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Phil Hammon - Shale Mine Cableway

Customer **Phil Hammon**

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Date first issued			signature	
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Revision		
Prel	13/11/2020	Preliminary issue
1	15/12/2020	Original issue
2	15/07/2021	Brake on return sheave added. Return wheel was dia 1500. Rope was 9mm, 30kN MBF0.3kg/m Bucket spacing was 103m. Separate calculations with and without brake added. Double drive wheel and 4 part sheave block add to the tensioning systrem.

Note -
Phil Hammon (of Scenic world) is writing a book on the history of coal in the Jamison valley. The research was originally confined to the coal railway originally bringing coal up from the valley floor directly below the present "Scenic World", which is now the tourist attaction. The research now extended to two other Hauling systems operating in the vicinity.

1. An overhead Cableway, going right down into and across the floor of Jamison Valley to a shale mine at the base of Mt Solitary.

2. A "tramway", going from the processing plant at the site of the present Scenic World, across the plateau toward Katoomba, to the main State Railway, to transport product to the ports at Sydney.

The calculations below are for the first item, the suspension cableway into Jamison Valley. This consisted of two suspension rope joined by fixed steel loops at each end, AND a continuous loop haul rope.
The buckets were suspended from a trolley frame, with two wheels rolliing on the suspension rope. Part of this trolley frame contained facility for a "rope clip" that could be engaged onto the Haul Rope.

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35 Meadow Rd
Springfield NSW 2250

The cableway decended from the coal plant (at "Scenic World"), down to the valley floor, across the river, then ascended back up to the mine at the base of Mt Solitary. A major problem to be resolved was to establish whether a brake was required to prevent the loaded buckets from the mine down to the river from running-away. and to explain how the suspension rope was prevented from lifting off the towers at the river crossing.

Contents

Ian D'Arth
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1 Input Data

1.1 Load Conditions

Refer to Spreadsheet "Copy of Bleichart.xls" on USB stick

	kg	kN
Bucket Empty mass	208	2.04
Payload	350	3.43
Total	558	5.47
Bucket spacing		140 m
Total number of buckets		See 2.1.1.4 below

1.2 Haul Rope Information

Refer to Spreadsheet "Copy of Bleichart.xls" on USB stick

Rope specific mass	1.4 kg/m	
Breaking load	156.5 kN	**15.7** Tons
Approx equivalent	19mm 7x7 (6/1)grade 1240MPa (80tsi)	

1.3 Suspension rope information

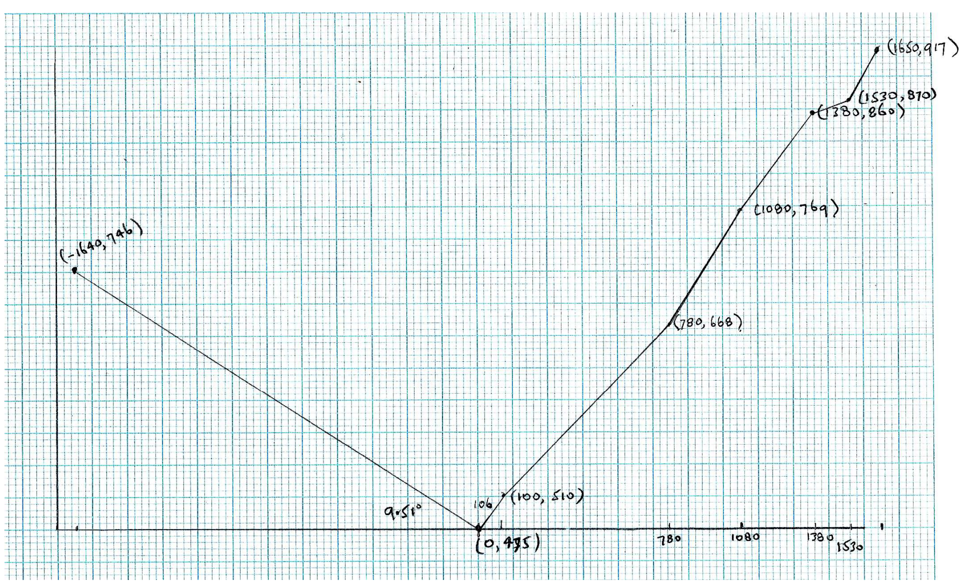
Loaded side

Dia	33.0 mm
Specific weight	5.0 kg/m
MBF	305.0 kN

Empty side

Dia	28.0 mm
Specific weight	3.6 kg/m
MBF	219.0 kN

See Sketch by Phil 5/10/2020



1.3.1 Discrepancies in information

1.3.1.1 Phils sketch

Phil does not give the Distance cordinate for the creek to the mine, only the RL and the chaina

RL at mine	746	m
RL at creek	475	m
Difference	271	m
Chainage	1660	m
Thus, horizontal dist	1638	m

	RL	RL	Diff	Dist	Dist	Diff
Scenic world down to creek	919	475.0	444.0	0	1662	1662
Creek up to mine	746	475.0	271.0	1662	3270	1608

Angles (Phils sketch)	RL	Dist	Angle
Scenic world to creek	444.0	1662	15.0
Creek to mine	271.0	1608	9.6

1.3.1.2 Profile data from excel file Bleichart11

Various different sheet have slightly different data, so for reference here the sheet "Profile" has been used

Coordinates		
Scenic world	1.0	931.7
Creek	1622.0	432.0
Mine	3270.0	768.3

	RL	RL	Diff	Dist	Dist	Diff
Scenic world down to creek	931.7	432.0	499.7	1.0	1622.0	1621
Creek up to mine	768.3	432.0	336.3	1622.0	3270.0	1648

Angles (Sheet "profile")	RL (m)	Dist (m)	Angle
Scenic world to creek	499.7	1621	17.1
Creek to mine	336.3	1648	11.5

1.3.1.3 Data used in the calculations below

The data on sheet "Profile" is quite old (2012?), so it is probable that Phil has more current data, so his data was used

Section	Vertical	Horizontal	Slope	Chainage
Scenic World down to creek	444.0	1662.0	15.0	1720.3
Creek back up to shale mine	271.0	1608.0	9.6	1630.7
		3270.0		3351.0

Vice Versa for the return trip

Change in angle at creek = 180-(Slope1)-(Slope2) 155.5 degrees

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1.4 Tower Information

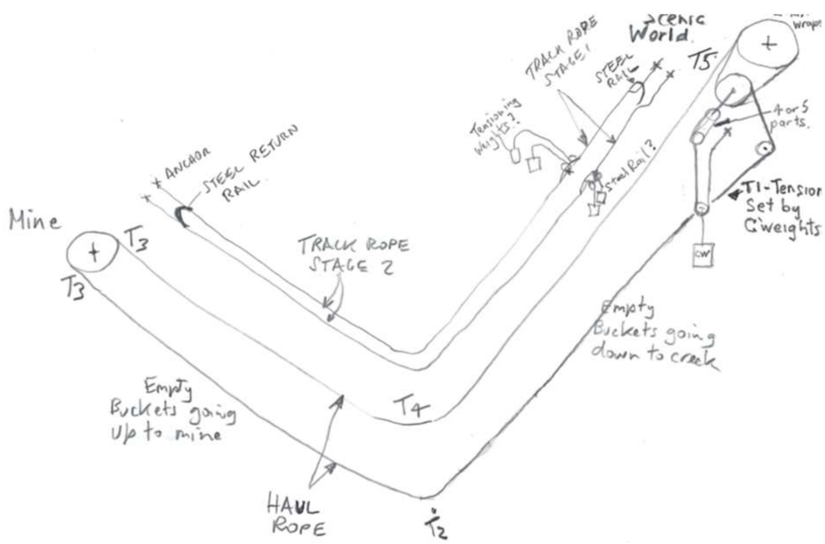
Total number of towers (see Bleichart11.xls)	46	towers
Total horizontal dist	3270.0	m
Thus average tower spacing	72.7	m (horizontal)

This is average, apparently the span at the creek was 250m

i.e. Towers down to creek	23
Towers up to mine	22
	45

1.5 All Ropes Configuration

The diagram below represents the configuraton of the rope.



1.6 Frictional constants

Effective friction at each bucket	0.03
Friction of rope on drive pulley	0.30

1.7 Speeds and Acceleration rates

Operating speed	3.0	mph	Guess
Assumed operating speed	1.34	m/sec	

1.8 Brake on Haul Rope Return Sheave.

Diameter of return sheave	2031	mm	was 1500

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Diameter of Brake path		150	mm	Guess	
Number of wraps of hemp rop	7.2	6.0			3
Coefficient of friction		0.1			
Counterweight		300	kg		
Conver to kN		2.9	kN		

2 Calculations - Haul rope

2.1 Weights being hauled

Simplify the path into 4 simple sections
- empty buckets down to the river
- empty buckets from the river to the Mt Solitary Mine
- Full buckets from the mine down to the river
- Full buckets up from the river to the Scenic World site.

2.1.1 Sample calculation of weights per meter (Segment 1)

2.1.1.1 Empty Buckets down to creek

Length of path (See 1.3.1.3)	1720.3	m
Spacing of buckets (See 1.2)	140.0	m
Thus number of buckets	12.3	buckets
Mass of empty buckets (See 1.1)	2.04	kN
Thus , Weight of buckets	25.07	kN

2.1.1.2 Haul Rope

Length of path (See 1.3)	1720.3	m
Specific weight of rope (See 1.2)	1.4	kg/m
Thus, Weight of Haul Rope	23.12	kN

2.1.1.3 Friction

Note - Buckets moving on the catenary rope, RATHER than a running rope that travels over the towers.

Weight of loaded bucket (See 1.1)	5.47	kN
Friction factor (See 1.6)	0.03	
Thus, friction force per bucket	0.16	kN

2.1.1.4 Number of buckets per segment

Spacing of buckets (See 1.1) 140 m

Segment	Length m	No of buckets
Top to river, empty	1720.3	12.3
River to mine emp	1630.7	11.6
Mine to river full	1630.7	11.6
River to top, full	1720.3	12.3
Total	6701.9	47.9

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2.1.2 Tabulate weights for each segments

This tabulation ia following the same method as Clause 2.1.1)

Segment	Length	Ave slope	Rope weight	Bucket weight	Total	At incline
	m	deg	kN	kN	kN	kN
Top to river, empty	1720.3	14.96	23.12	25.07	48.19	12.44
River to mine emp	1630.7	9.57	21.92	23.77	45.68	7.59
Mine to river full	1630.7	9.57	21.92	63.76	85.68	14.24
River to top, full	1720.3	14.96	23.12	67.26	90.38	23.33

2.2 Tabulate Friction per segment

Friction per bucket (See 2.1.1.3) 0.16 kN
Bucket Spacing (See 1.1) 140.0 m
Friction per segment = length of the segment/bucket spacing*friction per bucket

	Length (m)	No of buckets	Friction load (kN)	
T1, Pre-tension from Counterweight (Ref)				
T2. At creek, unloaded side	1720.3	12.3	2.02	Haul r
T3 (Haul side, at mine sheave)	1630.7	11.6	1.91	
T3 (empty side, at mine sheave)	0.0	0.0	0.00	
T4. At creek, Loaded side	1630.7	11.6	1.91	
T5. At drive pulley, pulling up from creek	1720.3	12.3	2.02	
		47.9		

2.3 Consider the performance WITHOUT return sheave brake

2.3.1 Tensioning Counterweight without brake

The "reference" tension T1 is the tensioning device, at Scenic World, on the side down to the creek

The device must provide tension GREATER than the weight of the empty bucket and rope for this first segment down to the creek, but it must also ensure that T2 at the creek is enough to prevent the loaded buckets from the mine to the creek from causing run-away.

Weight of buckets and rope down to creek (See 2.1.2) 12.44 kN (incline comp
Thus tension T1 , allow a 15 % margin 14.30 kN
(i.e. For reference, Counterweight mass (T1x2) 28.61 kN)

2.3.2 Tabulate the net final tensions without brake

See clause1.5 for the location of the various tensions

Consider the following tensions

T1	At the drive pulley, at the top station, lowering empty buckets
T2	At the river, unloaded side
T3	At the mine return sheave (both the loaded and unloaded sides equal)
T4	At the river, loaded side
T5	At the drive pulley, at the top station, pulling loaded bucket up.

See (2.1.2) for the weights added or subtracted
See (2.2) for the Friction added per segment
The brake on the return wheel is set to 0 kN (at perimenter) (No Brake)
Positive weights are resistive (lifting), -ve is regeneration
Friction is always resistive.

	Weight added (kN)	Friction kN	Tension kN	
T1, Pre-tension from Counterweight (Ref)			14.30	kN (See 2.3)
T2. At creek, unloaded side	-12.44	2.02	3.88	kN
T3 (Empty side, at mine sheave)	7.59	1.91	13.39	kN
T3 (Firction force from return wheel brake)		0.00	13.39	kN
T4. At creek, Loaded side	-14.24	1.91	1.06	kN
T5. At drive pulley, pulling up from creek	23.33	2.02	26.41	kN

2.4 Consider the performance INCLUDING a return sheave brake

2.4.1 Tensioning Counterweight with brake

The "reference" tension T1 is the tensioning device, at Scenic World, on the side down to the creek

The device must provide tension GREATER than the weight of the empty bucket and rope for this first segment down to the creek, but it must also ensure that T2 at the creek is enough tc prevent the loaded buckets from the mine to the creek from causing run-away.

Weight of buckets and rope down to creek (See 2.1.2)	12.44	kN (at incline)
Thus tension T1 , allow a 5 % margin	13.06	kN
(i.e. For reference, Counterweight mass (T1x2)	26.12	kN)

2.4.2 Tabulate the net final tensions with brake

See sketch at clause 1.5 for nonclamenture

Consider the following tensions

T1	At the drive pulley, at the top station, lowering empty buckets

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T2	At the river, unloaded side
T3	At the mine return sheave (both the loaded and unloaded sides equal)
T4	At the river, loaded side
T5	At the drive pulley, at the top station, pulling loaded bucket up.

See (2.1.2) for the weights added or subtracted
See (2.2) for the Friction added per segment
The brake on the return wheel is set to 5 kN (at perimenter)
Positive weights are resistive (lifting), -ve is regeneration
Friction is always resistive.

	Weight added (kN)	Friction kN	Tension kN	
T1, Pre-tension from Counterweight (Ref)			13.06	kN (See 2.4)
T2. At creek, unloaded side	-12.44	2.02	2.64	kN
T3 (Empty side, at mine sheave)	7.59	1.91	12.14	kN
T3 (Firction force from return wheel brake)		5.00	17.14	kN
T4. At creek, Loaded side	-14.24	1.91	4.82	kN
T5. At drive pulley, pulling up from creek	23.33	2.02	30.16	kN

2.5 Brake Details on Haul rope return sheave

The aim for the brake is to minimise tension T2, to avoid uplift at T2 (creek emty side)
However, all of the brake torque is additived to T4, and therefore also to T5 (final drive)
Even with no brake, T5 would be close to 30kN (the given breaking load for the rope)

Brake is a full "self-applying" type, with one band going from anchor to counterweight

P = tangential force on wheel		
T_1 = Force supplied by counterweight	1.0	kN
υ = coefficient of friction	0.4	
α = Angle of wrap	270	deg
Convert to radians	4.71	radians
Thus $e^{\upsilon\alpha}$ =	6.59	
$P=T_1(e^{ua}-1)$		
Thus P (tangential braking force on wheel perimeter)	**5.59**	kN
Required perimeter force (See 2.3.2)	5.00	kN
Thus **5.59 kN >**	**5.00**	**kN Ok**

2.6 Drive Pulley

From 2.3.2

T1, Pretension from counterweight	14.30	kN
T5. Tension to pull load up from creek	26.41	kN
Thus T5/T1 =	1.85	
Drive Pulley friction (See 1.6)	0.3	
Wraps around drive pulley	0.5	turns
Convert to radians	3.14	radians

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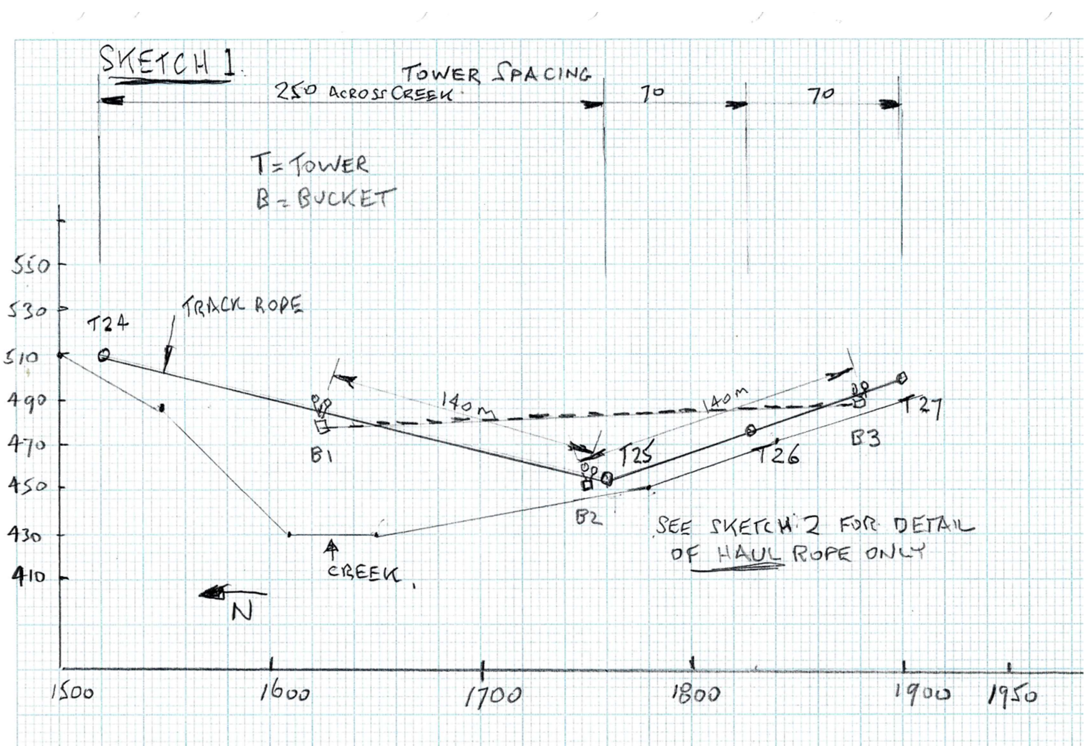
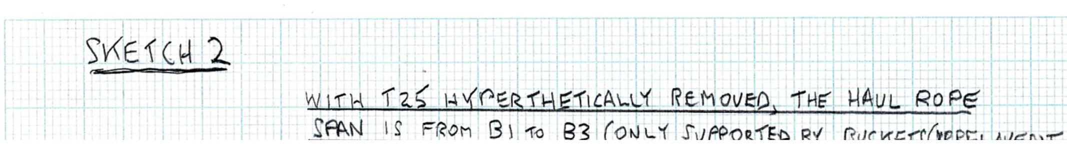
Thus $e^{\mu\theta}$ 2.57

Thus **1.85 <=** **2.57 Does not Slip**

2.7 Consider possible up-lift at the creek, un-loaded side
Haul Rope fully supporting centre bucket

- The section between T24 and 27 was considered, with an empty bucket positioned at T25 (first tower south of the creek). This puts a bucket in the T24-T25 span (at roughly 50% along from T24), and a bucket Mid-span T26-T27, almost at T27 (see Sketch 1)
- The reason for this is that T25 is the lowest point, and therefore the position where uplift might be a problem.
- The sag of the track rope is not included in the analysis. Any track rope sag improves the situation. (puts the start and end of the Haul rope catenary to a lower point)
- If we now consider "1" span of the HAUL rope to be from the bucket 50% down T24-T25 at one end (B1), and the T26-T27 bucket at the other end (B3)(see sketch 2)
- i.e. Hyperthetically removing the tower T25, Bucket B2 becomes the point load in the centre of the span.





Ian D'Arth
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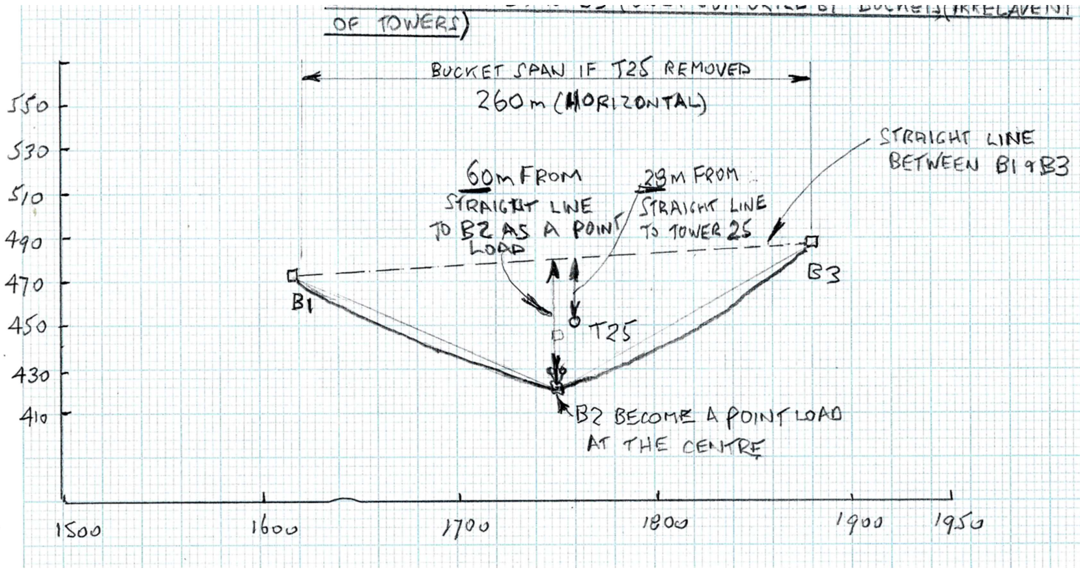

Spacing of buckets (See 1.1)	140	m
Thus, Haul rope span, no centre bucket	280	m
Horizontal span (See Sketch 2)	260	m
Rope tension T2 at the creek (See 2.3.2)	3.88	kN
Empty bucket weight (See 1.1)	2.04	kN
Sag (from "HaulRopeCatenary.xlxs")	60	m (see Sketch 2)

If the tower T25 is then reinstated,

Distance from taut wire to T25	28	m (see Sketch 2)

i.e. If the Haul rope alone was fully supporting the bucket, it would sag
60 m, however, the track rope at tower T25 is holding it at 28 m, so the track tower is holding the rope up (rather than the rope liffing off.).

Note from clause	2.3.2	gives a T2	3.88	kN with no brake
from clause	2.4.2	gives a T2	1.91	kN with 5 kN braking Force

Thus, by using the brake, T2 becomes less, the sag becomes more, and tower 25 has to lift it even further

2.8 Production Rate

Rope Speed (See 1.7)	1.34	m/sec
Bucket Spacing (See 1.1)	140	m
Thus bucket rate into unloading station	104.4	sec
Bucket Payload (See 1.1)	3.43	kN
Thus , production rate	118.4	kN/hr
Convert to tonnes	12.1	Tonnes/hr

(transfer times, empty and filling times to be added)

2.9 Power Required

Rope Speed (See 1.7)	1.34	m/sec
Pulley Diameter (See 1.8)	2031	mm
Thus, pulley speed	12.6	rpm
Convert to rad/sec	1.32	rad/sec
T5, full buckets up (See 2.3.2)	26.41	kN
T1, Tensioner setting (See 2.3.2)	14.30	kN
Thus, torque required	12.3	kNm
Power required (T.ω)	16.2	kW
Convert to HP	21.8	HP

3 Calculations - Track ropes

3.1 Empty side, at creek

Refer to separate Catenary spread sheet J21004-CablewayCatenary
The longest span is between T24 and T25, but this is also a point where there is plenty of clearance below the track rope (over the creek)

Arbitarily position the bucket trolleys such that there is a trolley at T25
This puts a trolley near T24, one mid span T24-T25, one at T25, and the next one roughly midspan T26-T27

3.1.1 Span T26-T27

Because of the proximity to the ground, the T26-T27 span is going to be more critical

Span T26-T27			70	m
Point Load (Empty Bucket) (See 1.1)			2.04	kN
Convert to kg			208	kg
Sag			1.5	m
Rope tension			43	kN
Rope MBF (28mm) (See 1.3)			219.0	kN
Thus	**43.0**	**kN <**	**219.00**	**kN Ok**
Rope F of S			5.1	: 1

3.1.2 Span T24-T25

T24-T25 has the longest span

Span T24-T25			238	m
Point Load (Empty Bucket) (See 1.1)			2.04	kN
Convert to kg			208	kg
Sag			8	m
Rope tension			47	kN
Rope MBF (28mm) (See 1.3)			219.0	kN
Thus	**47.0**	**kN <**	**219.00**	**kN Ok**
Rope F of S			4.7	: 1