The Economics Of Removing Arsenic From Copper Concentrates Using The Toowong Process

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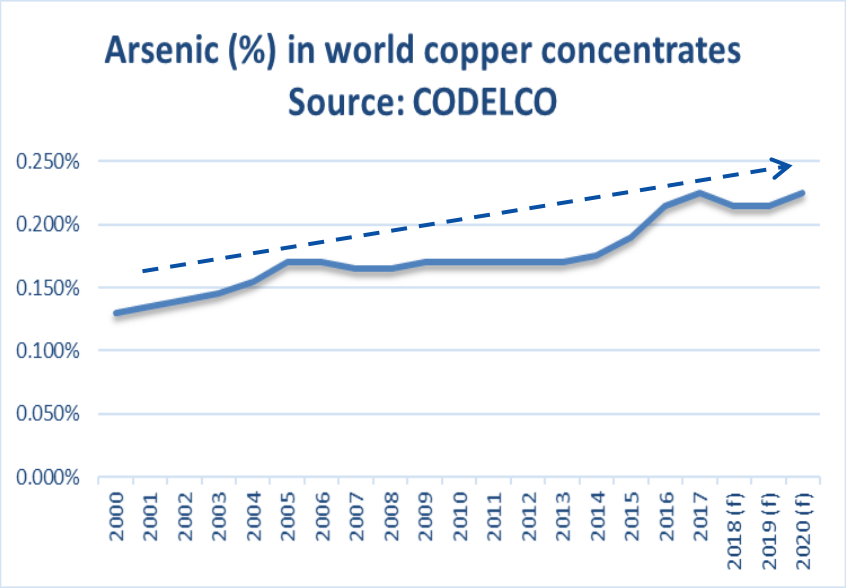
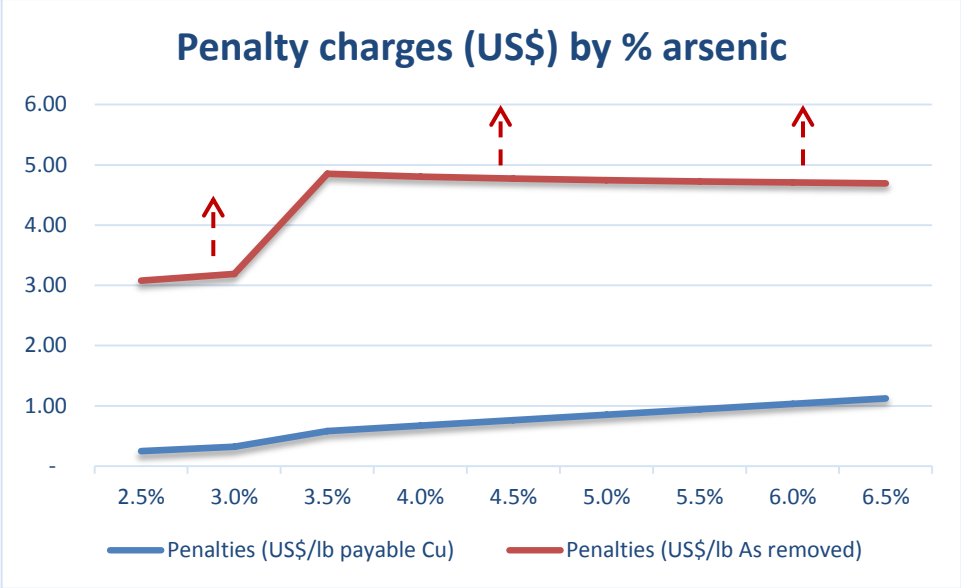
1 – Core Resources, 2 – Mineral Technologies, 3 – Whittle Consulting

Outline

- Industry Context – “industry need”
- Technology Commercialisation – “the Core way”
- Technology and Recent Results
- Capex/Opex Study
- Enterprise Optimisation Study
- The Future – “next steps”

Industry Need - The Arsenic Problem is Getting Worse





Industry Need - The Problem with Today's Solutions

- Blend copper concentrates to meet target arsenic levels for smelters. Smelters deal with arsenic; or,
- Roast arsenic rich concentrates ahead of smelting the copper calcine material; then treat arsenic dusts; or
- During copper metal production use leaching-SX-EW. Arsenic is fixed in the process and disposed in dedicated tailings facilities.

The Problem?

...smelting generates unstable arsenic residues

...major arsenic environmental issues in & around smelters

...tightening government controls on allowable levels

...expensive/prohibitive treatment charges for miners

...increasing arsenic levels in mining projects globally

From Process to Pilot (and Beyond)

- From Process to Pilot Competed – discussed last year
- and Beyond
  - Demonstration of the process continues – new ores, optimising flowsheet, with new lower cost arsenic fixation options
  - Advancing engineering design and costings – appointed Technology Delivery Partner, Mineral Technologies (Downer)
  - Advancing the value proposition – collaboration with Whittle Consulting evaluating impact of Toowong Technology on project value

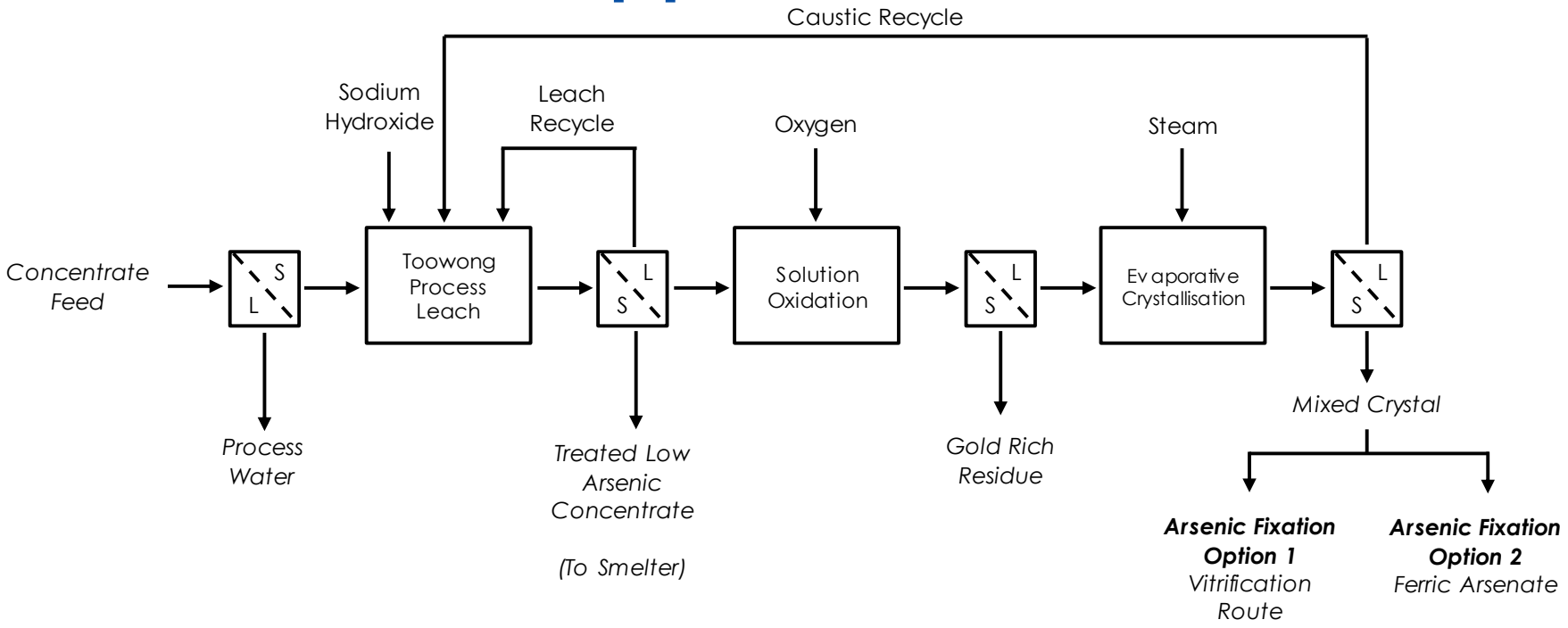
Background

Toowong Process:
A Demonstrated Technology

$4.5 M pilot plant in 2012
Treated 1.5 tonnes from three global resources: Bulgaria, Philippines, Chile
34 days of continuous treatment

- ✓ **>90% As Removal**
- ✓ **Final concentrate <0.1% As, down from 1.1%**
- ✓ **Arsenic product generated**
- ✓ **Low reagent consumption**
- ✓ **Process demonstrated at continuous steady state**

Flowsheet - Copper



Some more recent Program Results

Project			Sample A Tampakan	Sample B Toowong Blend*	Sample C Sth America	Sample D Sth America	Sample E Europe
Testwork Stage			Batch	Pilot	Batch	Batch	Batch
Starting Grade	As	%w/w	3.25	1.11	2.42	5.24	4.10
Final Grade	As	%w/w	0.13	0.11	0.06	0.59	0.10
Leach Extraction	As	%	**95.2**	**90.0**	**97.7**	**90.6**	**98.0**
Starting Grade	Sb	%w/w		0.06	0.81	5.61	0.05
Final Grade	Sb	%w/w		0.01	0.06	0.56	0.01
Leach Extraction	Sb	%		**78.0**	**93.7**	**92.0**	**90.9**
Starting Grade	Cu	%w/w		21.4	17.2	23.4	25.9
Final Grade	Cu	%w/w		21.9	18.8	26.6	27.3
Leach Extraction	Cu	%		**0.0**	**0.0**	**0.0**	**0.0**

*Toowong Blend Composition - 96 %w/w Collahuasi / 4 %w/w Chelopech

Capex – Ferric Arsenate Option

Concentrate Treated	2.5% As	40,000 tpa	200,000 tpa	400,000 tpa
Copper Concentrate	tpa	40,000	200,000	400,000
Copper Concentrate	tph	5.0	24.8	49.6
Capex - US$		$37,000,000	$98,000,000	$147,000,000

Mechanical Equipment	$6,927,722
Structural & Platework	$2,625,817
Earthworks & Civils	$1,513,296
Electrical & Instrumentation	$3,830,934
SMP Construction	$5,418,288
E & I Construction	$1,458,002
EPCM	$5,120,478
Contractors Margin	$2,924,923
Piping & Valves	$1,445,022
Transport	$909,667
Contingency (15%)	$4,826,123
TOTAL	$37,000,273

MECHANICAL EQUIPMENT	
Leach / Product Circuit	$ 836,676
Oxidation Circuit	$ 2,344,011
Crystalliser Circuit	$ 2,843,297
Dosing Circuit	$ 305,047
Other Items	$ 598,691
TOTAL	$ 6,927,722

Opex – Ferric Arsenate Option

Concentrate Treated	2.5% As	40,000 tpa	200,000 tpa	400,000 tpa
Opex - US$/lb As removed	low *	$4.59	$3.70	$3.58
Opex - US$/lb As removed	high	$5.49	$4.57	$4.48

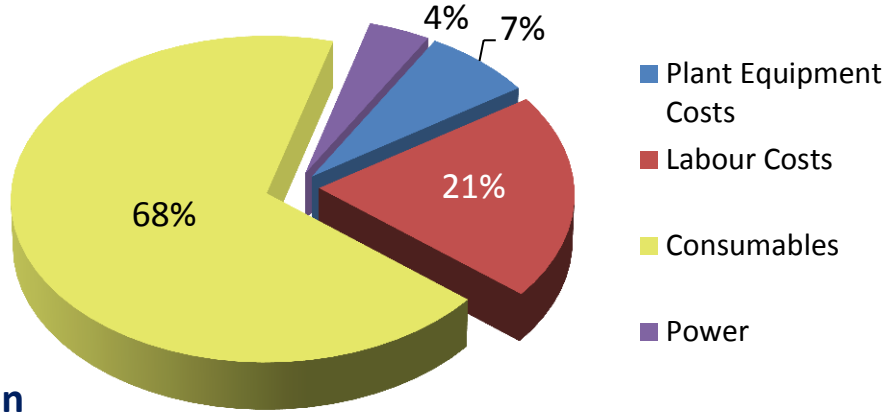
* low reagent costs - lime, caustic and ferric sulphate

Including capital amortisation, opex is in the range of:

US$5.30/lb As removed for larger plants

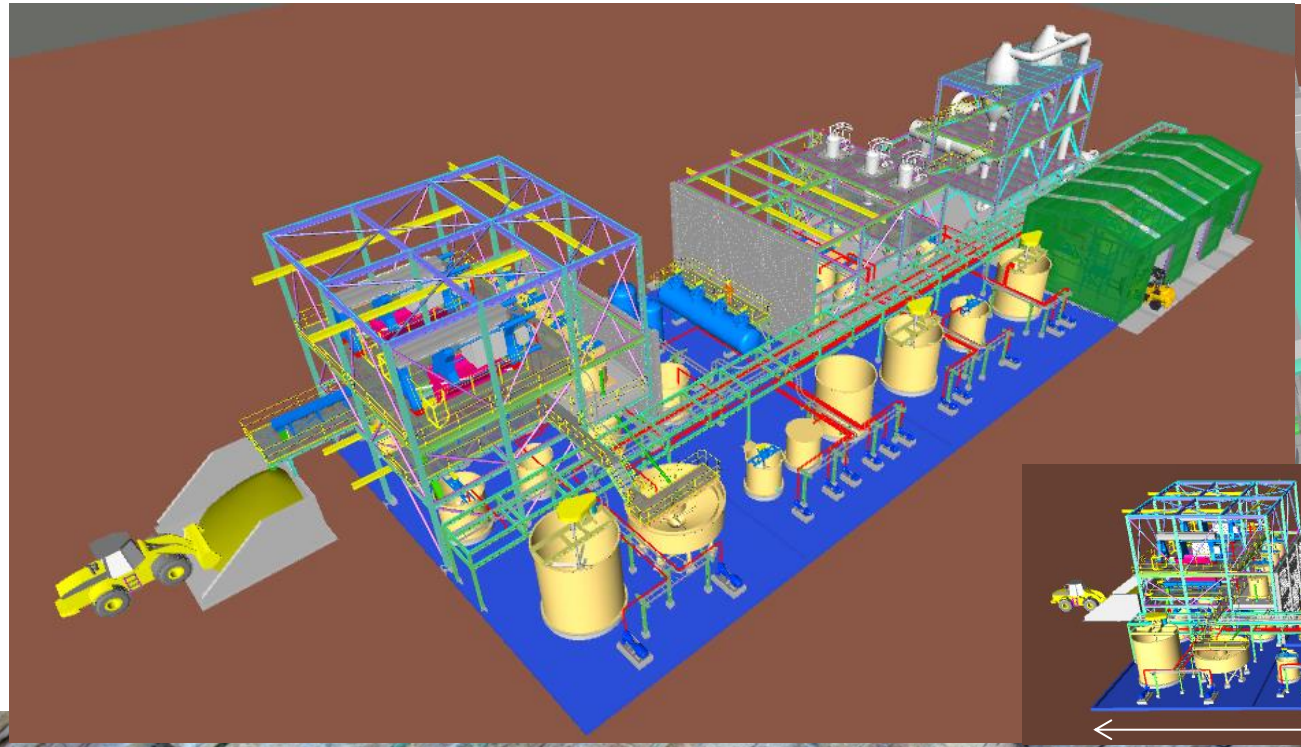
and

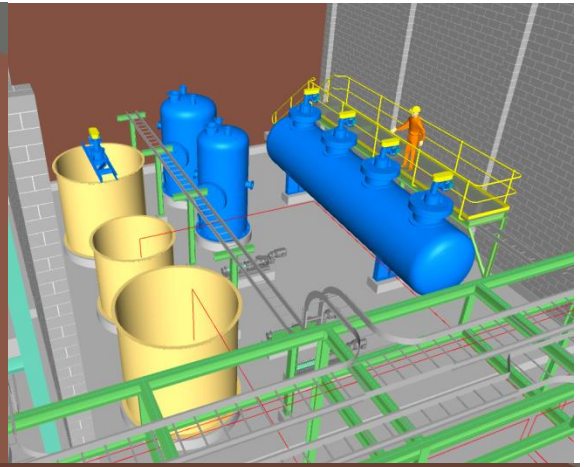
US$7.80 /lb As removed for smaller plants

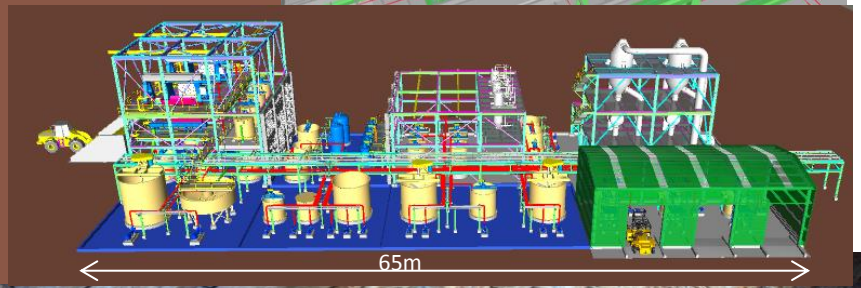


Next phase of development work is focused on an environmentally superior option to the industry standard ferric arsenate fixation approach

Example Plant Layout – 40,000 tpa concentrate







Why Toowong?

- Chemically separates arsenic at the mine site
- Captures arsenic in an environmentally stable form
- Returns arsenic to its original native location
- Creates premium clean copper concentrate for shipment to smelter
- No downstream copper metal recovery required

- ✓ **Environmentally superior technology**
- ✓ **Enabling technology for stranded projects**
- ✓ **Significant cost savings for current mines**

Toowong	ASL
Nil/Low Sulphide Addition • 0 to 15 kg/t • 0 to US$7.5/t conc	High Sulphide Addition • 100 to 150 kg/t • US$50 to $75/t conc
Low Poly Sulphides	High Poly Sulphides
Low Sulphate Bleed	High Sulphate Bleed
Low Gold Dissolution	High Gold Dissolution

This technology should be considered a "game changer". … The Toowong Process has the potential to unlock sites that are currently considered unviable mineralisations for sustainable mining throughout the world.

Dr David Way, CEO, JKTech (University of Queensland)

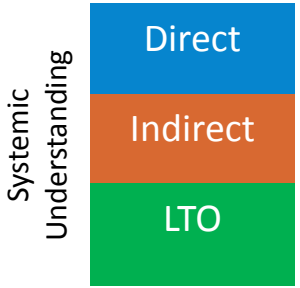
Context of EO with a Technology

A methodology that:

- expands practice to entire value chain, modelling systemic impacts
- maximizes the rate of net cash flow
- Incorporates activity-based-costing, theory-of-constraints concepts and sustainability.

For a technology, method or idea:

- Direct benefit in NPV terms
- Indirect benefit from an re-optimisation case
  - Enablement
  - Strategic Mine Plan
- Licence-to-operate benefit
  - Tangible
  - Intangible



A: Activity Based Costing
B: Theory of Constraints
1. Pit/Underground
2. Phases
3. Schedule
4. Cut-off
5. Stockpile
6. Blending
7. Processing
8. Products
9. Logistics
10. Capital
11. Sustainability
12. Risk and uncertainty

Prerequisites
Mining
Downstream and Commercial
Reality/Context

Verifying the Technology Benefits in a Whole-of-Business Analysis.

Previous Work

Partner	Tech/Concept	Published
CRC Ore	Grade Engineering	Jul 2016
Safescape	Edge Protector	Oct 2016
CORE Resources	**Toowong Process**	**May 2017**
S. Howe (Masters)	Intensive Blasting	Jun 2017
MTGA	Driverless Trucks	Jun 2017
Mining Sense	Bucket Sensor	Jul 2017

For Toowong - what proportion of total benefit can be ascribed to:

- The direct benefit of reduction in penalties against Capex & Opex?
- The direct benefit of blending Hi/Low-As cons?
- The indirect benefit from a re-optimisation case?

Details of the Toowong Optimisation

Case Study Set-up

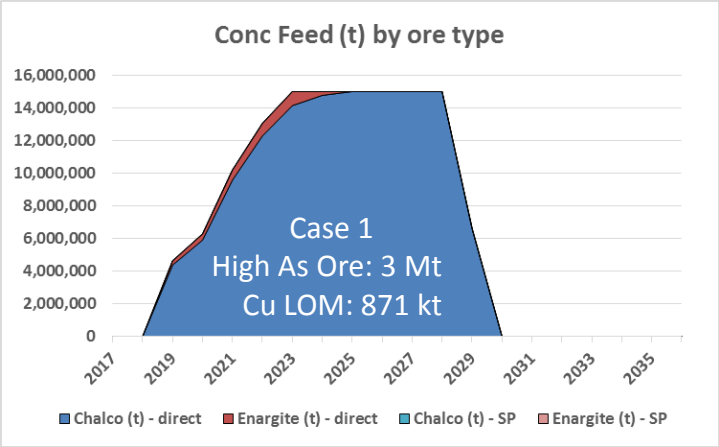
- Marvin copper gold ore body;
- Assigned As values through in typical deportment; emulation of high As mineralisation
- 3 cases modelled:
  1. Base Mining & Process
  2. Apply Optimisation mechanisms; basic & uncomplicated
  3. **Model a Toowong Process treatment route**
- Included cut-off, stockpile & blending
- Excluded other more complex mechanisms

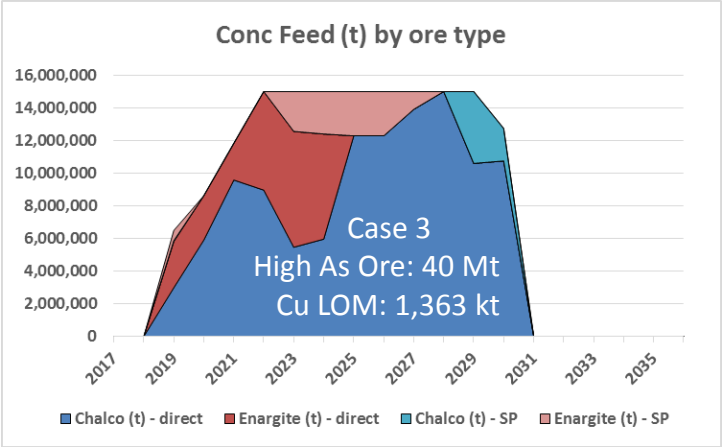
Assumptions

- Capex add $70 M for Toowong Process (Case 3)
  - 100,000 tpa Concentrate treatment
- Capex added additional $50 M for Concentrator in Case 3
- $5/lb As removal charge - opex
- Mining limit 40 Mt/y
- Processing limit 15 Mt/y
- Concentrate limit 0.5% As
- Typical penalties applied where needed

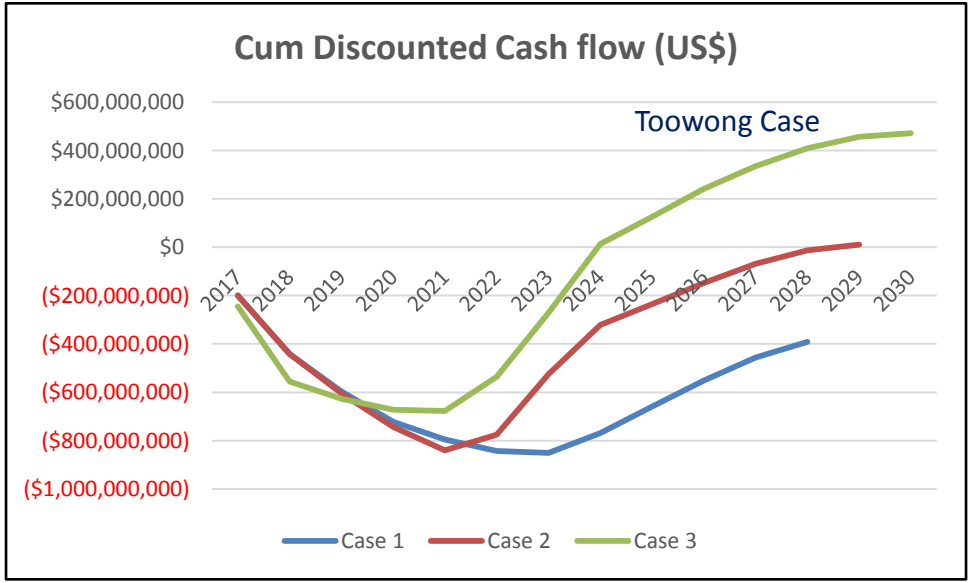
Results of Optimisation - Physicals

- The real benefit is coming from being able to process material you otherwise had to discard
- High As material treated increases from 3 Mt to 40 Mt with Toowong Process circuit available
- Only 28% of the LOM concentrate has to be treated, the rest by-passes directly to product
- Extra 56% Copper sold in concentrate over LOM





Results of Optimisation - Financials



- 14 Year Mine Life for Toowong Case
- LOM Revenue (Nominal US$)

  Case 1 US$ 6.4B

  Case 2 US$ 8.3B

  Case 3 US$10.2B

Next Steps

Core has a clear development path for the Toowong Process.

Toowong Process:
Project Funding

- ✓ ~$1 M Accelerating Commercialisation Grant to mid 2018
- ✓ Downer – Mineral Technologies appointed as Delivery Partner
- ✓ End user engagement has commenced with study work being conducted right now for global clients

Commercialisation Timeline

- ✓ Ongoing identification of opportunities
- ✓ Strong interest from producers, traders and smelters seeking a competitive advantage
- 🕐 Studies for end user clients 2016-2017
- 🕐 End user licences issued Q1 2018

Acknowledgments

- Core would like to thank its clients and dedicated staff, who were involved in the development of the Toowong Process from testwork to piloting to achieving recognition in various innovation awards.
- Downer – Mineral Technologies for their support as the Delivery Partner for the Toowong Process.
- Whittle for its support in completion of an Enterprise Optimisation study to support this presentation.
- AusIndustry for providing an accelerating commercialisation grant to support the Toowong Process commercialisation.

Questions?