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The Implementation of Snowden's Reconciliation Software — A Case Study from Telfer

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ABSTRACT

Newcrest Mining Limited's Telfer Mine is a world-class gold and copper producer, situated in the Great Sandy Desert, in the north west of Western Australia. The mine has a number of distinctive characteristics such as being one of Australia's most remote mine sites, being within 270 km of the hottest town in the southern hemisphere (Marble Bar) and having been shut down and reopened after a two-year feasibility study. The construction of a new plant and reopening of the mine gave Newcrest the opportunity to review their mining practices and systems including the opportunity to incorporate reconciliation as a core process. Telfer is now well on the way to being one of the largest gold and copper concentrate producers in Australia.

When the mine reopened in June 2003, Telfer implemented Snowden's Reconcilor software system to facilitate reconciliation of geological models, production data and plant measurements. The system was implemented on site in June 2004, as a web-based information management system, integrating other existing mining and plant software packages. It continues to provide an auditable process and consistency of data, providing ease of analysis with standard and customised reporting.

This paper provides a case study of the reconciliation system implementation at Telfer. It outlines the consolidation of a number of management systems into one centralised system that can be used to compare and reconcile the tonnes and grades from the mine through to the mill. The authors outline the key estimates and measures that are used for reconciliation at Telfer, detailing the characteristics of the system used to capture the information and the benefits that have been gained through the use of a rigorous reconciliation process on a complex orebody.

INTRODUCTION

Hosted within the 2.5 billion year old Yeneena Basin, Newcrest Mining Limited's Telfer Mine is a world-class gold and copper producer, situated on the fringe of the Great Sandy Desert, in the north west of Western Australia (Figure 1). The location is remote and inhospitable, being some 270 km from the hottest town in the southern hemisphere, Marble Bar, the world record holder for consecutive days over 100°F (~38°C). The climate of the region is characterised by hot summers with daytime maximums exceeding 104°F (40°C) and warm winters. Rainfall is strongly seasonal, predominantly falling between December and March and is usually associated with remnant cyclones and thunderstorms. Average annual evaporation is 4160 mm compared to annual rainfall of 312.2 mm.

The landscape is a monotonous flatness, punctuated by dunes, where almost everything that grows has a spine or a thorn and everything that moves a bite or a sting, and often both. Wild dingoes, camels, horses and birds are bountiful, roaming the outskirts of the mine and often venturing in for a closer look.

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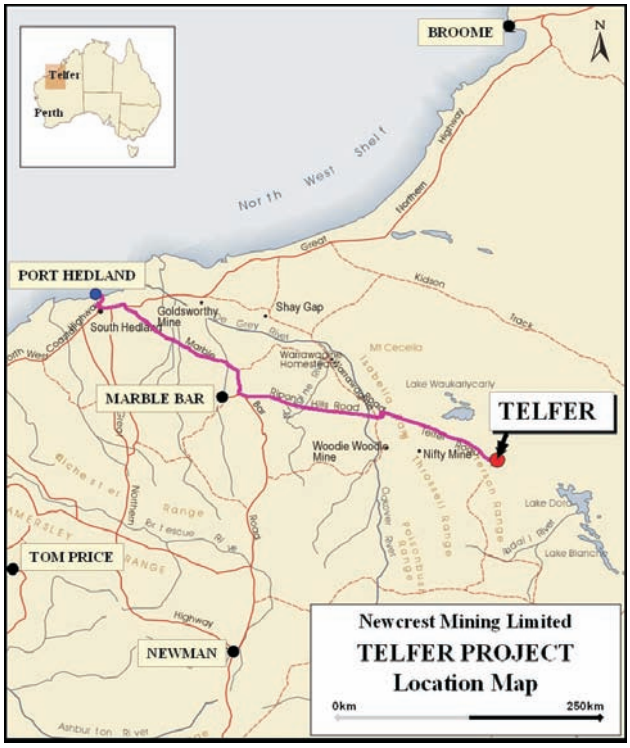


FIG 1 - Location map of Telfer, Western Australia.

In 1971, Day Dawn Minerals NL undertook a regional sampling program that returned anomalous copper and gold values from the gossanous outcrops of the Telfer Dome (Tyrrwitt, 1995). Following this, an extensive exploration and drilling program was undertaken by Newmont Pty Ltd from 1972 to 1975. Figure 2 shows the Telfer Dome at this early stage of development. After the feasibility study, Newmont brought in BHP Gold. The eventual merger, in 1991, of Newmont Australia Limited and BHP Gold Limited created Australia's largest independent gold miner and Australia's third largest mining company, Newcrest Mining Limited (Newcrest). From 1977 to 2000, Telfer was to be the cornerstone operation of Newcrest, producing almost six million ounces of gold.

In October 2000, mining operations were suspended due to increasing costs primarily associated with high cyanide soluble copper grade in the open pit ore. Subsequently, the site was placed on care and maintenance and extensive redevelopment and feasibility studies were undertaken. In November 2002, the feasibility study confirmed the viability of the Telfer Project and the board approved the funding for redevelopment and expansion. A new strategy was adopted for mining and processing of the open pit and underground orebodies with production expected to average 800 000 ounces of gold and 30 000 tonnes of copper per annum over a 24 year period.

The complex geology and mineralisation consists of gold and copper mineralisation hosted within reef and stockwork domains in Proterozoic sediments, weakly metamorphosed, structurally deformed by folding and faulting and intruded by granites.

The current underground sublevel cave operation (SLC) extends to 1000 m below surface and mineralisation has been defined to at least 1.5 km. Figure 3 is an aerial photograph of the Telfer Main Dome Pit.

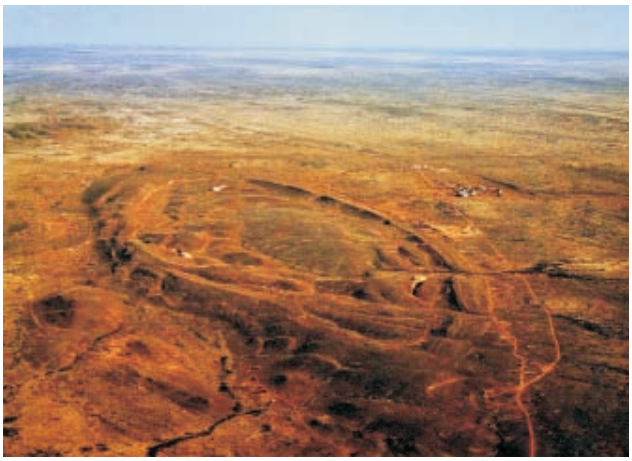


FIG 2 - The Telfer Dome – pre-mining in the early 1970s.

FIG 3 - Telfer as it is today. (A) Telfer open pit and (B) Telfer plant.

The construction of a new plant and reopening of the mine gave Newcrest the opportunity to review their mining practices and systems including the opportunity to embed reconciliation as a core process. It was realised that a commercial solution was required to assist in the reconciliation process from the mine through to the plant. Telfer made the decision in 2004 to implement a best practice reconciliation software system known as 'Reconcilor'.

MINING RECONCILIATION

Mine reconciliation is the comparison of an *estimate* (a Mineral Resource model, a Mineral or Ore Reserve model, grade control information, or a mine production plan or schedule) with a *measurement* (survey information, material movement records or the official production, usually from the processing or treatment plant) (after Morley and Moller, 2005; Schofield, 2001). The basic aims of reconciliation are to (after Glacken and Morley, 2003):

- measure performance of the operation against targets,
- confirm grade and tonnage estimation accuracy,
- ensure valuation of mineral assets is accurate, and
- provide key performance indicators.

Due to the time associated with collating and comparing these measures, most reconciliation reports concentrate over a long period of time (monthly, quarterly or annually) and may only be reported annually. Data that is generated regularly over long periods of time will naturally result in larger data sets that more accurately reflect trends. If reconciliation is performed on a regular basis, any variances in the tonnage and grade estimations can be identified earlier and the mine may then look at ways to decrease any variances and therefore correct any potential undesirable longer term trends. Identifying large discrepancies between each estimate and measurement will provide a guide on where improvements in the process should be focused.

KEY PARAMETERS USED FOR RECONCILIATION

Critical to the success of any reconciliation system is the capture of key data. Typically data may be sourced from (after Morley, 2003):

- Resource and Reserve models;
- survey pickups of the actual mining activities;
- mining personnel's observations of mining activities;
- plant feed sources, such as weightometers and auto samplers;
- plant performance indicators, such as crusher power consumption, cyclone throughput, etc;
- plant balance calculations; and
- plant actuals, such as commodity produced, reject and tailings volumes and assays.

As stated by Gy (1979), sampling of particulate materials is always an aleatory operation. There will always be a margin of error in any measurement and these should be estimated and considered in the results. Capturing information automatically and electronically from the source alleviates one aspect of error; the human component. Other sources of error may include (after Glacken and Morley, 2003):

- sampling precision or accuracy issues as detailed above;
- survey errors, particularly with respect to stockpiles;
- stockpile grade modelling;
- ore held up in draw points and internal orepasses;
- any estimate of stocks associated with sublevel or block caving;
- volume calculation errors within overhanging or partially blocked stopes; and
- estimating in-pit ore stocks.

Dilution of ore, under/over loading of trucks, incorrect tracking of material movements and uncalibrated weightometers are just a few of the other contributing factors which inadvertently affect reconciliation. These factors are often

incorrectly used as actual measurements, whereas they should be used as indicators of poor mining practice only. Reconciliation highlights the efficiency (or otherwise) of the mining process, and so it is important to separate the 'signal' (the true reconciliation result) from the 'noise' generated by the sources of measurement error (Glacken and Morley, 2003). It is clear that there are relationships between the different parts of the mining process which are able to be reconciled against, keeping in mind that the key process of reconciliation is that of comparing estimates with actuals. Figure 4 provides a schematic diagram of the key data sources used in reconciliation and their relationships.

DATA SYSTEMS USED AT TELFER

The Telfer deposit is currently being mined via large open pit and underground operations. On the surface, the pre-existing Main Dome and West Dome pits are being expanded and deepened while underground development and operation of a 6 Mtpa SLC has commenced. In total these bulk mining activities are feeding an annualised mill throughput of greater than 22 Mtpa.

Data systems currently utilised at Telfer for reconciliation include:

- Resource, Reserve and grade control models;
- feeds into open pit and underground databases;
- end of month (and mid month) survey pickups;
- modular mining (open pit) dispatch data;
- PITRAM (underground) dispatch and underground stockpile control; and
- PI/JK met accounts (plant).

For the open pit operations, the geological Resource, Reserve and grade control models have been designed and evaluated using Datamine mining software. The Resource, Reserve and continually updated grade control models are then interrogated on a dig block basis with the data loaded and stored in a separate Access database (the open pit grade control database or OPGC). OPGC was designed specifically for Telfer and stores a broad spectrum of data, including the suite of grades (Au, Cu, S, As, Co) and the associated attributes of each blast/dig block, including weathering, oxidation level, mineral domains, rock type and preferential processing path. A large portion of this data is only used periodically but provides considerable flexibility for ad hoc and in-depth reconciliation. This data is then sourced for both dispatch as well as reconciliation.

By having all data captured electronically, the risk of transcription errors and time delays is minimised. Changes made to a dig block in Datamine are incorporated into OPGC and subsequently the other data systems are updated with the changes. There is no manual intervention as the reconciliation system sources the data directly. The personnel responsible for generating the data are those that use Datamine and OPGC regularly and are therefore both familiar with and ultimately responsible for the information.

The open pit mine material movements are tracked through the Modular Mining System. This is a fully automated control system from which the reconciliation system imports the transactions which record the source material, the actual destination and the measured tonnes per truck for a date and shift. This data is then used to build and reclaim material from the surface stockpiles.

The underground mine tonnes and grade movements are tracked through Micromine's PITRAM Production Management System and its add-on Grade Control Module. Grades based on the updated grade control model are loaded into the grade control module, with development and ring production treated separately. PITRAM then tracks all underground movements through a series of stockpiles (including underground stockpiles, orepasses, crusher feed, etc).

Underground mine reporting is provided via Micromine's DOME. The reconciliation system imports the underground ore tonnes and grade from DOME and assigns movement to a dedicated stockpile on the surface for underground mill feed.

Survey captured data includes end of month pit surfaces, stockpile pick-ups and volumes of the coarse ore stockpiles (crushed ore) feeding the mill. The pit and ROM stocks are surveyed at the end and mid month by standard GPS based survey methods and used to provide reference volumes for stockpile adjustments. The coarse ore stockpiles are surveyed by I-Site laser scanning. I-Site is utilised to provide remote, safe and accurate volumes as access limits access.

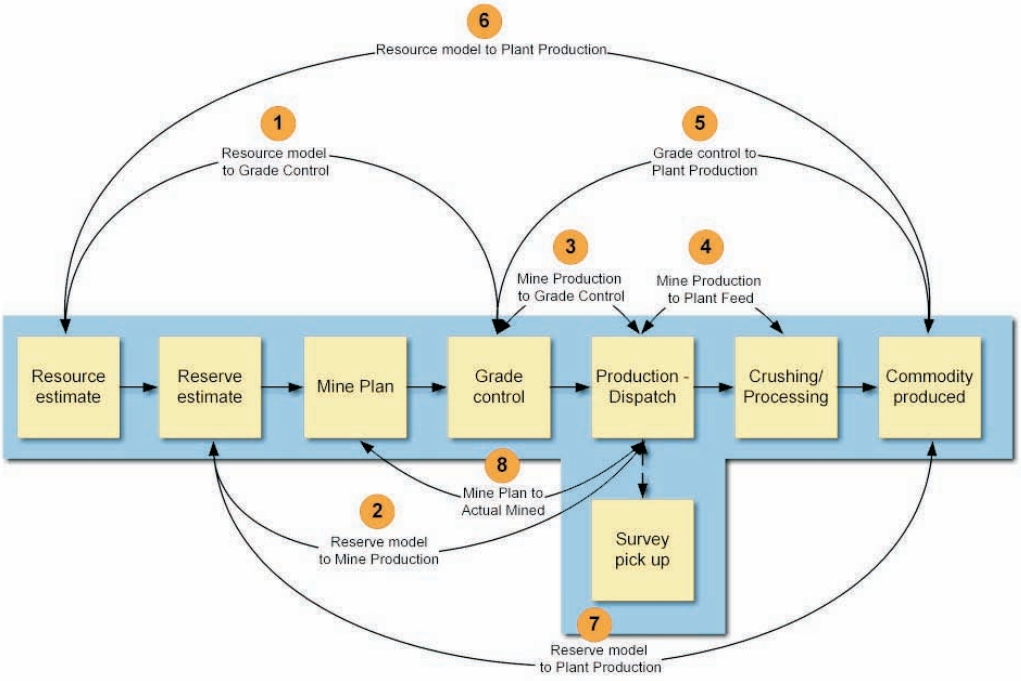


FIG 4 - Generalised mining process map showing the key relationships in the reconciliation process (after Morley and Thompson, 2006).

The plant data that is imported into Reconcilor is captured through the PI data source system with metallurgical accounting carried out using the JK Met Accounting system. Actual measurements from mill weightometers are used to deplete the coarse ore stockpile (COS) balance and provide closing balances. In the reconciliation system, all stockpiles are made up of a series of synchronous transactions. Each transaction has grade attached to it which is used to build the estimate of the stockpile grade. By using these estimates the mine is able to provide a predicted head grade based on the tonnes depleted from the COS over a specified period.

RECONCILIATION AT TELFER

Reconciliation at Telfer primarily follows the relationships shown in Figure 4 but is more than just a metal balance. In addition to these relationships there is also consideration of:

- multiple ore sources including direct feed of underground and open pit ore, rehandled ROM stocks and historic stockpile feed to the plant;
- multiple processing paths (Telfer nomenclature includes bulk flotation, sequential flotation, copper only flotation, pyrite only flotation and dump leach of oxide material); and
- multiple elements including Au, Cu and S and to a lesser extent cyanide soluble copper, As, Co and potentially acid forming (PAF) material.

IMPLEMENTATION OF A NEW RECONCILIATION SYSTEM

When the mine reopened in June 2003, Telfer instigated implementation of Snowden's Reconcilor software. The system is specifically designed and built for reconciliation, is web based and incorporates a SQL server database, importers and reporting tools to collect, process and present mining information back to users for analysis. A detailed scoping study was completed at Telfer that involved working with site personnel to define data, import/export requirements and formats, to define the optimised reconciliation process flow and all reporting requirements. A schematic diagram of Telfer's reconciliation architecture is shown in Figure 5.

Reconcilor was selected by Newcrest on the basis of functionality, ease of use and cost-effectiveness. It allows unlimited users read only (unless given administrative or edit privileges) access over the Newcrest Intranet enabling the information to be shared between departments and head office. Being a web-based system, it requires minimal user training as most people are familiar with web interfaces as a result of the internet.

By automating much of the data handling and validation, as well as removing the reliance on Excel spreadsheets, Reconcilor provided Telfer personnel with a tool to handle routine daily and end of month tasks. Data from all sources is captured, validated and then essentially locked so that there is a single set of numbers for mine tracking. This enables the staff to be proactive in analysing the data they collect and providing them with the opportunity to focus on process improvement to more accurately define ore and waste on a day-to-day basis. It continues to provide an auditable process and compliance with JORC standards. Reconcilor facilitates the reconciling of data for easy analysis with both standard and customised reporting. The following outlines the type of reports available through the reconciliation system at Telfer:

- material movement reports,
- crushing by source,
- model and material destination reports,
- reconciliation reports,
- daily block movement summaries, and
- stockpile tonnes and grade balances.

The reconciliation system provides the ability to track closely what is being delivered to the Plant and provides information on the blended characteristics of this material. By having this information online and on a shift-by-shift basis plant personnel are able to understand more fully what impact the different feed characteristics may have on the performance of the plant.

The system also provides the ability to analyse assumptions that are used on truck factors and material movement productivity. Reconcilor provides a comparison of truck weights, weightometer readings and grade control estimated tonnes via preconfigured reports. Users can track variances and drill into detail to analyse trends or to identify poorly calibrated equipment.

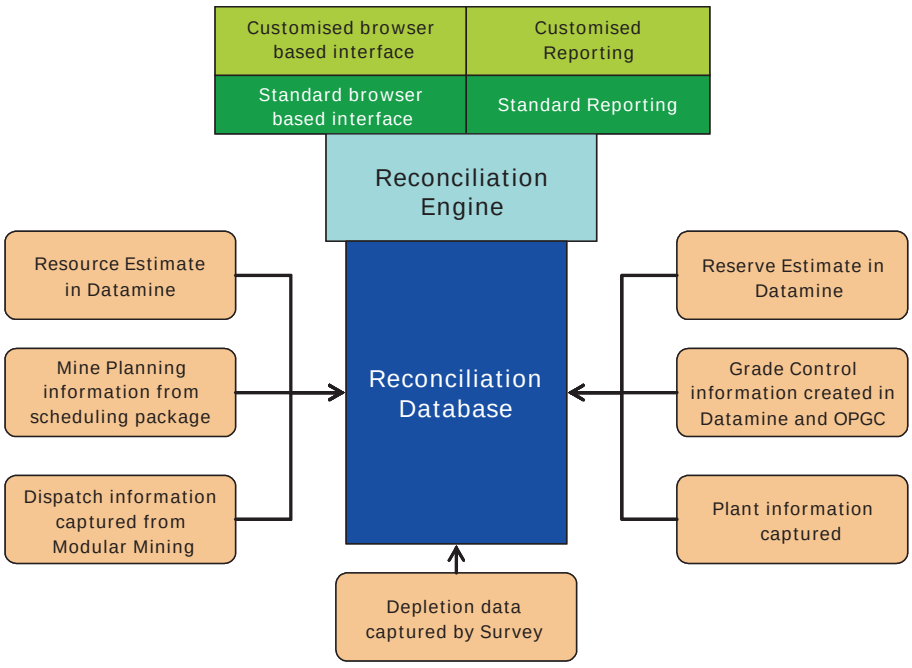


FIG 5 - Architecture of the reconciliation system implemented at Telfer (Morley, 2003).

By allowing Resource modellers and mine planners to compare their predictions with production results the reconciliation system provides Telfer with the capability to assess variances and identify areas in their methodologies and processes that can be improved. The system performs the reconciliations required under the JORC Code (2004) and provides the relevant reconciliation information required by Telfer for annual and statutory reporting. The reconciliation processes completed using the system are key to demonstrating that Newcrest is ensuring that corporate disclosures on Resource, Reserve and mining performance are monitored and accurate.

CONFIGURATION OF THE RECONCILIATION SYSTEM FOR TELFER

An important part of the new reconciliation system implementation was the configuration to suit the needs of Telfer. For example, Table 1 outlines the reports that are available through the reconciliation system at Telfer that have been designed and implemented specifically for the site. All reports were customised to produce the same data as the original Excel spreadsheets used on site that were labour intensive and prone to manual error.

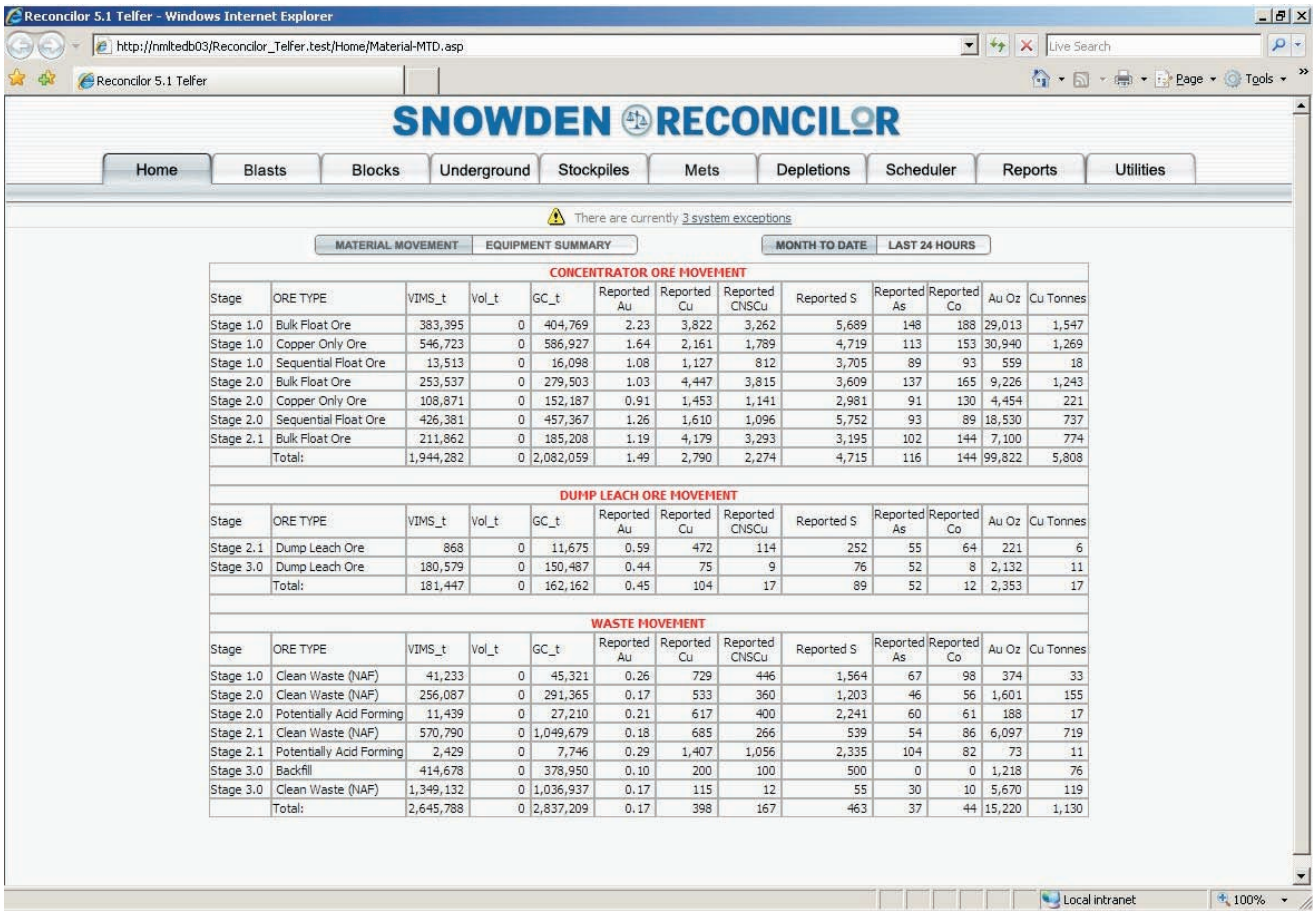
The home screen of Telfer's reconciliation system (see Figure 6) was also designed to provide site personnel with a customised overview of the material moved over the past 24-hour period, with the option to view material moved for the month to date. Whilst this is not reconciliation information, it is captured by the system and presented in a view that is useful to all personnel. The remaining sections of the system are broken down into manageable groups; digblocks, blasts, underground, stockpiles, metallurgy and reports being the most active screens.

TABLE 1

Types of reports being produced by the reconciliation system at Telfer.

Report type	Description	
Reconciliation	Reserve (plan)/grade control/mill (actual)	
Material movement	Pit depletion by:	Material type
		Date range
		Destination
	Tonnage comparisons by:	Grade control
		Trucking
		Crushing
	Crusher feed by:	Direct feed
		Rehandle
Stockpile tracking	Tonnes and grade available	
Engineering	Tonnes by equipment	
	Production by stage (performance against plan)	

Due to the large volumes of open pit ore and movement over a 24-hour period, it is a primary requirement at Telfer to manage and record the material movements and details at all times. For the open pit, this is performed using the Modular Mining System, which is an automated control system for all surface equipment and tracks source and tip destination for ore and waste as well as all rehandle. An automated link to the Modular Mining System's data was an integral part of the implementation of the reconciliation process at Telfer.



CONCENTRATOR ORE MOVEMENT

Stage	ORE TYPE	VIMS_t	Vol_t	GC_t	Reported Au	Reported Cu	Reported CNSCu	Reported S	Reported As	Reported Co	Au Oz	Cu Tonnes
Stage 1.0	Bulk Float Ore	383,395	0	404,769	2.23	3,822	3,262	5,689	148	188	29,013	1,547
Stage 1.0	Copper Only Ore	546,723	0	586,927	1.64	2,161	1,789	4,719	113	153	30,940	1,269
Stage 1.0	Sequential Float Ore	13,513	0	16,098	1.08	1,127	812	3,705	89	93	559	18
Stage 2.0	Bulk Float Ore	253,537	0	279,503	1.03	4,447	3,815	3,609	137	165	9,226	1,243
Stage 2.0	Copper Only Ore	108,871	0	152,187	0.91	1,453	1,141	2,981	91	130	4,454	221
Stage 2.0	Sequential Float Ore	426,381	0	457,367	1.26	1,610	1,096	5,752	93	89	18,530	737
Stage 2.1	Bulk Float Ore	211,862	0	185,208	1.19	4,179	3,293	3,195	102	144	7,100	774
	Total:	1,944,282	0	2,082,059	1.49	2,790	2,274	4,715	116	144	99,822	5,808

DUMP LEACH ORE MOVEMENT

Stage	ORE TYPE	VIMS_t	Vol_t	GC_t	Reported Au	Reported Cu	Reported CNSCu	Reported S	Reported As	Reported Co	Au Oz	Cu Tonnes
Stage 2.1	Dump Leach Ore	868	0	11,675	0.59	472	114	252	55	64	221	6
Stage 3.0	Dump Leach Ore	180,579	0	150,487	0.44	75	9	76	52	8	2,132	11
	Total:	181,447	0	162,162	0.45	104	17	89	52	12	2,353	17

WASTE MOVEMENT

Stage	ORE TYPE	VIMS_t	Vol_t	GC_t	Reported Au	Reported Cu	Reported CNSCu	Reported S	Reported As	Reported Co	Au Oz	Cu Tonnes
Stage 1.0	Clean Waste (NAF)	41,233	0	45,321	0.26	729	446	1,564	67	98	374	33
Stage 2.0	Clean Waste (NAF)	256,087	0	291,365	0.17	533	360	1,203	46	56	1,601	155
Stage 2.0	Potentially Acid Forming	11,439	0	27,210	0.21	617	400	2,241	60	61	188	17
Stage 2.1	Clean Waste (NAF)	570,790	0	1,049,679	0.18	685	266	539	54	86	6,097	719
Stage 2.1	Potentially Acid Forming	2,429	0	7,746	0.29	1,407	1,056	2,335	104	82	73	11
Stage 3.0	Backfill	414,678	0	378,950	0.10	200	100	500	0	0	1,218	76
Stage 3.0	Clean Waste (NAF)	1,349,132	0	1,036,937	0.17	115	12	55	30	10	5,670	119
	Total:	2,645,788	0	2,837,209	0.17	398	167	463	37	44	15,220	1,130

FIG 6 - Screen shot of Telfer's reconciliation home screen showing general production data.

The reconciliation system at Telfer has also been used successfully and extensively as a stockpile management system, tracking the grades through the stockpiles and to the plant. Reconcilor includes the ability to track stockpile movements based on LIFO, FIFO, average or hybrid methods and also includes the ability to track multiple stockpile builds. Tracking of rock type and mineral domains is also incorporated though the reconciliation system and provides the capability to model/predict for example recoveries, profit and reagent use.

The COS (Figure 7) is modelled separately to the ROM stocks using a last on first off – average algorithm (LIFO-Avg). Each transaction of material delivered to the crushers is recorded so that material removed can be ordered properly and have grades applied correctly. Therefore, the last transaction delivered is the first material removed (through milling). If there is more material removed in a 24 hour period than is delivered, the COS grade will revert to a mass weighted average grade for the remaining depletion of the stockpile. This provides an approximation of what is actually happening on the COS. Most of the crushed material falls directly over the feeders and flows through to the mills (LIFO). However, there is periodic dozing and stacking away from the feeders necessitating the need to move away from a true LIFO model. Figure 8 is a screen shot of a stockpile screen from the reconciliation system showing the build and depletion of the stockpile over time. The system also has the ability to deal with survey and geological adjustments to the tonnes and grade through a manual adjustment facility.

The stockpiles on the ROM pad are modelled using an average algorithm, that is, the material is not tracked through the stockpile, rather the grade is calculated after all deliveries as a mass weighted average of the opening grade on the stockpile and related tonnes, and the delivered tonnes and grade. This grade is applied to all removals from the stockpile for the rest of that shift. By using the reconciliation system to manage the grades through stockpiles and material moved from the pit and UG, the mine is able to provide the mill with an expected head grade through the plant, based on the material fed and the known processing path the mill is operating in.

FIG 7 - Telfer's coarse ore stockpiles.

The application of truck factors to the volumes moved and recorded as truck counts is an important metric used by production and planning groups to monitor material movement. At Telfer comparisons can then be made using the reconciliation system to analyse the tonnages delivered to the mill by

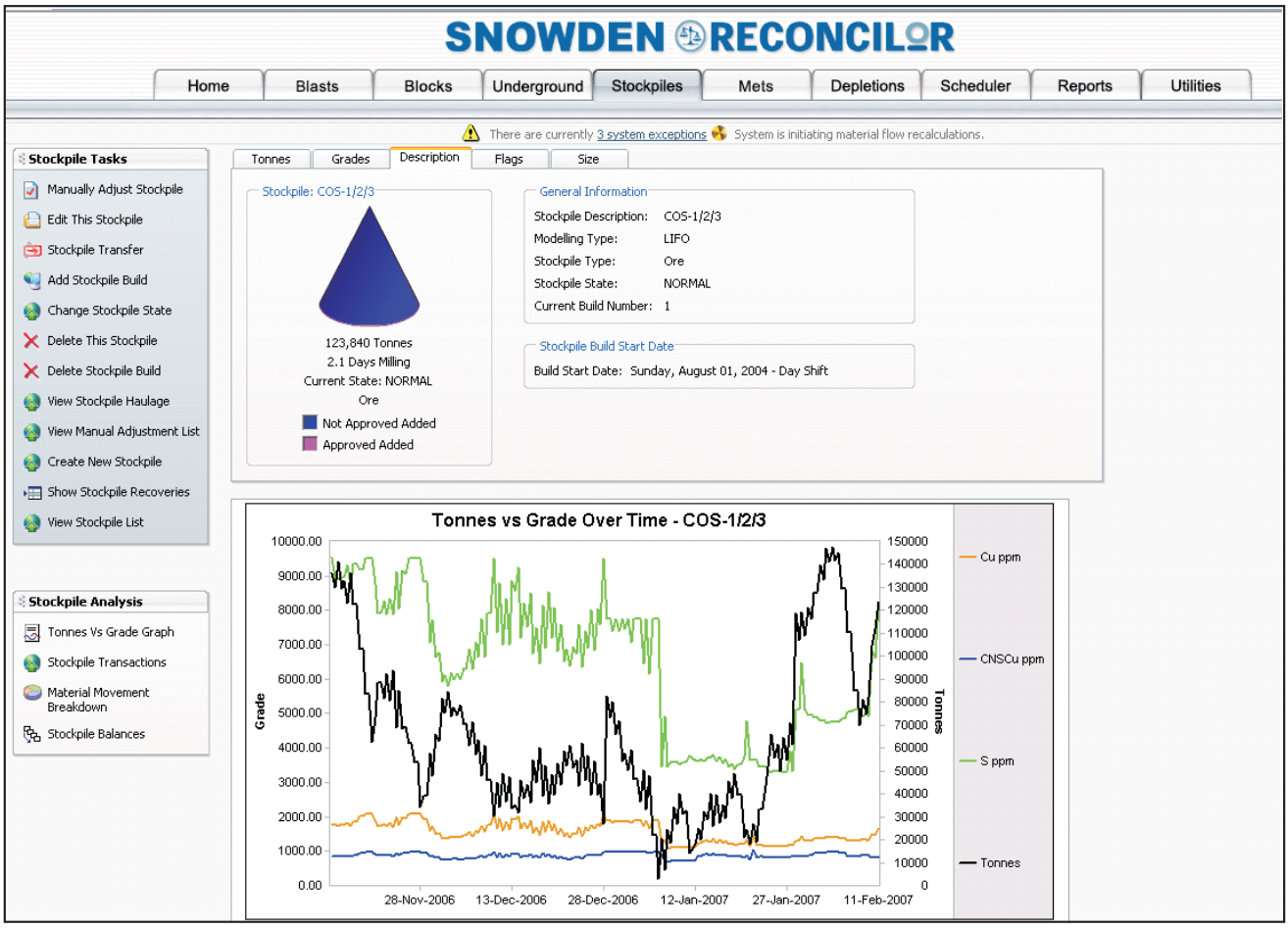


FIG 8 - An example of one of the stockpile screens presenting data and charts within the system.

comparing the truck delivered tonnes (Modular) and the crusher weightometers. The weightometers situated on the crushers and on the mill are calibrated regularly and so this analysis can highlight any issues associated with the degradation of the tonnages estimated via the trucks (Caterpillar VIMS – Vital Information Management System). As the VIMS data is critical to production monitoring, identification of variances is essential.

The grade control data is imported into the reconciliation system with any changes to the grade control data being made in the data source systems; Datamine or OPGC. Changes flow through to the reconciliation system at the next import stage (every 15 minutes) and are visible immediately, including on reports.

Metallurgical recoveries are also tracked through stockpiles by the reconciliation system. OPGC houses current metallurgical algorithms and applies factors to categorise each block and to evaluate the optimal processing mode for the ore. Reconcilor imports the metallurgical data associated with each block and tracks it through to a stockpile or the plant where it is mass average weighted with other blocks being delivered/removed from the stockpile.

Underground material movements are tracked through the reconciliation system as soon as they reach the surface. At this point a weightometer on the conveyor delivering the material to the plant records the tonnes delivered and the material is sampled to provide a head grade. The reconciliation system imports the actual tonnes and grade from the underground source system, DOME, so that the systems are both reporting the same figures. Changes are not made in the reconciliation system; they are made in the source system, so that at any time both systems are identical.

BENEFITS

The main benefits of having a reconciliation system implemented at Telfer are:

- the centralisation of the existing data sources,
- the accessibility of comparisons between predicted and actual measurements, and
- the availability of this information to all employees from the mine to the mill through to the general manager.

With a large number of active stockpiles at Telfer, there was a requirement to track and model their grade. No other system on site is able to perform this task in such a reliable way. By tracking the grade and metallurgical characteristics through the stockpiles, with the flexibility to model the stockpiles differently (average, LIFO-Avg), it is possible that a best estimate of grade can be provided to the plant.

In addition the ability to compare actual trucked haulage against grade control or Reserve estimates is being used to show ore gains or ore losses over time. This information is used to calibrate the grade control models.

End of month reporting at Telfer is now completed in half a day as opposed to several days. Everyone across the mine site is also now using the same numbers; surveyed stockpile volumes, material moved by truck haulage, grade control model grades and mill weightometer figures. This not only minimises double handling of data, it ensures integrity of the data used is maintained as the source system is the place for any changes. Subsequently, the reconciliation system is used as a viewing platform and reporting service for the different source systems across Telfer.

Reports have been generated for the Engineering Department to evaluate the truck tonnes, movements and utilisation in the open pit. With this information readily available for any part of the pit or over any period of time, the engineers are able to modify their mine plans to reflect the achievable targets based on what is happening in the pit.

FUTURE IMPROVEMENTS

The reconciliation system and processes at Telfer are dynamic and constantly undergoing improvement. Projects currently underway or planned include:

- Surveyed pit depletions to be imported into Reconcilor, which will allow the geologist to easily compare the haulage and the surveyed volume for each digblock. There will be the ability to approve the depletion using either haulage, surveyed or the most accurate tonnage per block.
- The ability for the Processing Department to use Reconcilor to estimate the optimum processing path and maximise profit margins.
- Further improvements to allow the mining engineers and planners to use the system for scheduling – providing the comparison of actuals to plan and allowing the comparison of different mine plans.
- Further development of OLAP Cubes to improve the data querying functionality.
- Data analysis – a real time, snap shot or a landing page that contains general KPIs as well as some specific elements selected by individual users that they want to monitor (it will be different per user – while the home page would be the same for all). From the Analysis tab the user will also be able to drill into more detail and do some analysis – this is where OLAP cubes become particularly useful.

CONCLUSIONS

The reconciliation systems established at Telfer are easy to use and provide access for user's right across site. This combined with the automation of data handling and the use of a single set of numbers for mine tracking has provided the personnel with the ability to identify areas for improvement in costs, ore loss, dilution, treatment paths and resource and reserve estimation parameters. The integration of many data sources in to the system implemented at Telfer continues to provide relevant information for management and the reporting of key performance indicators across the site.

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