



# Haulage Profile

Advances in Vulcan 9

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Strategy Optimisation Systems





Haulage Profile is a Vulcan tool which helps to users to estimate truck hours for a particular mine plan.

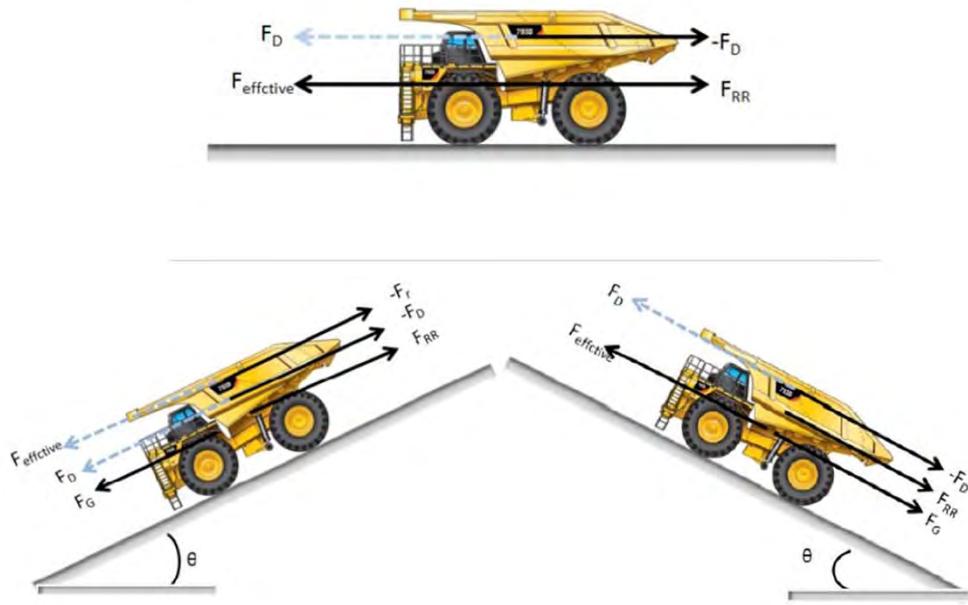
It consists basically of two set of activities: define or select routes, and define or estimate truck speed.

So far Haulage Profile has been recognised as a 'good' tool to estimate truck hours, providing a good graphical interface to design the haulage routes.

Some users however were asking to incorporate the speed calculation based on the truck rimpull curves to provide more confidence to their fleet requirement calculation, and avoid subjectivism at the time of assigning the truck speed for calculations.

Particularly for mines with many phases and destinations, a simplification on the process of route selection was requested to save time.

## Forces Acting During Truck Movement



If a truck moves at a constant speed, then there is a balance of forces between the resistance (FR) as opposed to the movement of the truck and the thrust force (FT) that it performs to keep moving.

# THRUST FORCE x SPEED

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# POWER

Given that the power of the truck is constant, it can be inferred that the push for speed is a constant as well.

This means that a greater thrust force is required to neutralise a greater resistance to the movement and consequently slows down the speed of the truck.

This phenomenon can be seen as an analogy to the gears of common motor vehicles: if a higher engine power is required (minor gear), the speed that the vehicle can produce is lower.

It can be inferred that the engine power (W) is equal to the thrust force (FT) multiply by the speed (S).

road grade

rolling resistance of the ground (soil friction)

internal friction (usually negligible)

**=Rimpull**

(Road grade% + rolling resistance %)\*Truck Weight

The rimpull is the equivalent of all resistance forces which are in opposition to the truck movement. Rimpull is proportional to the truck weight and road conditions.

The rimpull is the result of three factors:

- road grade
- rolling resistance of the ground (soil friction)
- internal friction (this is usually negligible)

Then the rimpull can be modelled according to the following equation:

# What is the maximum truck speed?

$$EnginePower = Rimpull * Speed$$

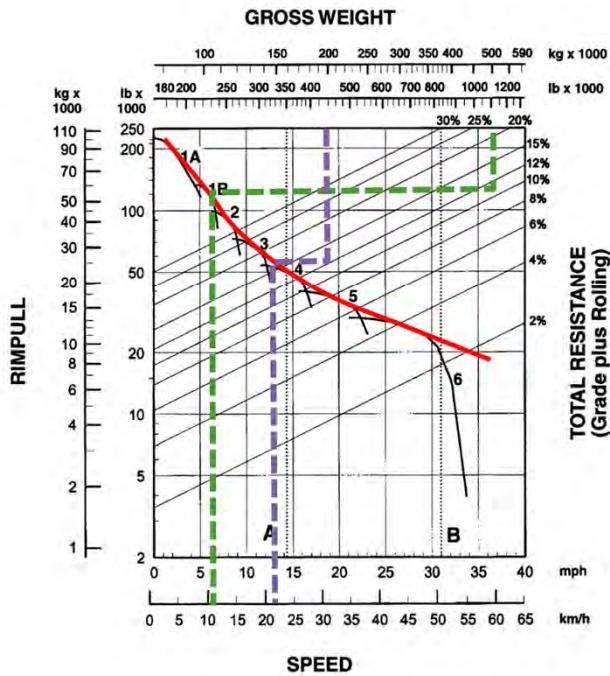
During the truck movement the thrust force is in equilibrium with the resistance force (rimpull) and directly proportional to the engine power (W) and inversely proportional to the truck speed (S), then the rimpull can be formulated as shown.

# What is the maximum truck speed?

$$Max\_Speed = \frac{Max\_EnginePower}{Weight * (RoadGrade\% + Rolling Resistance\%)}$$

Then the truck speed can be calculated as a function of the truck weight, the road conditions and the engine power as shown in the equation shown.

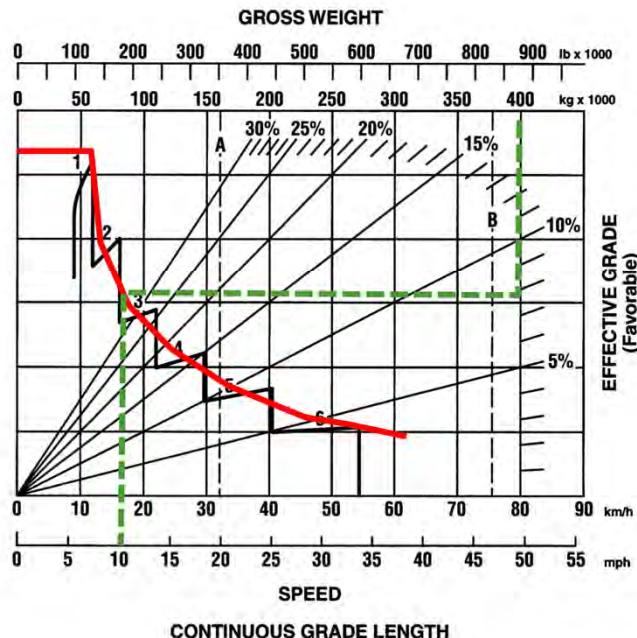
## Rimpull Curve



The rimpull curve defines the maximum operating speeds for different road configurations (grade and rolling resistance).

10% positive road grade resistance working against the truck + 2% positive rolling resistance working against the truck = 12% total resistance.

## Retarding Curve

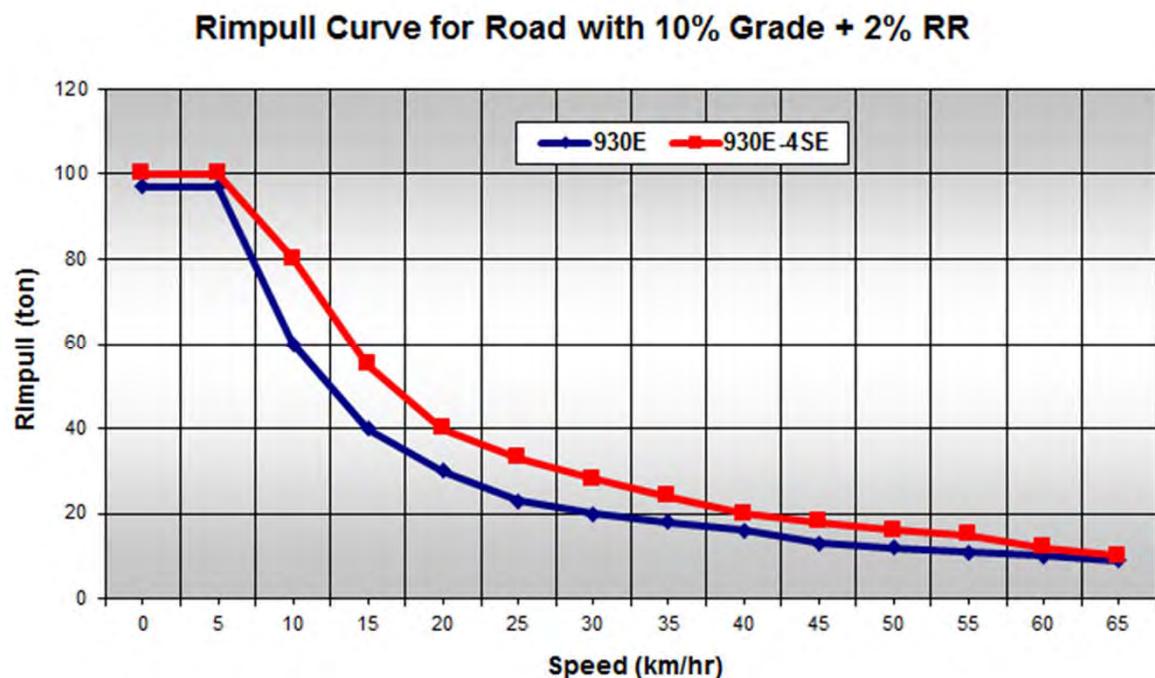


The retarding curve is the equivalent to rimpull curve when the truck is moving down the road, and reflects the speed for the engine gear which avoids the brakes overheating.

The retarding curve also depends on the length of the road.

10% negative or grade favouring to make the truck roll away + 2% rolling resistance opposing the truck movement (rolling resistance is always against you).

Give a total effective grade of -8%, where minus means a favourable grade and the need to use a retarder chart.



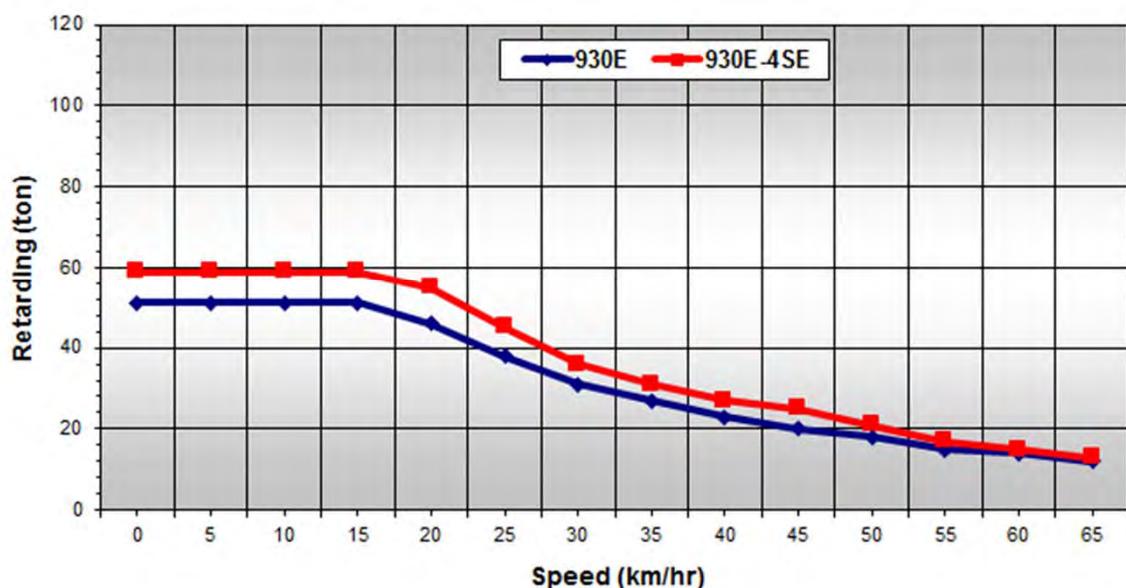
The rimpull and retarder curves represent maximum speed the vehicle can mechanically achieve.

The maximum engine power could be achieved for a optimum combination of speed and rimpull.

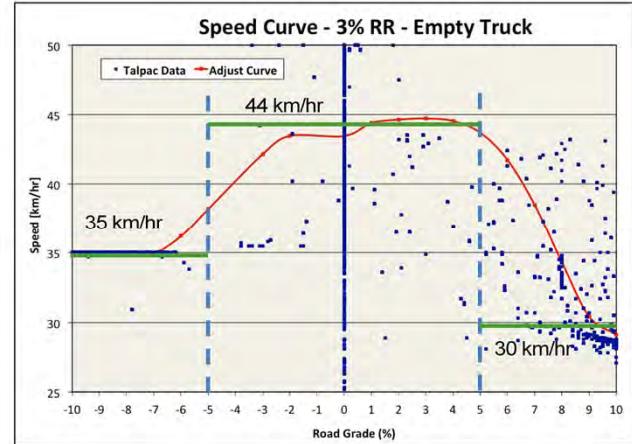
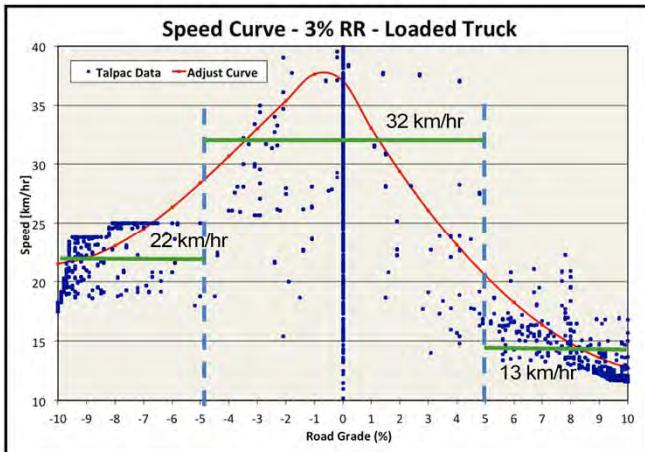
Certainly using rimpull and retarding curves enables more accurate speed calculations, however there are some factors which these curves do not consider, such as:

- Congested areas or sharp turns where speed must be lower.
- Haul roads are commonly broken into segments where grades or conditions change.
- Operator skills.

### Retarding Curve for Road with 10% Grade + 2% RR



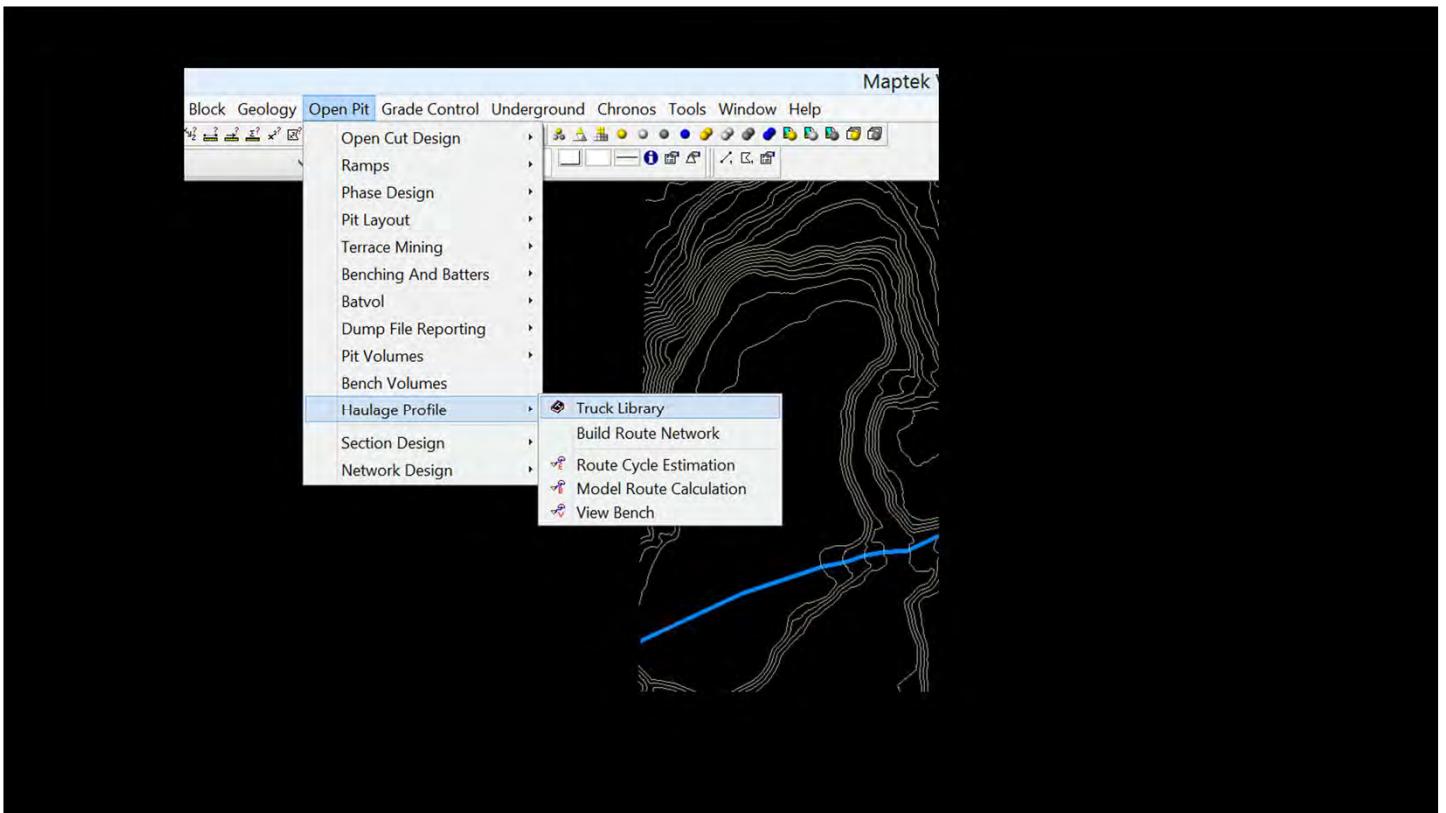
## Average Speed Assumptions

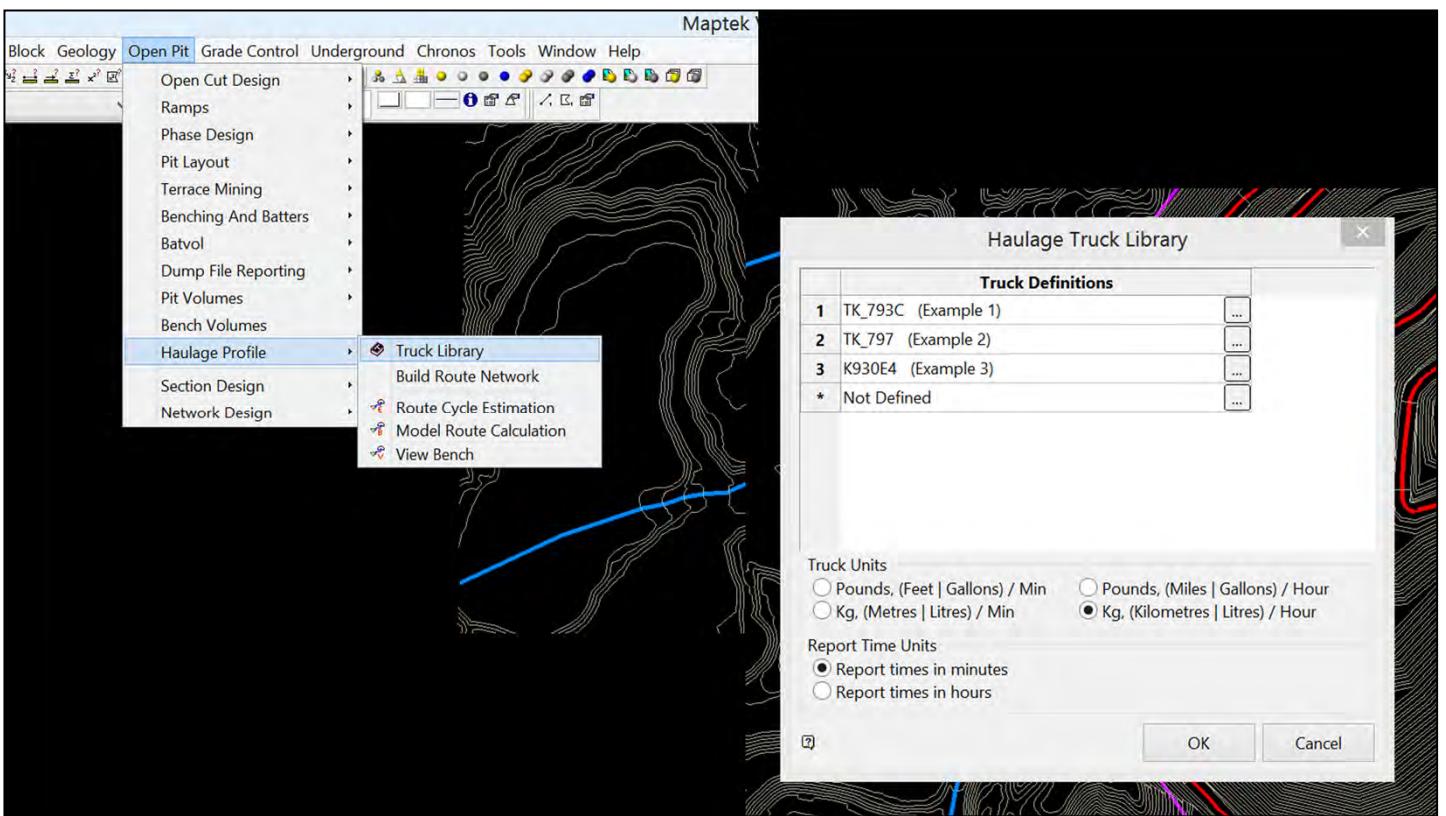


Given Vulcan was not able to manage rimpull and retarding curves, Haulage Profile was using average speed assumptions typically for 6 route types:

- Loaded Truck: ramping up, flat and ramping down
- Empty Truck: ramping up, flat and ramping down

Some users prefer to take average speed from Talpac, however the time to prepare routes and conduct further analysis in Talpac is too long given time constraints to deliver fleet calculations.





# Truck Definition

Truck Definition

Specification Performance Route Delays

Identification

Name: K930E4

Description: Example 3

Materials (in Mins)

Defaults: Ore | Waste | Other

Capacity (in Tons): 290.0

Load/Dump Times

Loading: 2.65      Dumping: 1.0  
 Bucket capacity: 1.0      Loader cycle time: 1.0

Spot Time

Loader: 1.0

Spot Times (in Mins)

Crusher: 1.0      Dump: 0.5      Other: 0.5

Delays

Average delay: 1.0 (in Mins)      Fuel consumption: 20.0 (Litres/Hour)

Calculate Equivalent Mass-Distance  
Vertical distance factor: 1.0

Calculate Equivalent Distance  
Vertical distance factor: 1.0

OK Cancel

# Standard Speed Setup

Truck Definition

Specification Performance Route Delays

Standard Rimpull

On the Flat

Speed: Loaded	45.0	Empty	50.0	(Km/Hour)	
Fuel:	Loaded	150.0	Empty	100.0	(Litres/Hour)

Loaded

Grade Cutoff (%)	Speed-Uphill (Km/Hour)	Speed-Downhill (Km/Hour)	Fuel-Uphill (Litres/Hour)	Fuel-Downhill (Litres/Hour)	Colour	Line
1	5.0	13.0	25.0	350.0	150.0	-----
*				1.0	1.0	-----

Import... Preview...

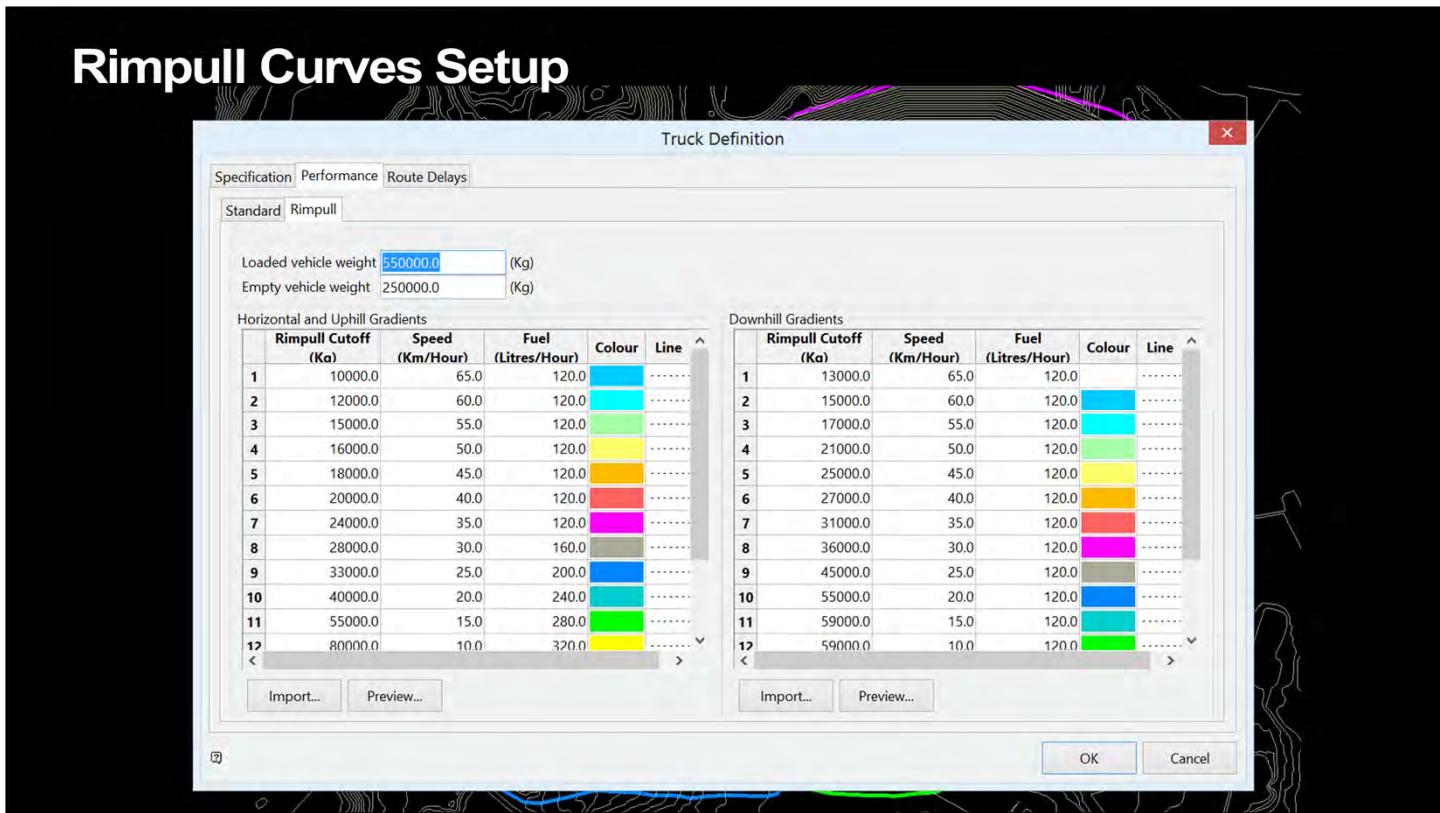
Empty

Grade Cutoff (%)	Speed-Uphill (Km/Hour)	Speed-Downhill (Km/Hour)	Fuel-Uphill (Litres/Hour)	Fuel-Downhill (Litres/Hour)	Colour	Line
1	5.0	20.0	30.0	200.0	50.0	-----
*				1.0	1.0	-----

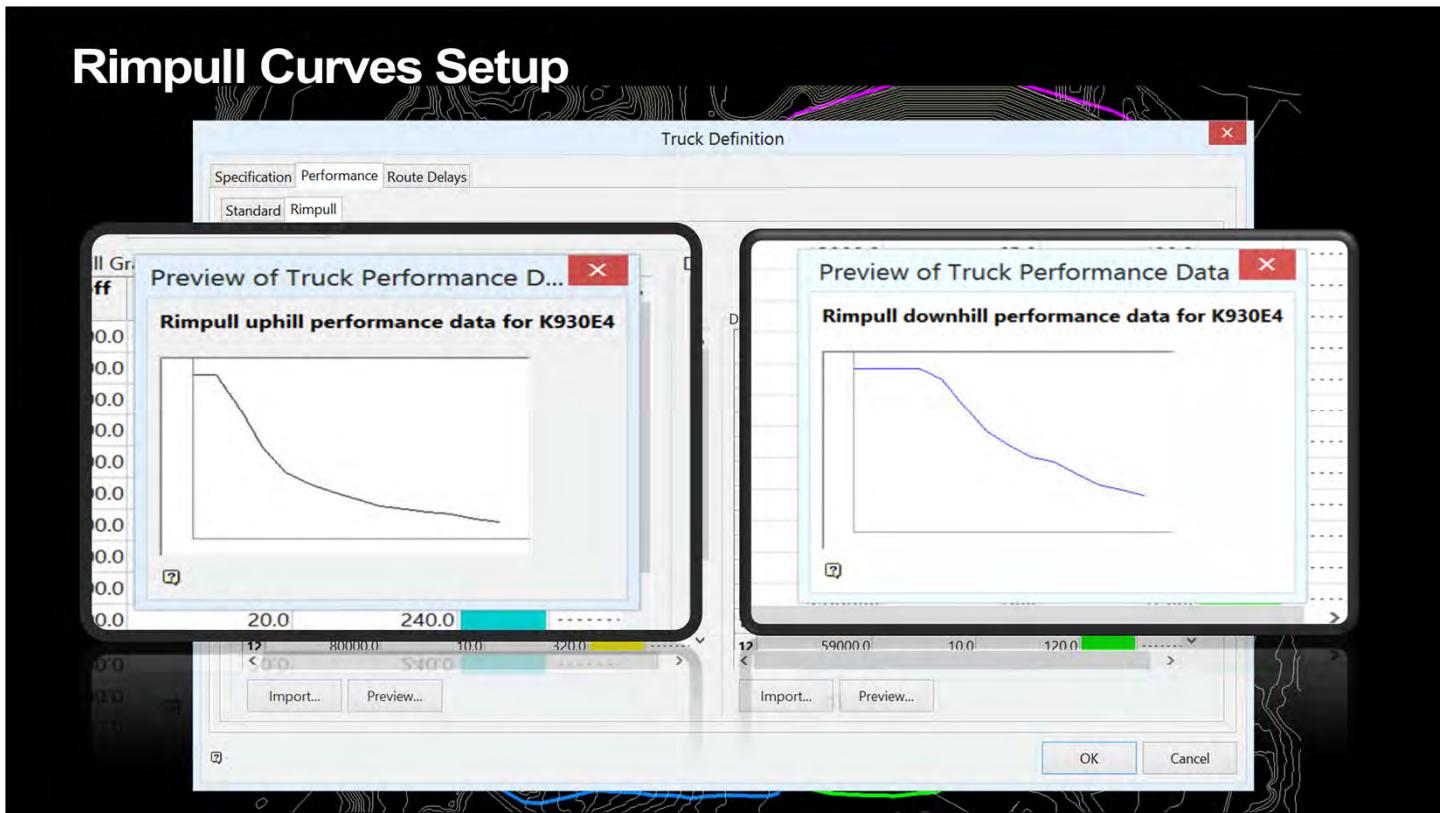
Import... Preview...

OK Cancel

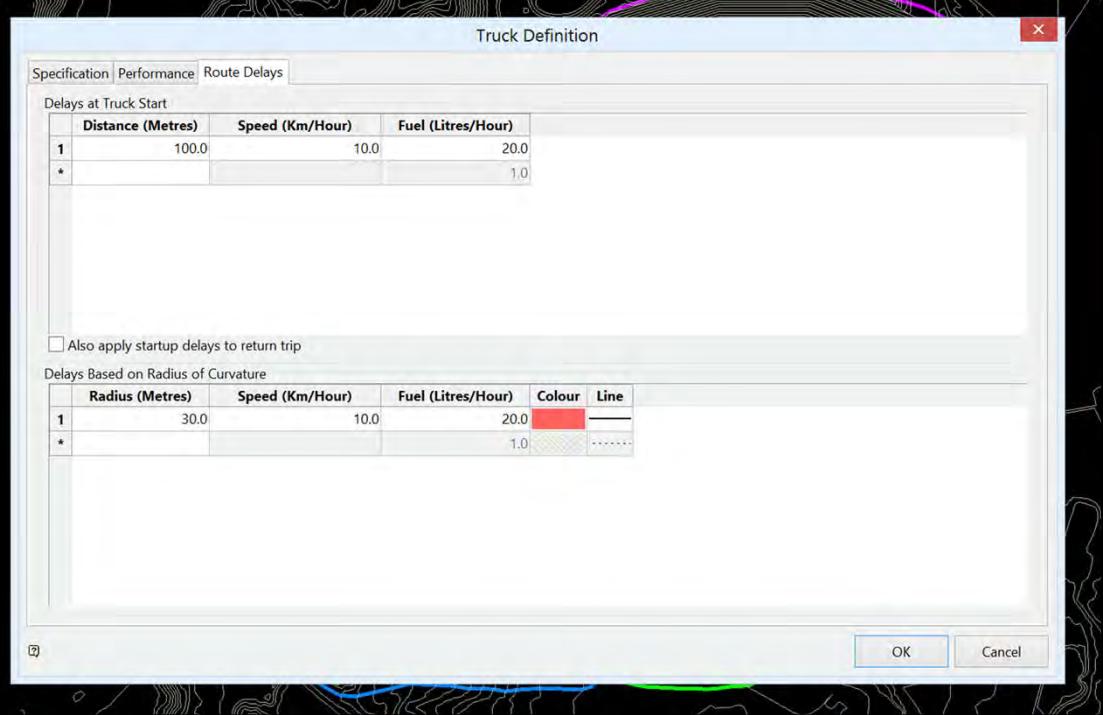
# Rimpull Curves Setup



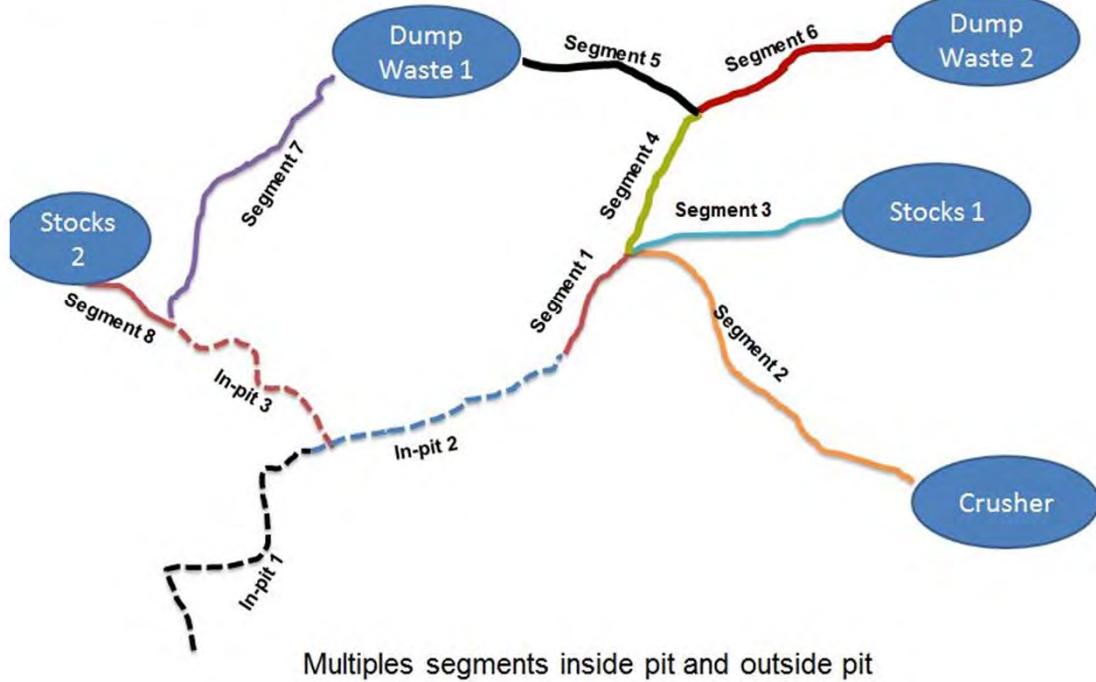
## Rimpull Curves Setup



## Route Delays



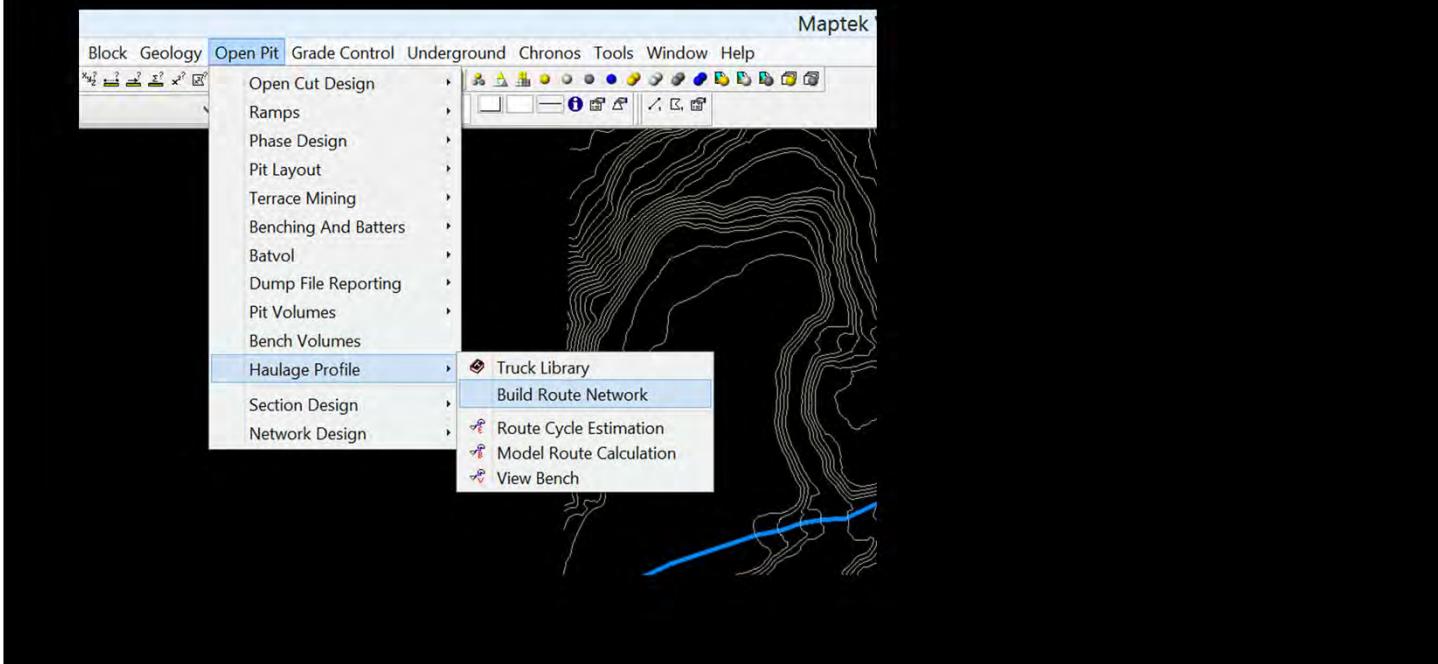
## Route Construction

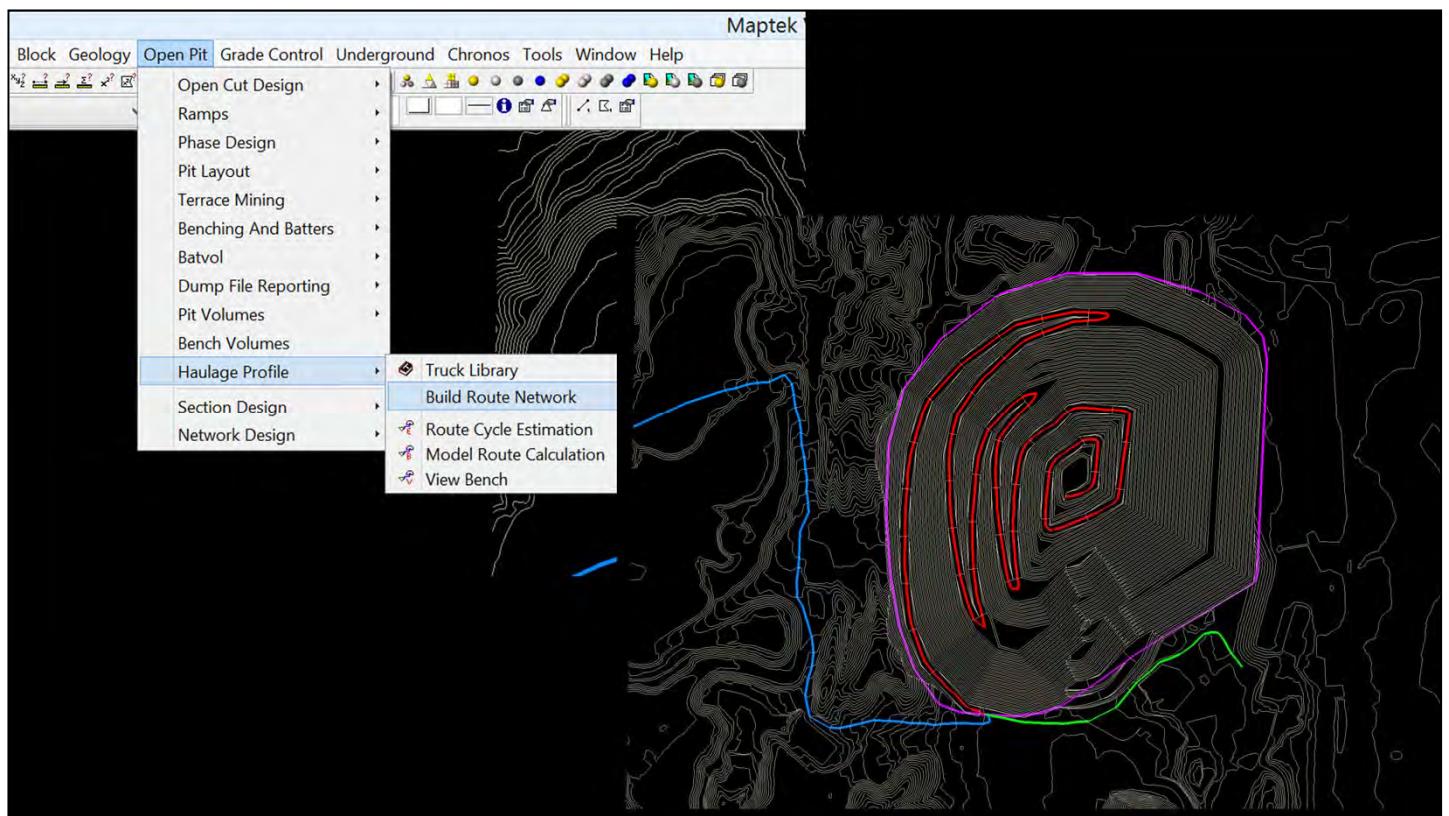


Now with the predefined routes and the external executable program, you can run multiples scenarios reducing clicks and improving Vulcan user experience.

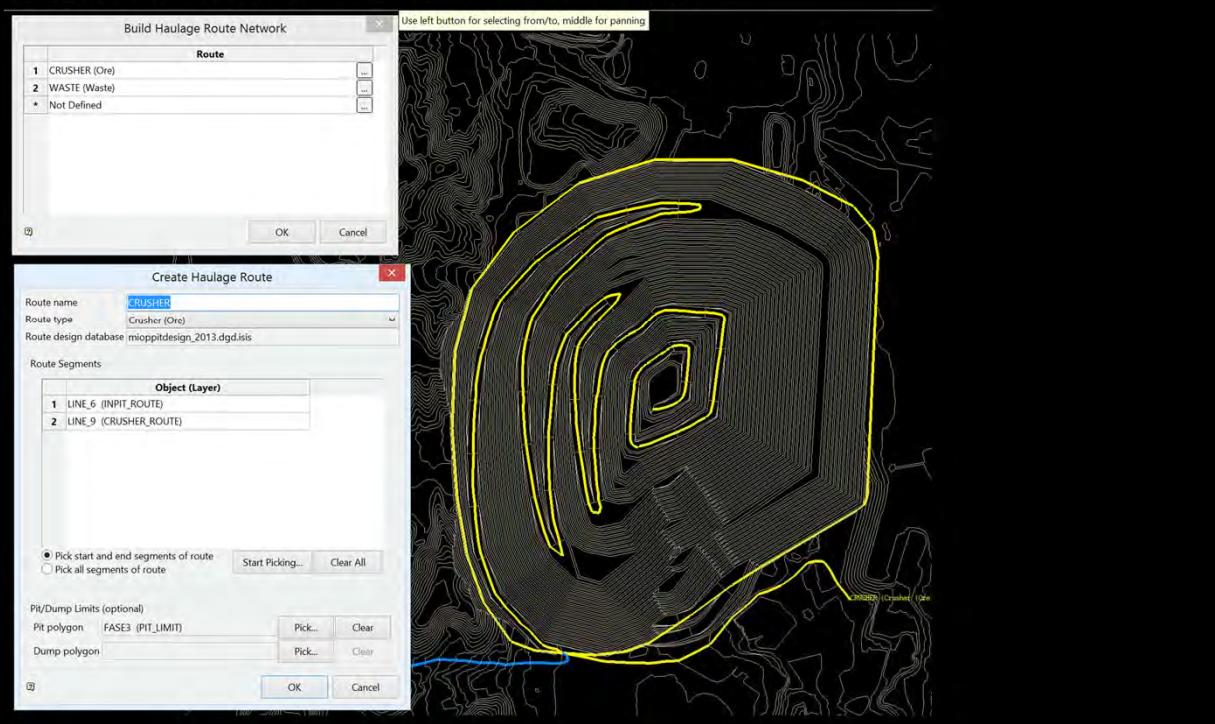
And create a haulage database to be used with scheduling.

## Build Route Network - Simple Case

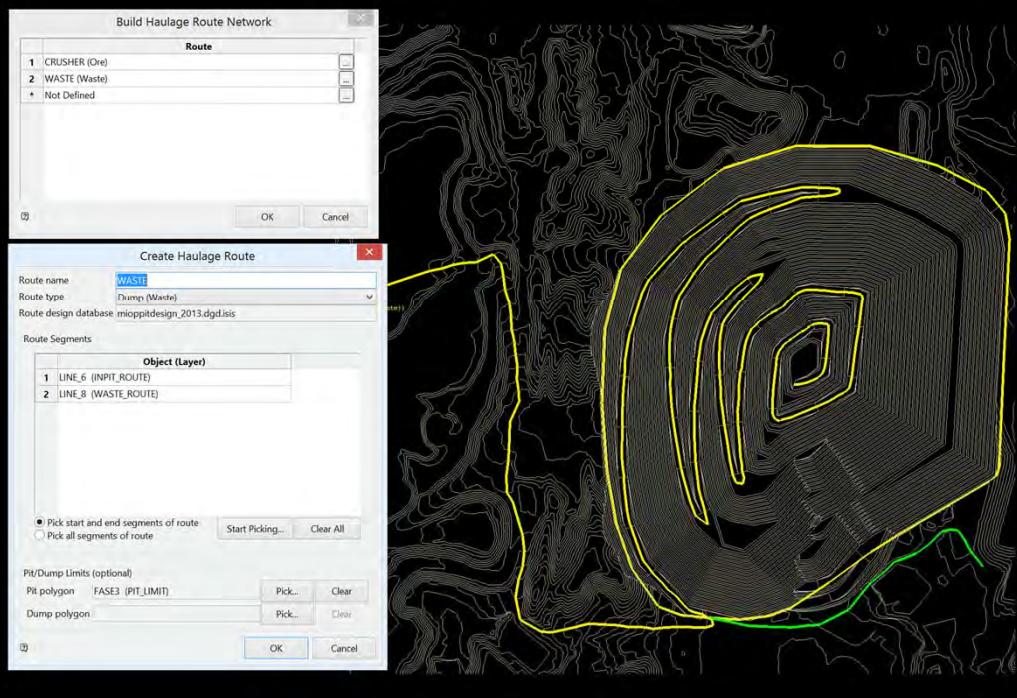




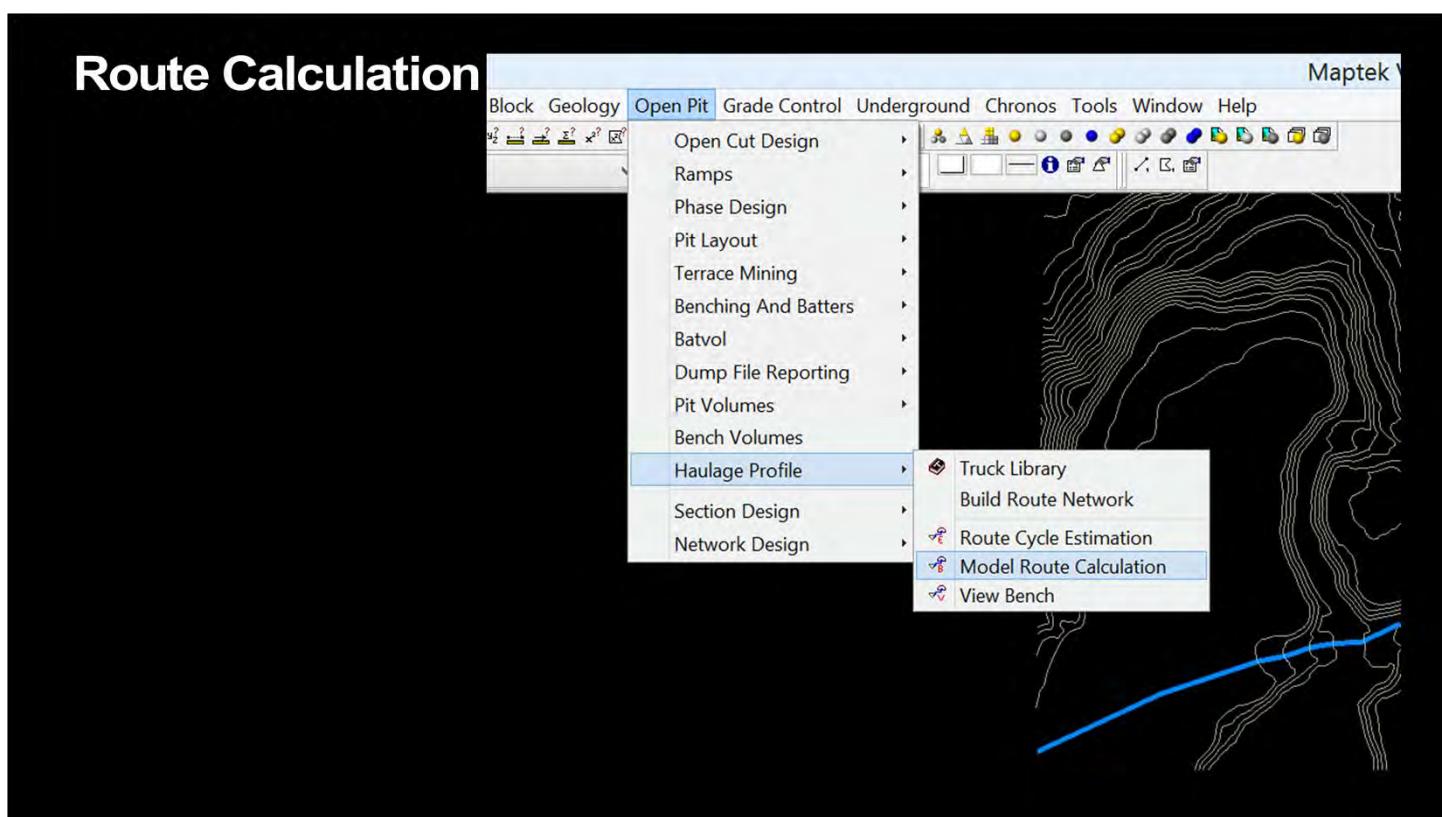
## Build Route Network - Ore to Crusher



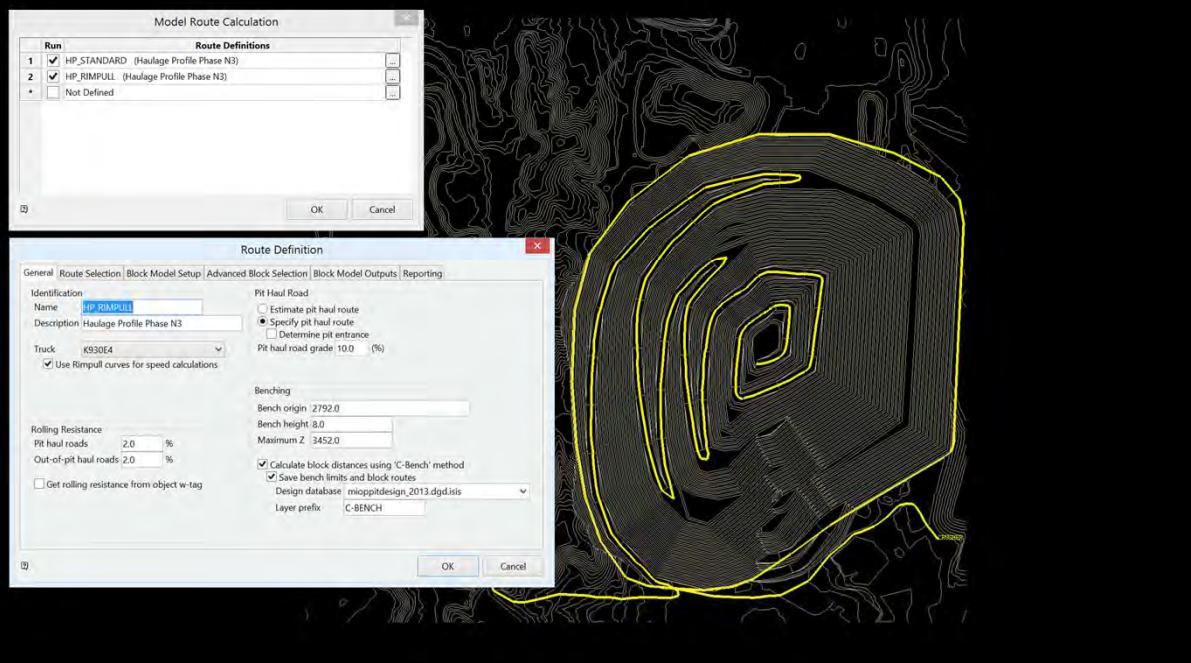
## Build Route Network - Waste to Dump



# Route Calculation

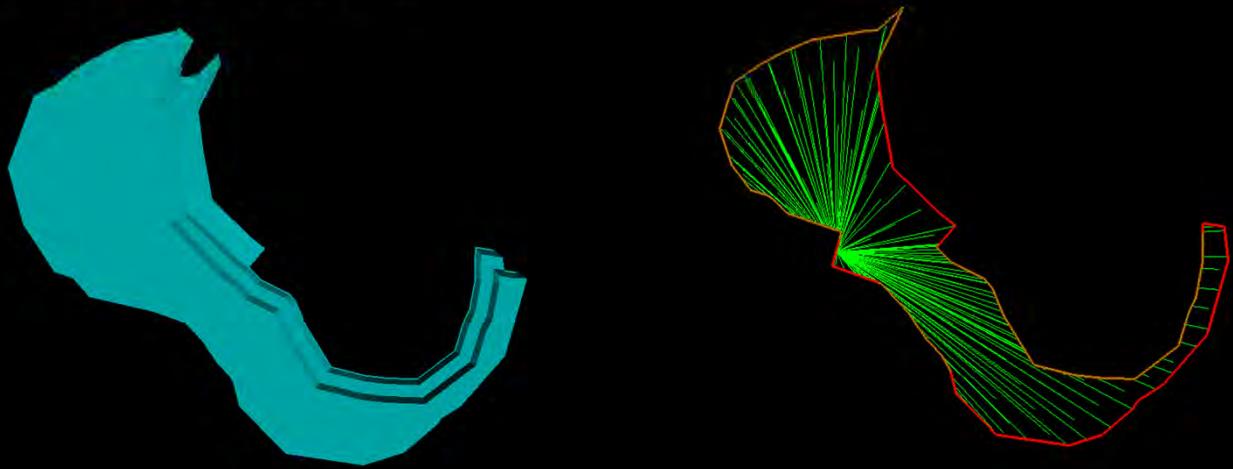


# Route Calculation - Using Rimpull Curves

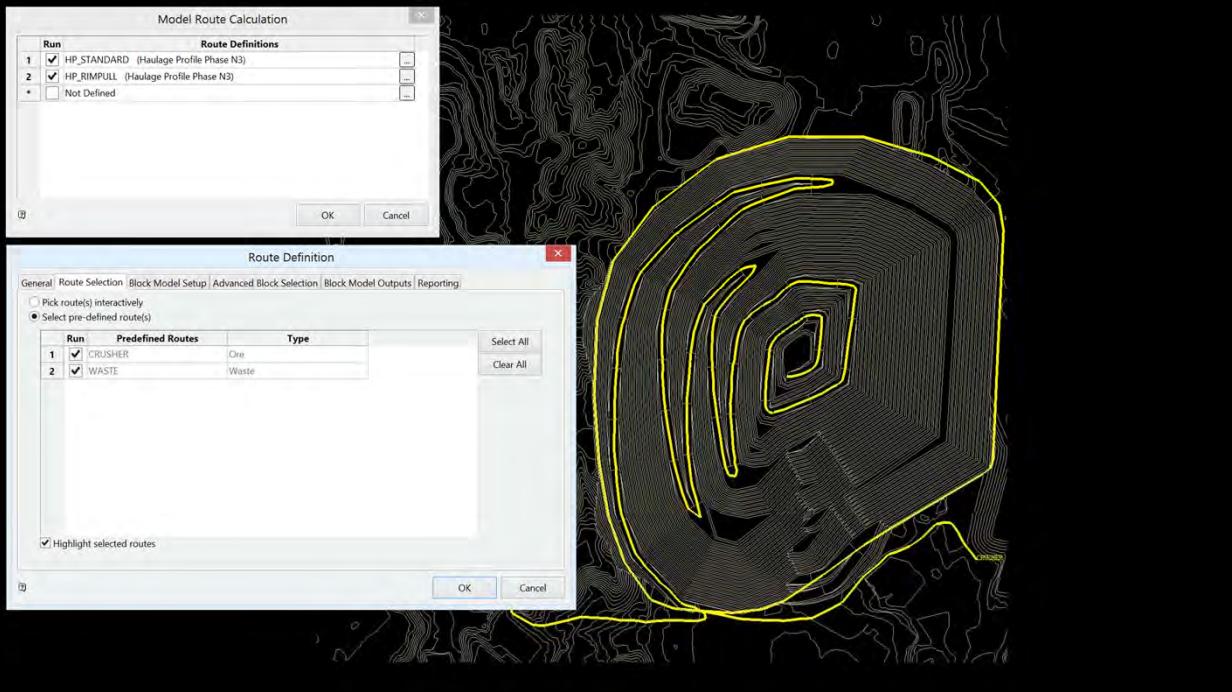


## Route Calculation - Using C-bench Option

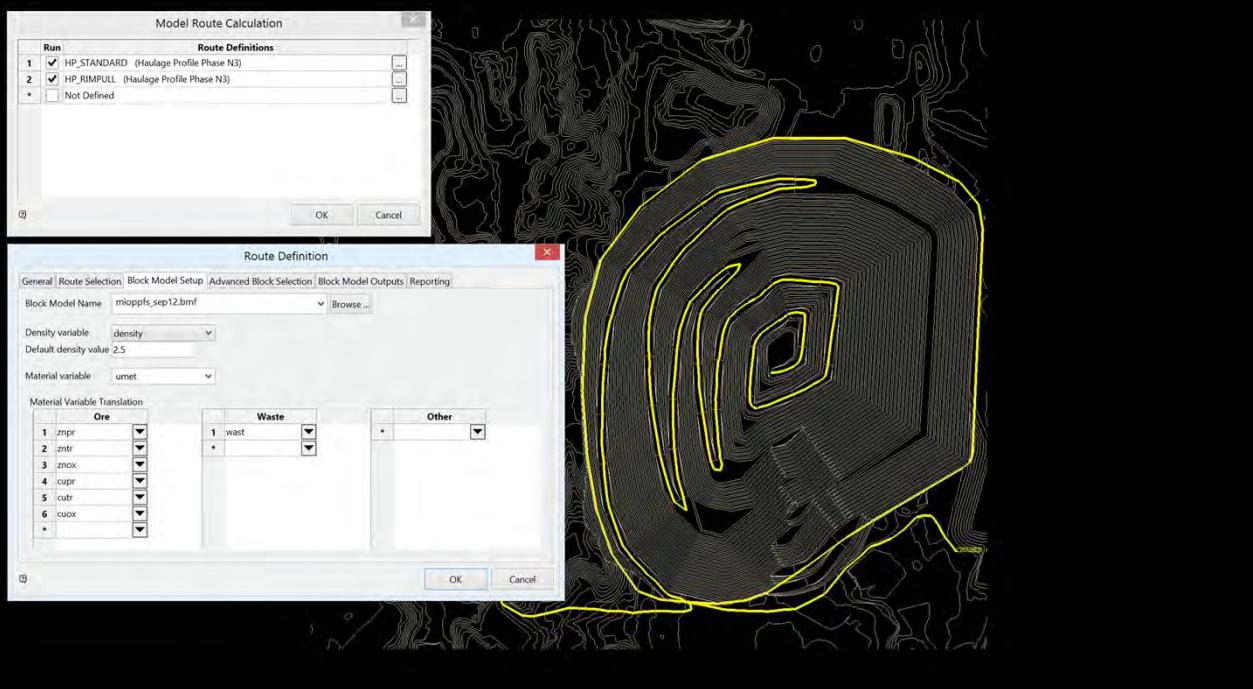
- Avoids straight line between the block centroid and the ramp exit
- Takes into account operational constraints during the cycle time calculation - useful in short/medium term



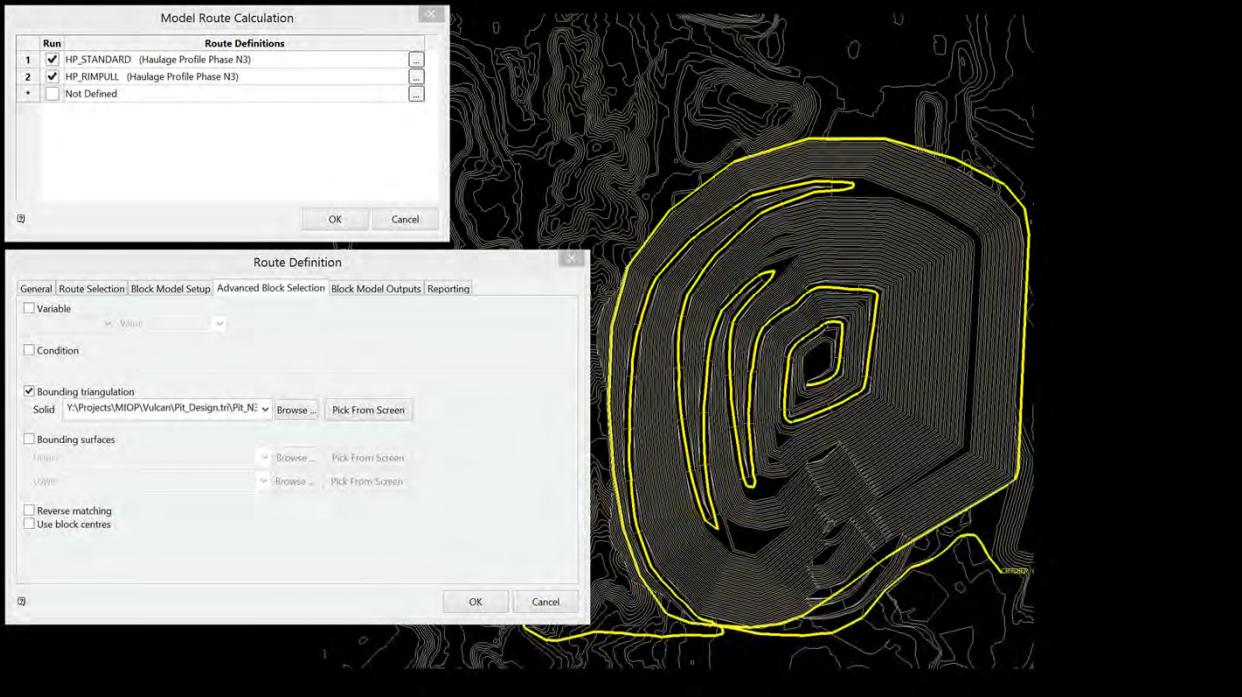
# Route Calculation - Selecting Routes



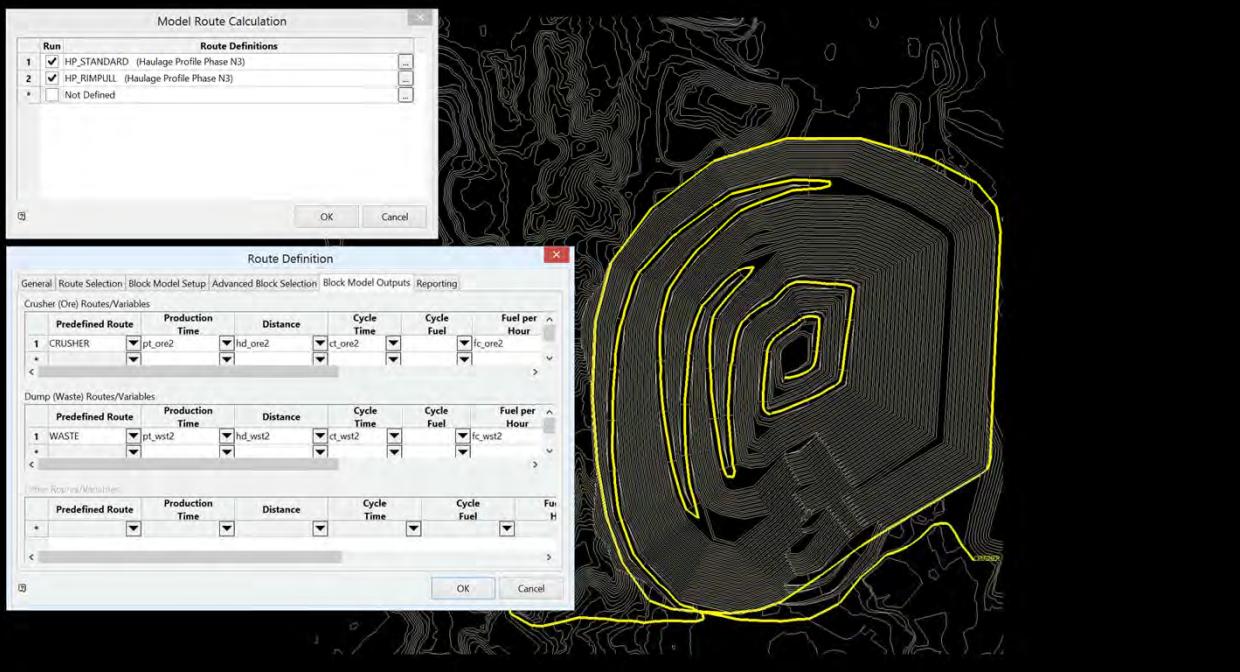
## Route Calculation - Block Model Setup



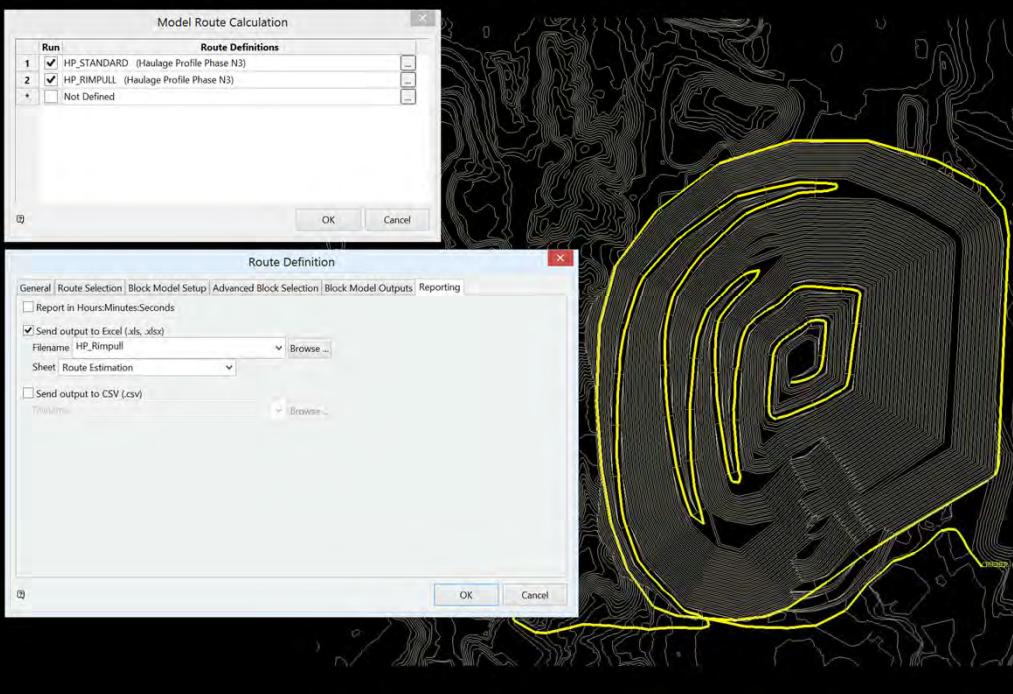
## Route Calculation - Block Selection



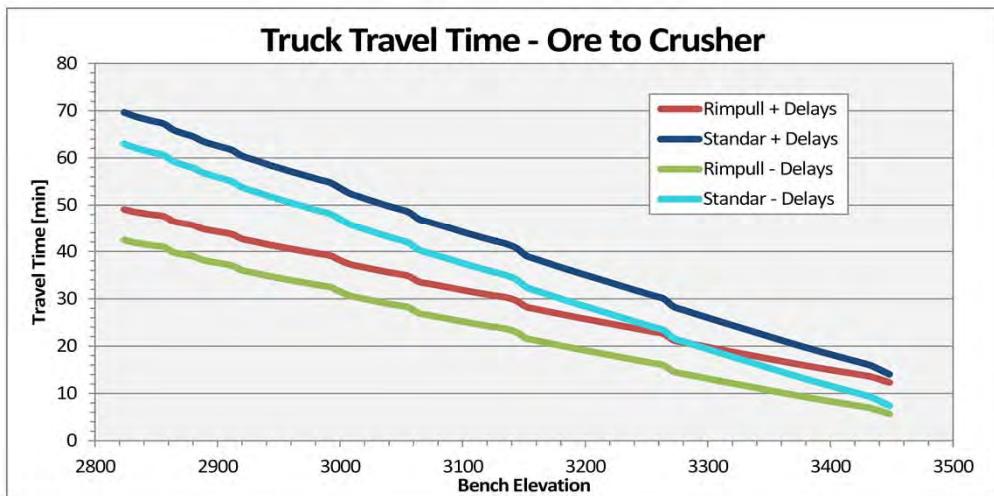
# Route Calculation - Block Model Output Setup



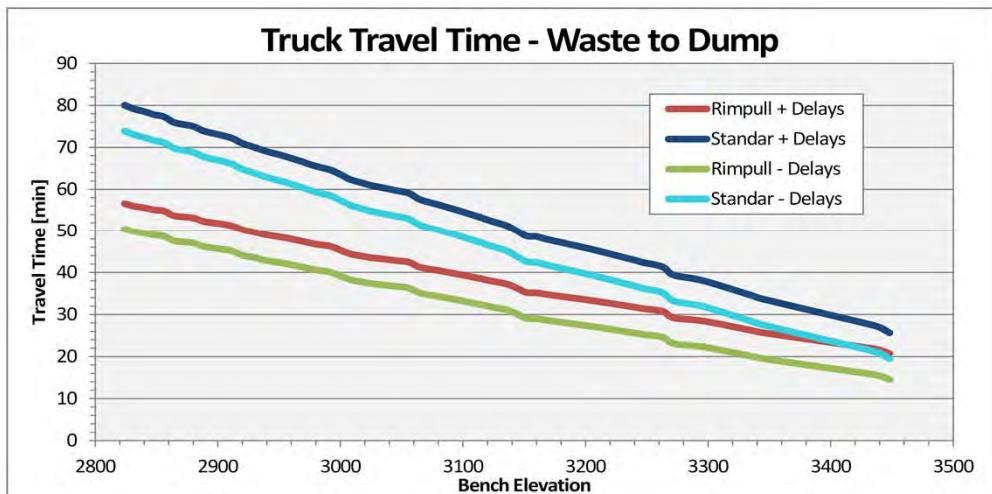
# Route Calculation - Reporting Setup



## Cycle Time Calculations - Standard vs Rimpull



## Cycle Time Calculations - Standard vs Rimpull



Functionality	Vulcan 8.2.1	Vulcan 9
Cycle time calculations using standard speed curves	✓	✓
Cycle time calculations using rimpull/retarding curves	✗	✓
Apply start-up delays at truck start	✓	✓
Apply start-up delays to return trip	✗	✓
Fill in the information from CSV (speed and/or rimpull)	✗	✓
Plot the speed and/or rimpull in a graph	✗	✓
Digitise routes from origin to destination	✓	✓
Digitise segments to be shared with common routes	✗	✓
Predefined routes to use later on	✗	✓
Add block model variables 'on the fly' to store the results	✗	✓
Avoid straight lines from block centroid to ramp exit	✗	✓
External executable (exe) to run multiples scenarios at once without selecting routes from screen	✗	✓

## New Vulcan Haulage Profile

- Increased productivity
- Greater accuracy
- Better user experience
- And just a bit of homework for the next version...

Haulage Profile in Vulcan 9 reduces the number of clicks in every operation and provides an external program to generate automatic process.

The new algorithm for C-bench and the inclusion of rimpull and retarding curve tools provides more precise calculations.

Greater accuracy doesn't mean less truck units, it means more confidence in the calculations.

The user can predefined routes and use later on, without needing to recreate all the routes (just using segments) and avoid selecting routes every time.

In the future, allowing users to add more than one retarding curve will provide a better representation of the different road segment lengths.