units to serve as subsidies for the adoption of water demand management actions. Actions are implemented into the processes aiming at water reduction, losses and waste control, effluent generation reduction, and reuse and recycling.

## 2.1 Relevant Canadian legislation

Recommendation R 302 of the Canadian Environmental Code of Practice for Metal Mines **[2]** states that ore processing facilities should be designed to:

- *minimize the volume of fresh water that is used for ore processing by:*
  - *Using ore processing methods that require less water;*
  - *Maximizing the recycling of water to reduce requirements for freshwater intake; and*
- *avoid or minimize the use of reagents that require treatment prior to effluent discharge.*

Further, recommendation R 403 of the above mentioned Code states that water management activities during the mine operations phase should include, amongst others, efforts to identify and implement ways to recycle water and reduce the use of fresh water as much as possible.

On the other hand, Recommendation R 301 of the Environmental Code of Practice for Base Metals Smelters and Refineries **[3]** establishes that water use should be minimized to the maximum practicable, possibly through the recycling or reuse of water and the cascading of cooling water and wastewater between production processes using lower-quality water.

# 3 MANITOBA OPERATIONS

Vale's Manitoba Operations neighbour the southeastern side of the City of Thompson, MB, Canada (55°44'36"N, 97°51'19"W). First established as INCO in the mid 1950's, later named CVRD Inco and Vale INCO, the Operations comprised the first integrated nickel mining and processing complex in the world. Vale's Manitoba Operations at present consist of two production clusters – Thompson Operation and Birchtree Mine. The Thompson Operation is comprised of T1 and T3/1D[2] mines, a Mill, a Smelter and a Refinery facility[3]. In addition, Thompson Operation has a Utilities facility, responsible for the supply of both potable and process water to the Operations and for the supply of potable (drinking) water to the City of Thompson.

At present, Thompson Operation smelt and refine nickel ore concentrate from Voisey's Bay Vale's Operation in the province of Newfoundland and Labrador. However, Vale has decided that from 2015 onwards, all the nickel concentrate produced at both Thompson and Voisey's Bay will be smelted and refined at the latter's facilities. As a result, Thompson Smelter and Refinery facilities are scheduled to be permanently closed at the end of 2014 and a new Concentrate Load-out facility is to be built in Thompson[4].

For about half a century up to 2007, Vale Inco's Thompson site had produced 1.86 million metric tons of nickel **[4]**. In the year 2011, Vale Inco's Thompson site produced 25 thousand metric tons of finished nickel, which accounted for 10.3 % of the company's production of the metal in that year. Also in 2011, Thompson Operation have yielded a production of 1000 metric tons of copper and 158 metric tons of cobalt **[5]**.

[2] T3 Mine has 1D development as an extension.
[3] Birchtree Mine ore is processed at Thompson Operation's facilities.
[4] Likewise, Voisey's Bay will have newly built processing facilities to accomplish the planned purpose.

# 4 INDICATORS CALCULATION METHODOLOGY

This section presents the methodology used for the determination of the **GRI** environment performance indicators **EN8**, **EN10** and **EN21**. These parameters belong to the Indicator Protocols Set of the Global Reporting Initiative. The first two, **EN8** and **EN10**, are classified under **GRI** Aspect Water and the latter, **EN21**, is classified under **GRI** Aspect Emissions, Effluents and Waste. **EN8** and **EN10** indicators are used for the calculation of %**EN10**, the recycling and reuse indicator. The indicators are defined as follows:

- **EN8** - Total water withdrawal by source, $m^3$/year

**GRI** defines **EN8** as the sum of all water volumes drawn into the boundaries of the reporting organization[5] from all sources (including surface water, ground water, rainwater and municipal water supply) for any use over the course of the reporting period.

- **EN10** - Total volume of water recycled and reused, $m^3$/year

**GRI** defines **EN10** as the sum of all water volumes deriving from the act of processing used water/wastewater through another cycle before discharge to final treatment and/or discharge to the environment.

Recycling and reuse indicator **%EN10** is calculated as a percentage ratio of the total recycled and reused water volume to the total water volume used by the organization in a given period (**Equation 4.1**).

$$\%EN10 = \frac{EN10}{EN8 + EN10} \cdot 100\ (\%) \qquad \textbf{4.1}$$

- **EN21** - Total water discharge by quality and destination, $m^3/year$

[5] **GRI** reporting organization.

**GRI** defines **EN21** the sum of water effluents discharged over the course of the reporting period to subsurface waters, surface waters, sewers that lead to rivers, oceans, lakes, wetlands, treatment facilities, and ground water, either through:

- A defined discharge point (point source discharge);
- Over land in a dispersed or undefined manner (non-point source discharge); or
- Wastewater removed by truck from the reporting organization. Discharge of collected rainwater and domestic sewage is not regarded as water discharge.

**GRI EN21** indicator must be reported in $m^3/year$, broken down into volumes by destination and by treatment method. If applicable, the effluent volume used by another organization must be reported. Vale has established that **EN21** disclosure must also be accompanied, as applicable, by an account of the total loading of **oil and grease** and **total suspended solids** discharged into the environment.

Furthermore, according to **GRI** directives, **EN21** may be estimated in cases where discharge flow measurements are not available. The estimation is made by subtracting the actual volume of consumed water from the volume of withdrawn water, as computed into **GRI EN8** indicator. The calculation of **EN21** does not take into consideration the volume of domestic sewage discharges. In cases where domestic sewage is discharged together with industrial effluents, its volume should be estimated and subtracted from the previously obtained difference.

In **EN21** calculations Vale does not take into account any volumes of tailings discharged into the Tailings Basin.

## 4.1 General water-flow diagram for the calculation of GRI EN8 and EN10 indicators

**Figure 4.1** presents the general water-flow diagram for the calculation of the **GRI EN8** and **EN10** environment performance indicators of mining operations.

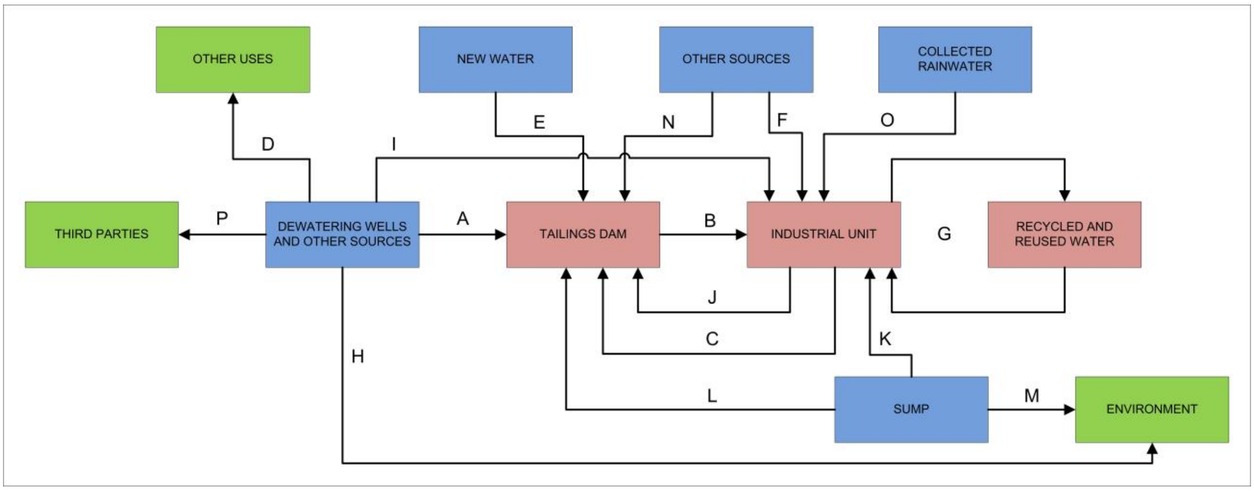


**Figure 4.1: Mining operations general water flow diagram**

In **Figure 4.1** water transfer or exchange flow lines are coded as follows:

**A**: Dewatering volume flowing into the tailings dam

**B**: Total volume of water diverted from the tailings dam flowing into the industrial unit

**C**: Volume of water contained in the tailings discharged into the dam

**D**: Dewatering volume directed to other uses (dust abatement, water treatment plants, mechanical shops, etc.)

**E**: Volume of new water diverted from the tailings dam:

> **E = 0** if the volume entering the dam **(A+C+J+L+N)** is larger or equal to the volume **B** diverted from the dam to the industrial unit
>
> **E = [B - (A+C+J+L+N)]** if the volume entering the dam **(A+C+J+L+N)** is smaller than the volume **B** diverted from the dam to the industrial unit

**F**: Volume of water from other sources directed to the industrial unit

**G**: Volume of water recycled or reused in the industrial unit

**H**: Dewatering volume directed to the environment

**I**: Dewatering volume directed to the industrial unit

**J**: Water volume discharged into the dam, other than the water contained in the tailings

**K**: Water volume diverted from sumps to the industrial unit

**L**: Water volume diverted from sumps to the tailings dam

**M**: Water volume diverted from sumps returned to the environment

**N**: Water volume from other sources (springs, supply wells, rivers, etc.) directed to the tailings dam

**O**: Collected volume of rainwater used in the industrial unit

**P**: Dewatering volume and water from other sources directed to third parties or used for water-bodies replenishment

**EN8** and **EN10** are respectively calculated with **Equations 4.2** and **4.3**.

$$EN8\ /m^3/year = A + D + H + I + E + F + L + K + M + N + O + P \qquad \textbf{4.2}$$

$$EN10\ /m^3/year = D + I + G + K + [B - (E + N)] + O \qquad \textbf{4.3}$$

where the difference $\mathrm{B} - (\mathrm{E} + \mathrm{N})$ corresponds to the volume of reused water, withdrawn from the tailings dam.

Vale reviews **Equation 4.1** into **Equation 4.4**.

$$\%EN10\ /\% = \frac{EN10}{(EN8 + EN10) - P - O} \cdot 100 \qquad \textbf{4.4}$$

Although taken into account for the computation of **EN8**, **P** is subtracted from the denominator in the right term of **Equation 4.4** because Vale considers that it is not a part of the water demand of its operations. In the same **Equation 4.4**, **O** is subtracted from the denominator because its value is computed twice, for the calculation of **EN8** and **EN10**.

## 4.2 Calculator

Under the terms of a special contract, Crono has developed in behalf of Vale a MS-EXCEL® calculator[6] with the aim of facilitating the computation of **GRI EN8** and **EN10** indicators (Appendix A). The main features of the calculator are:

a. reproduces **Figure 4.1** general water flow diagram;

b. variable values may either be inserted on a graphical screen or typed into cells;

c. allows the accumulation of up to 12 sets of results;

d. instant simulations made possible;

e. allows the calculation of effective water-balance values: takes start-up volumes in;

f. user-chosen language (Portuguese, English and Spanish);

g. embedded help available;

h. MS-Excel® 97-2003 compatible tool.

## 4.3 Calculation of GRI EN21 indicator

In this work, only point source discharges were considered and their volumes were added up to find **GRI EN21** indicator.

[6] "GRI-CALC-vv.xls", where vv designates the tool's version.

# 5 MANITOBA OPERATIONS WATER FLOW

This section presents a brief description of Thompson and Birchtree water flow. Initially, the current flow is presented, followed by a discussion on the expected flow after the Smelter and Refinery closure planned for the end of the year 2014.

## 5.1 Present situation of water usage and effluent discharge

**Figure 5.1** shows Manitoba Operations water macro-flow (all-site flow) diagram, comprising both Thompson Operation and Birchtree Mine. The diagram indicates the flow lines where measurements are available, as well as those lines where measurements are estimated and also those where neither measurements nor estimates exist, but nevertheless are needed for a reasonable quantification of the water flow.

Thompson Operation[7] is supplied with water withdrawn from Burntwood River at PS1 diversion point situated on the right bank of the river[8]. Diversion and pumping are under the responsibility of the Utilities, which treats a part of the diverted flow and distributes both potable and process water to all facilities.

Part of the water withdrawn from Burntwood River is pumped at PS1 to TPw1 main water treatment plant while another part is pumped in raw state to the Utilities. At TPw1, approximately 62% of the treated volume[9] is supplied as potable (drinking) water to the City of Thompson, while the remaining 38% are pumped to the Utilities. This facility utilizes part of the potable water for its own use, for instance, for human consumption and for the production of steam for heating of all facilities. Both potable and raw water are distributed to the Mill, the Smelter, the Refinery, and to T1 and T3/1D Mines. Raw water is distributed by the Utilities as process water.

[7] T1 and T3/1D mines, Refinery, Smelter, Mill, Support Services and Utilities Department facilities.
[8] 55°42′58″N, 97°56′11″E
[9] 2011 data.

On the other hand, Birchtree Mine, is supplied with water from PS2 diversion point, also situated on the right bank of the Burntwood River[10]. Birchtree is responsible for both water diversion and treatment (at TPw2) for its own operational purposes.

[10] 55°44′32″N, 97°53′44″E

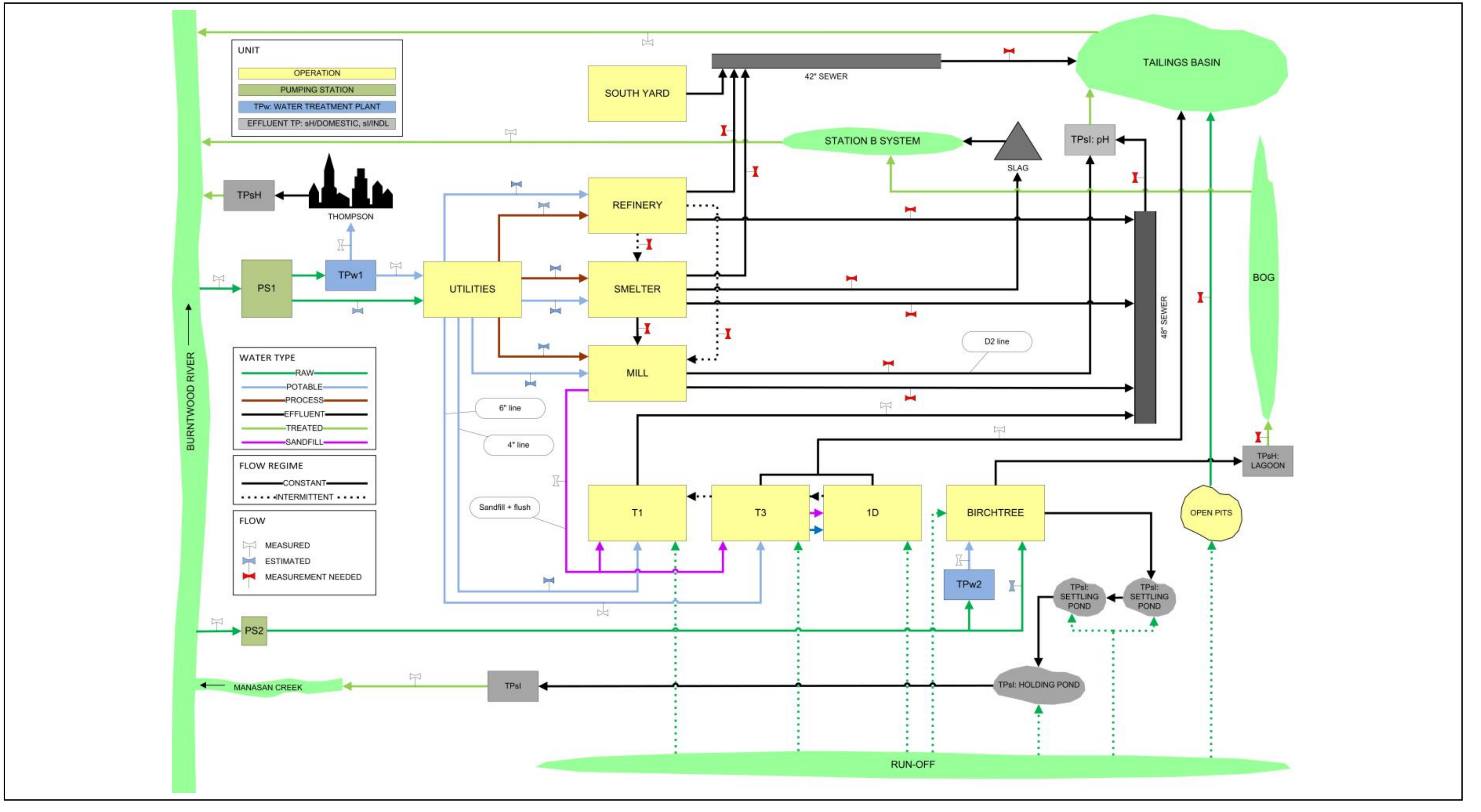


**Figure 5.1: Manitoba Operations Water Flow.**

5.1.1 Mill

The Mill uses potable water for both human consumption and the fire protection network. At the Mill process water is used for the processes run by the facility, as shown in **Figure 5.2**. Ore milling for further processing is done by crushing, milling and flotation. In the Sand Plant, the Mill facility also prepares sandfill that is used in mines T1 and T3/1D. Process water is used for sandill mixing as well as sandfill pipes flush.

Mill processes employ several reagents, amongst them use-ready diluted Soda Ash from the Refinery.

The facility's products are finished by flotation. Nickel concentrate slurry is pumped to the Smelter and copper concentrate is sent for further processing to Ontario Operations[11]. An effluent line connected to 48" Sewer, as indicated in **Figure 5.1**, derives from Flotation (**Figure 5.2**). Tailings derive from the Sand Plant through a line also represented in **Figure 5.2**. The Mill also receives part of the Smelter effluents on a regular basis. Eventually the Mill also receives part of the Refinery effluents.

Effluents and tailings are discharged through D2 Line (tailings) and 48" Sewer (effluents) to an effluent treatment plant (TPSi: pH in **Figure 5.1**) for pH correction[12]. From TPSi: pH the effluents are directed into the Tailings Basin, whose waters flow into Burntwood River.

[11] Vale's copper plant in Sudbury, Ontario.
[12] To operate after the end of year 2012.


CRONO ENGENHARIA LTDA.
Rua Bernardo Guimarães, 895/508, 30140-081 Belo Horizonte, MG, Brazil – Phone +55-31-3261-9209
cronoengenharia@crono.eng.br

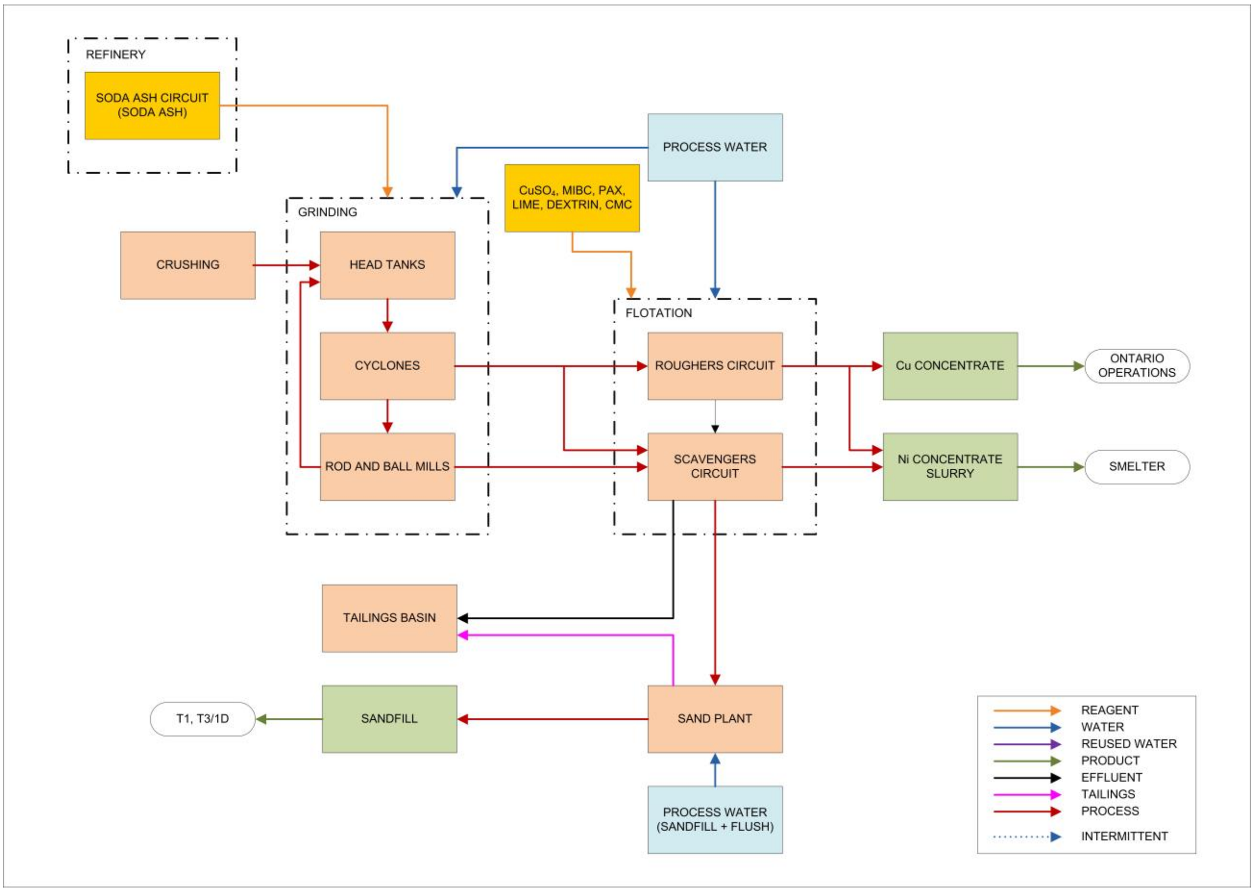


**Figure 5.2: Water in Mill Processes**

### 5.1.2 Smelter

Nickel concentrate slurry from the Mill is further concentrated at the Smelter (**Figure 5.3**). The thickening process uses a flocculant made with potable water. The Thickener Overflow Tank receives the process overflow water, a part of which returns to serve as flocculant dilutant[13] while the remaining volume flows into the 48" Sewer.

Thickener underflow is directed to the pressure filters from where the product is directed to a conveyor belt to be loaded to the smelting process proper. The filtrate is sent back to reenter the process into the thickener[14].

[13] Reused water. Contributes to **GRI EN10**.
[14] Same as previous footnote.

The Smelter also uses process water for slag cooling and for pressure filters washing. To this latter end, process water is stored in Wash Water Tanks (**Figure 5.3**).

In addition to the effluents discharged through the Mill, the Smelter discharges effluents directly into 42" and 48" Sewers, as well as to the Slag pile. Effluents carried by both 42" and 48" Sewers flow directly into the Tailings Basin. After the end of year 2012, 48" Sewer effluents will be previously treated in TPSi: pH for pH correction before being discharged into the Basin. Slag cooling effluents flow into the Station B System, from where they are discharged into the Burntwood River (**Figure 5.1**).

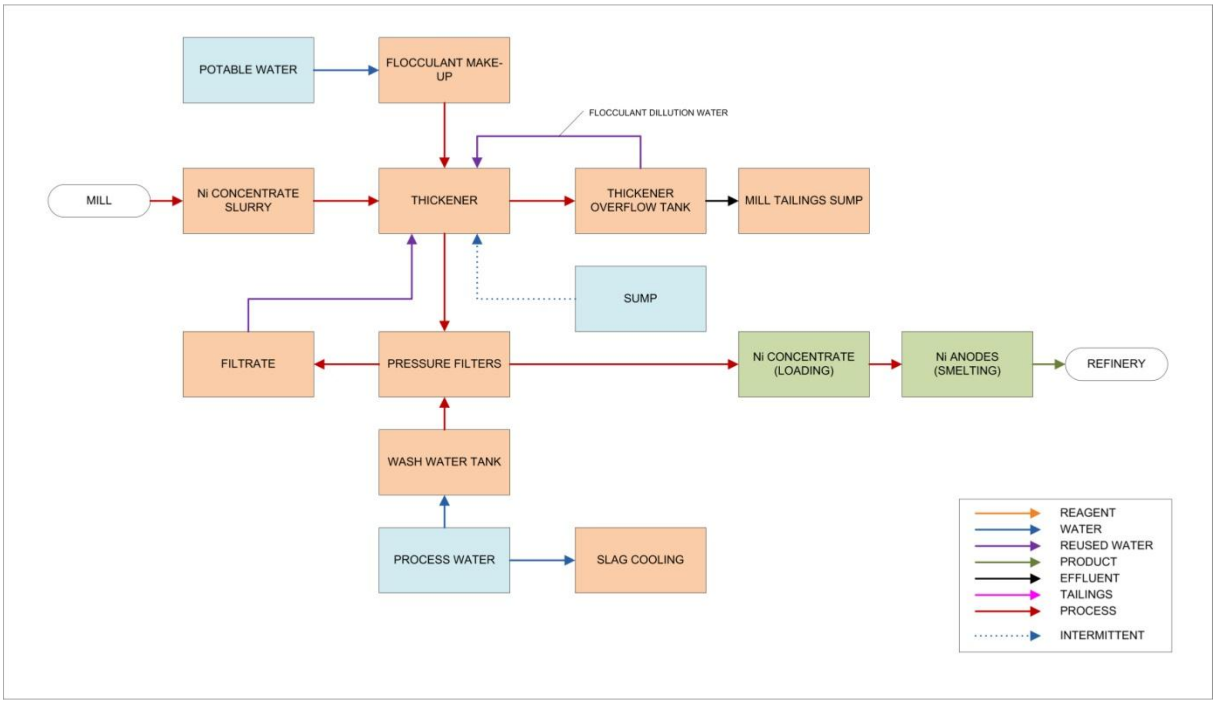


**Figure 5.3: Water in Smelter Processes**

### 5.1.3 Refinery

Both potable and process water are used in all stages of the processes run by the Refinery: Purification, Tankhouse, Scrapwash, Mandrel Plant, Stripping Floor and Shear Shed (**Figure 5.4**).

At Purification, the filtrate from several processes and the Tankhouse anolytes are purified into electrolytes that are sent back to the Tankhouse. In the Purification decantation stage the precipitated fractions are sent to pressure filters, of which the resulting solids are directed to the Smelter while the filtrate returns to the decantation tanks.

In the Tankhouse, in addition to the anolytes that return to Purification, spent anodes are directed to Scrapwash, round mandrels to the Mandrel Plant, finished rounds to the Stripping Floor, and full-size plates (slabs) to the Shear Shed.

At Scrapwash, the spent anodes from the Tankhouse are crushed, drum washed, crushed for a second time, and finely ground in a ball mill, to be returned to Purification as ground matte.

At the Stripping Floor, materials from the Tankhouse are hand selected and either directed to shipment or returned to the Tankhouse, depending on their quality performance indicators. At the Shear Shed, products are hand selected, weighed and sent to shipment.

In addition to the water used in the process, the Refinery uses potable water for human consumption and for the fire protection network. The Refinery also uses process water in gas scrubbing, lime quenching, bag washing, and as coolant for the current rectifiers bank and for soda-ash preparation (**Figure 5.4**).

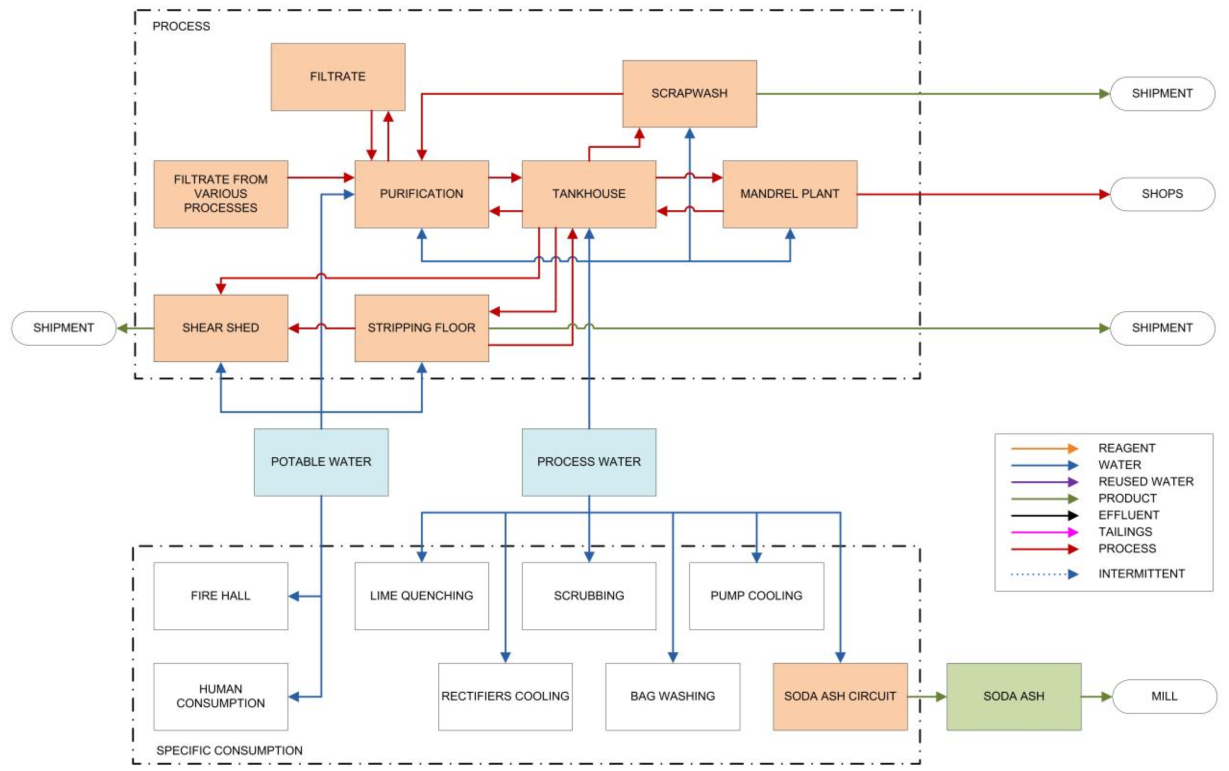


**Figure 5.4: Water in Refinery Processes**

Effluents generated from the Refinery are discharged into 42" and 48" Sewers. No water reuse or recycling has been identified in any stage of the process run by the Refinery.

### 5.1.4 T1 and T3/1D Mines

Mining facilities on the main plant site (T1 and T3/1D Mines) are fed by the Utilities with potable water only, that is, no process water is sent to these mines, except, as above mentioned, process water deriving from the Mill as sandfill mixing water or sandfill pipe flushing water.

About 50% of T3/1D Mine effluents are pumped[15] from the 3600 ft level directly into the Tailings Basin. The remaining 50% are recycled to be used in drilling[16]. In cases of disarrangement of the GEHO pumps the effluents are directed to T1 Mine to be pumped out.

At T1 Mine, most of the effluents are pumped out from 1640 ft level to the 48" Sewer. A minor part of the effluents is used for sludge dilution.

### 5.1.5 Open Pits

There are three inoperative open pits in the Thompson Operation area, named A, B and C. At Pit C, there is a station which pumps the sump water out of the open pits to a pond[17]. From the pond it flows to the Tailings Basin. This discharged volume is not measured.

### 5.1.6 Birchtree Mine

Birchtree Mine uses both process and potable water. Most of the process water supplied to Birchtree is used for drilling. Process water is also used at the Mine for sandfill mixing and sandfill pipes flushing. Potable water is used for human purposes.

## 5.2 After-closure Scenario: water usage and effluent discharge

At the end of 2014, after the planned deactivation of the Smelter and Refinery the water demand from Thompson Operation will decrease. Despite of the construction of the new Load-out facility, lower volumes are expected to be withdrawn at PS1 from Burntwood River, thus lowering the value of **GRI EN8** indicator (section ahead).

[15] GEHO pumps.
[16] According to information obtained during field visit to Mine T3 in 2012-05-31, 4 diamond drills are cooled with 50% of the GEHO Pumps water flow.
[17] Goose Pond.

# 6 CALCULATION OF GRI EN8, EN10 AND EN21 INDICATORS

This section presents the calculation of **GRI EN8**, **EN10** and **EN21** indicators both for the present situation and for the After-closure Scenario. The calculation was performed considering the terms previously defined in this document and refer to the aggregate figures of Thompson Operation and Birchtree Mine.

## 6.1 General

(a) All water diverted from Burntwood River at PS1 and distributed by the Utilities as potable or process, is considered to be first-use water[18] thus being computed into the **GRI EN8** indicator.

(b) Likewise, all water supplied to Birchtree, either directly pumped from PS2 as process water, or from TPw2 as potable water is considered to be first-use water.

(c) For the calculation of **GRI EN8**, **EN10** and **EN21** indicators, diverted and distributed water volumes, both to the City of Thompson and to Manitoba Operations, were identified by evaluating either measured or estimated figures made available by Vale. Similarly, the volumes of reused water and discharged effluents were identified (Appendix B)[19].

## 6.2 Current indicators

### 6.2.1 **GRI EN8** and **EN10** Indicators

**Figure 4.1** is simplified into **Figure 6.1** in order to represent Manitoba Operations water flow as considered for the calculation of **GRI EN8** and **EN10** environment performance indicators.

[18] Newly withdrawn water.
[19] Flow measurement or estimation still lack in several points.

Faded elements in **Figure 6.1** represent nonexistent, or irrelevant, flow units or flow lines, as far as the calculations of **GRI EN8** and **EN10** indicators for Manitoba Operations are concerned.

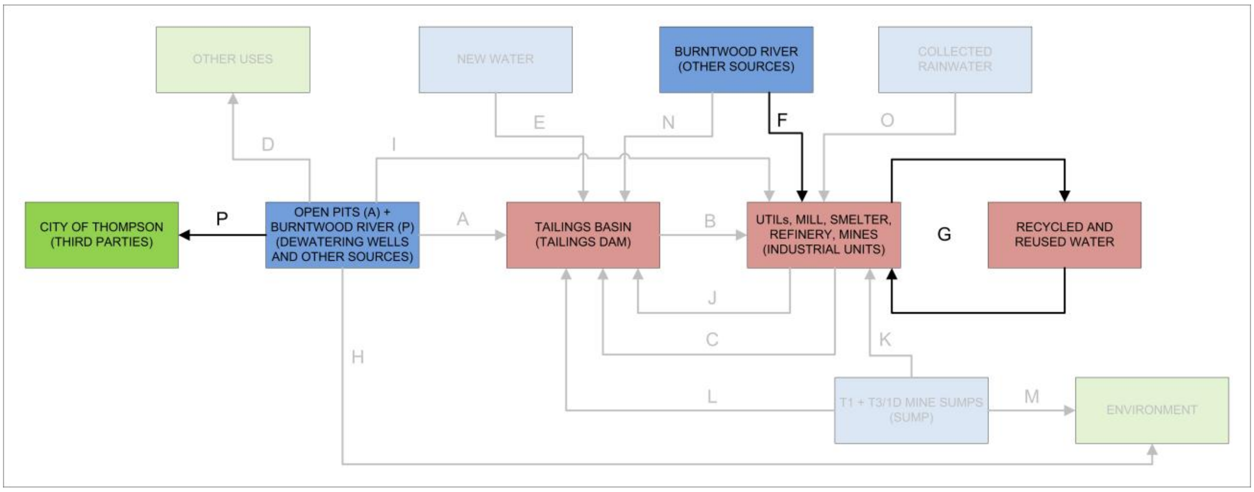


**Figure 6.1: Manitoba Operations Water Flow for the Calculation of GRI EN8 and EN10**

In the specific case of Manitoba Operations, flow lines are as follows: :

- **F**: Total volume of water diverted from the Burntwood River pumped to the facilities plus the water volume withdrawn from the River and pumped to Birchtree Mine.
- **G**: Total volume of reused or recycled water at the facilities: condensate return to the Soda Ash Circuit at the Refinery (**Figure 5.4**), flocculant dilution water from Overflow Tanks to Thickener and filtrate return from Pressure Filters to Thickner at the Smelter (**Figure 5.3**), recycled drilling water at T3/1D Mines and recycled sludge dilution water at T1 Mine.
- **P**: Volume of water supplied to the City of Thompson.

Therefore, **Equations 4.2**, **4.3** and **4.4**, employed for the calculation of **GRI EN8**, **EN10** and **%EN10**, simplify respectively into **Equations 6.1**, **6.2** and **6.3**.

$$EN8\ /m^3/year = F + P \qquad \textbf{6.1}$$

$$EN10\ /m^3/year = G \qquad \textbf{6.2}$$

$$\%EN10\ /m^3/year = \frac{G}{[(F+P)+G]-P} \cdot 100 \qquad \textbf{6.3}$$

**Table 6.1** is a summary of Manitoba Operations **GRI EN8**, **EN10** and **%EN10** calculation results. Indicators refer to the period spanning from January to December, 2011[20]. The complete data set from which the indicators were calculated can be found in Appendix C[21].

[20] Indicators were calculated with information obtained during the technical visit to Manitoba Operations, as well as with data made available by the Operations technical team and with data contained in the applicable references quoted in Section 9.

[21] Appendix C also contains data pertaining to the period January to August, 2012.

**Table 6.1: Manitoba Operations GRI EN8 and EN10 Indicators.**

| Month of 2011 | EN8 /$10^6$ $m^3$ | EN10 /$10^6$ $m^3$ | Third Parties (P) /$10^6$ $m^3$ | (EN8 + EN10) - P /$10^6$ $m^3$ | %EN10 /% |
|---|---|---|---|---|---|
| Jan | 4.84 | 0.0458 | 0.271 | 4.61 | 0.99 |
| Feb | 5.32 | 0.0458 | 0.226 | 5.14 | 0.89 |
| Mar | 4.82 | 0.0458 | 0.257 | 4.61 | 0.99 |
| Apr | 4.76 | 0.0458 | 0.271 | 4.54 | 1.01 |
| May | 4.84 | 0.0458 | 0.274 | 4.61 | 0.99 |
| Jun | 4.73 | 0.0458 | 0.234 | 4.54 | 1.01 |
| Jul | 4.81 | 0.0458 | 0.246 | 4.61 | 0.99 |
| Aug | 3.68 | 0.0458 | 0.246 | 3.48 | 1.32 |
| Sep | 4.71 | 0.0458 | 0.219 | 4.54 | 1.01 |
| Oct | 4.78 | 0.0458 | 0.216 | 4.61 | 0.99 |
| Nov | 4.70 | 0.0458 | 0.203 | 4.54 | 1.01 |
| Dec | 3.84 | 0.0458 | 0.188 | 3.70 | 1.24 |
| **All** | **55.8** | **0.549** | **2.85** | **53.5** | **1.03** |

The following observations apply, regarding the calculation of **GRI EN8** and **EN10**:

- Water volume pumped from Open Pit C to the Tailings Basin should be taken into account for the calculation of **EN8** indicator, as long as measurements are available.
- Although identified as reused, the water employed for sludge dilution at T1 Mine could not be taken into account in **EN10** calculation because there are not enough information about its volumes.
- The following figures were adopted for **EN10** calculation, in accordance with information supplied by Vale:
    a. condensate return flow: 200 USGPH (0.756 $m^3$/h);
    b. flocculant dilution water flow: 5.7 $m^3$/h;

c. pressure filters filtrate flow: 39 $m^3$/h;

d. recycled drilling water flow: 80 USGPM (18.2 $m^3$/h)

### 6.2.2 **GRI EN21** indicator

**GRI EN21** indicator was calculated considering the point source effluents at the final outlets before discharge into the Tailings Basin for both Thompson Operation and Birchtree Mine.

**Table 6.2** presents Thompson Operation effluent volumes for four pipelines, for the year 2011. It was assumed that these lines do not carry tailings. Figures for the 48" Sewer and the 42" Sewer were obtained from ECOMETRIX report of December 2011 **[6]**. Tailings Process Water, South Beach Tailings (Seepage), South Beach Tailings (Runoff) and Waste Rock volumes, all in ECOMETRIX report, were not taken into consideration because they are not considered point source discharges. On the other hand, T1 and T3/1D effluent volumes were obtained in "T1 Mine Water Pumping 2011.xls"**[1]**.

In **Table 6.2**, 48" Sewer flow rate includes the Smelter effluent, which is estimated at ECOMETRIX report as $3.1 \cdot 10^6\ m^3/year$.

As an approximation, T1 Mine and the 48" and 42" Sewer and T3/1D Mine pollutant loading assessment was made taking the average total suspended solids concentration as measured at the outflow structure at tailings management Area 5 Weir **[9]**.

**Table 6.2: Thompson Operation – 2011 effluents**

| Source | Destination | Treatment | Effluent flow rate $10^6\ m^3/year$ | Total suspended solids mg/L | Loading $10^3$ kg/year |
|---|---|---|---|---|---|
| TPsl-pH (T-1 Mine) | Tailings Basin | none | 1.18 | 3.7 | 4.4 |
| TPsl-pH (48" Sewer) | | | 7.75 | | 29 |
| 42" Sewer | | | 0.993 | | 3.7 |
| T3/1-D Mine | | | 0.019 | | 0.070 |

**Table 6.3** shows the effluent flow rates and total suspended solids loading for the Birchtree Mine effluents in the year 2011.

**Table 6.3: Birchtree Mine – 2011 effluents**

| Source | Destination | Treatment | Effluent flow rate $10^6$ $m^3$/year | Total suspended solids mg/L | Loading kg/year |
|---|---|---|---|---|---|
| Efluent Treatment Plant-TPsl | Manasan Creek | Physicochemical | 0.415 | 1.8 | 750 |

## 6.3 After-closure Scenario Indicators

### 6.3.1 GRI EN8 and EN10 indicators

At the end of 2014 a reduction of **GRI EN8** indicator will take place, due to a reduction of the diverted volumes from Burntwood River, at PS1, approximately corresponding to the volumes currently utilized by the Smelter and the Refinery[22]. **EN8** indicator is not expected to increase with the inception of the Concentrate Load-out facility. Water volumes involved in the operation of this facility will not be significant **[1]**.

**GRI EN10** indicator is expected to be fairly unaltered, given the currently observed reused and recycled water volumes will not be affected, because reuse and recycling occur in the concentration process stages in the Smelter[23]. These volumes refer to the reuse of part of the overflown thickener water and the water that returns from the pressure filters to the thickener (**Figure 5.3**).

A simulation of the Manitoba Operations **GRI EN8** and **EN10** After-closure Scenario indicators was made by subtracting from the 2011 figures, the water volumes consumed by the Refinery and the Smelter and by adding the water volume to be used by the new Concentrate Load-out facility. The decrease to be observed in the After-closure Scenario amounts to 47% of the currently consumed volumes, which includes 15 million cubic metres of water which use was not identified, as shown in Apendix C. **Table 6.4** presents the results of this simulation.

[22] It is assumed that the water in concentration processes is originated in the Mill processes. This assumption applies both to present day and to the After-closure Scenario.
[23] The Smelter concentration process stages are expected to remain unchanged in the After-closure Scenario.

**Table 6.4: Manitoba Operations GRI EN8 and EN10 After-closure Scenario indicators.**

| Situation | EN8 $/10^6\,m^3$ | EN10 $/10^6\,m^3$ | Third Parties (P) $/10^6\,m^3$ | %EN10 /% |
|---|---|---|---|---|
| Year 2011 | 55.8 | 0.550 | 2.85 | 1.03 |
| After-closure Scenario | 29.2 | 0.550 | 2.85 | 2.04 |

**Table 6.4** shows that **%EN10** is expected to increase from 1.03% to 2.04%, which is of little significance. This simulation points to the need of immediate actions towards an increase of water and effluent reuse and a decrease in water consumption rates.

It is worthy to mention that the After-closure Scenario also points to a reduction in the volumes of water treated at TPw1, given that the Smelter and the Refinery use potable water. In relation to the bulk of the potable water, which includes the City of Thompson drinking water and the potable water distributed by the Utilities to the Operations, a reduction of about 13% is expected. However, considering the potable water consumed by Operations alone, the expected reduction will be approximately 35%.

6.3.2 **GRI EN21** indicator

Following the deactivation of the Smelter and the Refinery planned for the end of 2014 a decrease in effluent volumes carried by the 48” and 42” Sewers is expected. At the 48” Sewer, the effluent flow rate is expected to decrease to $4.7 \cdot 10^6\ m^3/year$. At the 42”sewer, the effluent flow rate will decrease to correspond to the contribution of the South Yard flow, which, for the effects of this work, is considered a non-point source discharge (dispersed source).

In the After-closure Scenario, Birchtree will not contribute to any changes to be observed in **EN21** indicator.

# 7 WATER REUSE AND RECYCLING OPPORTUNITIES

Water reuse and recycling opportunities were identified for both Thompson Operation and Birchtree Mine. These opportunities must be interpreted and the proper actions should be taken under the light of the events that configure the After-Closure Scenario, with consideration to the due technical and financial feasibility studies.

## 7.1 Actions that can be immediately taken

- Development of studies aimed at the substitution of the potable water used in T1 and T3/1D mine processes for raw water or water submitted to a simplified treatment, just enough to attain the desired performance parameters levels. This is justified by the fact that potable water produced at TPw1 presents a high quality level in terms of turbidity (0.1 NTU), as required by Canadian legislation **[7]**.
- Project development with the aim of reusing sump water at Birchtree and T1 Mines as drilling coolant, as it is already the case for T3/1D Mine.
- Given that Bag Washing is a discontinuous Refinery process, installation of devices capable of turning the water flow off when not washing would be a water savings.
- Development of studies with the aim of increasing the reuse rates of the steam condensate, currently estimated by the Operations technical team to be 20%.
- Project development to implement recirculation of the raw water used as coolant for the Refinery current rectifiers bank (**Figure 5.4**).
- Development of studies for the assessment of the saturation level of the Refinery gas scrubbing water after successive cycles before discharge.

- Installation of flow meters at Open Pit C, capable of measuring pumped out volumes.
- Project development with the aim of using Open Pit C water as process water for the Operations. If necessary, a simplified treatment should be devised and implemented in order to grant this water a minimum quality level to be used, for example, as sandfill mixing water. Reuse rates and the **GRI EN10** indicator could thus be increased.
- Development of a measuring system capable of correctly assessing raw and potable water volumes pumped to, and distributed (as process water) by the Utilities. Currently, received raw water volumes are approximately 30% larger than distributed volumes.
- Development of a project aimed at reusing Birchtree Mine's effluent, in view of the large discharged volumes and the quality of the effluent.
- For a better assessment of **GRI EN21** indicator:
    - Installation of flow measuring systems at 48"and 42" Sewers endpoints.
    - If the water-oil separator effluents are directed to the Tailings Basin through exclusive pipelines, installation of flow measuring systems onto these pipelines.
    - Quality testing of water-oil separators effluents to measure oil and greases contents.
    - Quality testing of the effluents carried by 48"and 42"sewers and T3/1D Mine, for the assessment of total suspended solids contents.
- Development of an all-site program directed towards the adoption of the SI units **[8]** as measurement units, particularly for water flow rate and volume measurements.

## 7.2 Action that can be taken in the After-closure Scenario

The main action that can be taken in the After-closure Scenario is the development of a project aiming at the separation of Thompson Operation industrial and domestic effluents and the treatment of these effluents before their discharge into the Tailings Basin.


CRONO ENGENHARIA LTDA.
Rua Bernardo Guimarães, 895/508, 30140-081 Belo Horizonte, MG, Brazil – Phone +55-31-3261-9209
cronoengenharia@crono.eng.br

# 8 AFTERWORD

The small value of the recycling and reuse indicator **%EN10 = 1.03 %** clearly indicates the need to take actions towards water use optimization by means of reuse and recycling all throughout Manitoba Operations.

In the After-closure Scenario, there is an expected reduction of approximately 47% in the volume of water diverted from Burntwood River. If none of the recommended actions are taken, a small increase will be noticed in the value of the recycling and reuse indicator, **%EN10**, to approximately 2%. Still under this scenario, the production of potable water at TPw1 will drop 13% relative to the total volume currently produced for the City of Thompson and the Utilities. Considering potable water is currently distributed by the Utilities to Thompson Operation, the production reduction rate will be approximately 35%.

The study has pointed out the need to perform volume measurements on the reused water, in order to have a better estimation of **GRI EN10** indicator. There is also a need to measure effluent quality and flow rates, in such a way as to allow the calculation of pollutant loadings, to be reported together with this indicator.

The study has also identified the need to repair the inoperative measuring instruments, perform periodic measurements on the lines where water flow is estimated, and perform occasional measurements on the intermittent water flow lines, in order to obtain reasonably validated figures.

The need to segregate industrial from domestic effluents eventually carried by 48”and 42” Sewers has also been pointed out.

Opportunities of water use optimization have been identified. Amongst them are the reduction of the potable water used in Manitoba Operations – with a consequent treatment cost decrease – and the use of effluents as process water. The adoption of this practice would cause a reduction in the water volumes diverted from Burntwood River.

# 9 REFERENCES

**[1]** Information supplied by the Operations technical team

ENVIRONMENT CANADA. Environmental Code of Practice for Metal Mines. 2009. 108p. 1 file (780 KB). pdf.

ENVIRONMENT CANADA. Environmental Code of Practice for Base Metals Smelters and Refineries: Code of Practice, Canadian Environmental Protection Act, 1999. First Edition, 2006 March. 64p.1 file (2.57 MB). pdf.

GLOBAL REPORTING INITIATIVE. Indicator Protocols Set Environment (EN). Environment Performance Indicators. 2000-2011. 40p. 1 file (1.7MB). pdf.

VALE. 1-D Mine Water Samples Monthly 3600L. 2001-2012. 1 file (88 KB). MS-Excel® 97-2003.

VALE. 2012 Birchtree Water Balance. June 2011 – July 2012. 1p. 1 file (40 KB). MS-Word® 97-2003.

VALE. Apr 2011 Piped Utilities to Account. MS-Excel® 97-2003.

VALE. August 2011 to Account. MS-Excel® 97-2003.

VALE. Aug.EFF.11. 2011 September 30. 7p. 1 file (248 KB). MS-Word® 97-2003.

VALE. Feb 2011 to Accounting Rev 1 Geoff. 1 file (24 KB). MS-Excel® 97-2003.

VALE. BTETP 2011. 2011 March 27. 1 file (60 KB). MS-Excel® 97-2003.

VALE. Concentrate Loadout Bldg Flow Diagrams. 2012 February 17. 1p. 1 file (244 KB). pdf.

VALE. Concentrate Loadout Bldg Flow Table. 1p. 1 file (44 KB). MS-Word® 97-2003.

VALE. Dec.EFF.11. 2012 January 31. 7p. 1 file (240 KB). MS-Word® 97-2003.

VALE. December 2011 to Account (2). MS-Excel® 97-2003.

VALE. **GRI_EN8**_2011. 1 file (244 KB). MS-Excel® 97-2003.

VALE. **GRI_EN10**_2011. 1 file (368 KB). MS-Excel® 97-2003.

VALE. Jan 2012 Water Energy Steam. 1 file (36 KB). MS-Excel® 97-2003.

VALE. January 2011 Piped Utilities (29 Days). MS-Excel® 97-2003.

VALE. July 2011 Piped Utilities (29 Days). MS-Excel® 97-2003.

VALE. June 2011 Piped Utilities (29 Days). MS-Excel® 97-2003.

VALE. Piped Utilities Billing- Steam, Potable and Process Water. 2p. 1 file (1.52 MB). MS-Word® 97-2003.

VALE. Manitoba Regulations. 1 file (66 KB). MS-Word® 97-2003.

VALE. March 2011 Piped Utilities to Account. MS-Excel® 97-2003.

VALE. May 2011 Piped Utilities to Account. MS-Excel® 97-2003.

VALE. MMER Schedule 3 and 4. 2 files (235 KB). MS-PowerPoint® 97-2003.

VALE. November 2011 to Account. MS-Excel® 97-2003.

VALE. October 2011 to Account. MS-Excel® 97-2003.

VALE. Process_Water_T3 (2). 2012 March 23. 1p. 1 file (136 KB). pdf.

VALE. Q1.2011 Revised Jan 6 2012. 2012 January 6. 3p. 1 file (160 KB). MS-Word® 97-2003.

VALE. Q2.2011 Revised Jan 6 2012. 2012 January 6. 3p. 1 file (164 KB). MS-Word® 97-2003.

VALE. Q3.2011 Revised Jan 6 2012. 2012 January 6. 3p. 1 file (172 KB). MS-Word® 97-2003.

VALE. Q4.2011. 2012 February 14. 8p. 1 file (444 KB). MS-Word® 97-2003.

VALE. Refinery. Manitoba. 1p. 1 file (928 KB). MS-Word® 97-2003.

VALE. Station B 2011. 2011 March 27. 1 file (64 KB). MS-Excel® 97-2003.

VALE. September 2011 to Account. MS-Excel® 97-2003.

VALE. T1 Mine Water Pumping 2008-2012. 5 files (2.27 MB). MS-Excel® 97-2003.

VALE. T1 Mine Water Sample 1. 2012 March 19. 2p. 1 file (44 KB). pdf.

VALE. T1 Mine Water Sample 2. 2012 March 19. 2p. 1 file (48 KB). pdf.

VALE. T1 Mine Water Sample 3. 2012 March 19. 2p. 1 file (48 KB). pdf.

VALE. T1 Mine Water Sample 4. 2012 March 19. 2p. 1 file (48 KB). pdf.

VALE. Water Balance. 1p. 1 file (3.24 MB). MS-Word® 97-2003.

VALE. Water Treatment Plant Data 2007 to 2011. 1p. 1 file (36 KB). MS-Word® 97-2003.

VALE. Weir 2011. 2011 March 27. 1 file (52 KB). MS-Excel® 97-2003.

VALE and CITY OF THOMPSON. Water System Report - 2010. 15p. 1 file (316 KB). pdf.

**[2]**MINISTRY OF THE ENVIRONMENT OF CANADA. 2009. 108p. in: www.ec.gc.ca/lcpe-cepa/default.asp?lang=En&n=CBE3CD59-1 [1.14 MB; vis. 2012-09-18]

**[3]**MINISTRY OF THE ENVIRONMENT OF CANADA, 2009. 64p. in: www.ec.gc.ca/lcpe-cepa/default.asp?lang=en&n=9233a7e7-1 [2.60 MB; vis. 2012-09-18]

**[4]**VALE. Manitoba Operations Sustainability Report 2008. 8p. in: http://nickel.vale.com/sustainability/reports/default.aspx [vis. 2012-08-28]

**[5]**VALE. 2011 Production Report – US GAAP. "tabelas_rp_4T11i.xls" MS-Excel® spreadsheet. in: http://www.vale.com.br/en-us/investidores/press-releases/Documents/Forms/AllItems.aspx [vis. 2012-08-28]

**[6]** ECOMETRIX INCORPORATED. Final Report – 1-D Rationalization Pre Feasibility Study (FEL2) Shaft Site Water Balance – 2011

**[7]**CORRECTIONAL SERVICE CANADA. Environmental Guidelines Drinking Water Quality Management (DWQM). 2010 March 12. 20p. 1 file (268 KB). pdf.

HEALTH CANADA (2012). Guidelines for Canadian Drinking Water Quality—Summary Table. Water, Air and Climate Change Bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario. 22p. 2012 August.

VALE and CITY OF THOMPSON. Public Water Treatment & Distribution System Annual Reports. 2012 October 3. 20p. 1 file (680 KB). pdf.

**[8]**International System of Units. In http://www.bipm.org/en/si/ [vis. 2012-10-02].

**[9]**VALE. Private communication. 2012.12.07.

# 10 ACKNOWLEDGEMENTS

Crono wishes to thank the continued and prompt support given by Vale Team in every stage of this study, in special:

- Bernadete Backx and Pedro Almada, of Corporate Vale;
- Chantal Clement, Dave McDonald, Robyn Millar and Joe Armstrong, of Vale's Manitoba Operations;
- Production and managerial personnel of Vale's Manitoba Operations in Thompson.