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RAILWAY CONSTRUCTION NOTES.

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(To be read before General Section, April 15, 1909.)

This paper is compiled from notes made by the writer whilst Resident Engineer of Construction for the Canadian Pacific Railway Grade Reduction and Revision, Medicine Hat Section, 1907-8.

It is submitted primarily with a view to elicit the practice of the profession with regard to shrinkage and overhaul, and the discussion on points raised herein, the author trusts, will be of greater value than the paper itself.

Shrinkage.—The first question that comes up in this connection is, "What is the contractor to be paid for?"

On prairie work, when light, embankment quantities are often taken, and, considering the practical impossibility of accurately measuring shallow borrow pits, as left by the generality of contractors and sub-contractors, it would seem to be the most accurate method.

If, however, work is paid for from cut quantities, to be rational, all borrow pits must be staked and measured. The practice of paying for cuts up to limit of haul and balance on embankment quantities is not logical.

In the case of excavation quantities, the question of shrinkage is not a live one with the contractor, but the reverse is the case when embankment is paid for.

A method of applying shrinkage is required to be sufficiently elastic to meet the variety of conditions met with in the field, and at the same time sufficiently exact to do justice as between the company and the contractor. This question is often a bone of contention between them on account of the magnitude of the quantities involved being overlooked.

On side-hill ground, and when cuts and fills alternate rapidly, and are of considerable extent, the theoretical shrinkage, if applied on top, would lead to anomalous conditions. When track laying has closely followed construction, cases are not unknown where the top shrinkage applied has had to be removed, or where, as illustrated in Fig. 4, the shrinkage, if not immediately taken up by settlement, might exceed the permissible grade.

Fig. 1

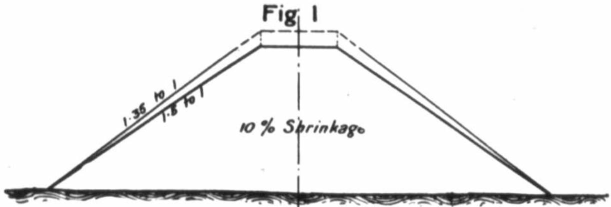


Fig. 2

Fig. 3

From these considerations it would appear reasonable to omit raising the fill above profile grade and applying side shrinkage only to make a full shoulder so as to carry the material required to make up to grade as bank settles.

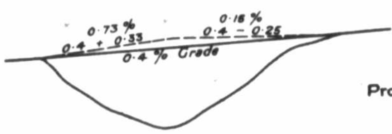
Fig. 1 shows the usual method of applying shrinkage, whilst Figs. 2 and 3 show modifications of this method according as to whether or not excess quantities are permissible, or whether or not it is thought desirable to steepen the side slopes.

Setting the slope stakes 1.3, 1.4, 1.6 or 1.7 to 1 instead of the customary 1.5 to 1 is easily done in the field by adding or subtracting 1/10 or 2/10 for every foot in height of fill to the 1.5 to 1 half breadths.

Tables 1, 2, and 3 are inserted for purposes of comparison; the quantities being based on these different methods of applying shrinkage (figured to profile grade only) whilst the actual percentage increase from the standard roadbed and side slopes, is stated.

To provide the full shoulder (always desirable), the width required at profile grade from considerations of height of fill at that point (fig. 4) is taken, reduced for practical purposes to the nearest foot and slope stakes set in accordance with Fig. 2 or 3.

Fig. 4



(I) Profile

(II)	·33	·67	1·0	1·33	1·67	2·0	2·0	1·75	1·5	1·25	1·0	·75	·5	·25	Top Shrinkage
(III)	17·0	18·0	19·0	20·0	21·0	22·0	22·0	21·25	20·5	19·75	19·0	18·25	17·5	16·75	Width at Profile Grade from Top Shrinkage
(IV)	6	10	14	16	18	20	20	17	15	12	10	5	2	1	Height of Fill.
(V)	17·8	19·0	20·2	20·8	21·4	22·0	22·0	21·1	20·5	19·6	19·0	17·5	16·6	16·3	Width at Profile Grade from Height of Fill
(VI)	18	19	20	21	21	22	22	21	21	20	19	18	17	16	Practical Width at Profile Grade used in Cross sectioning as per Fig. 3, or in figuring quantities and setting second grades as per Fig. 2.

Note discrepancy between III and V.

This representation in the cross section notes of the quantities to profile grade represents the cross sections as they are staked without additions or alterations, and avoids complication and consequent chances of error in figuring the quantities. It gives a definite and straightforward basis to work on, and enables another man to pick up one's notes and follow what has been done.

In paying for embankment quantities if an arbitrary classification of shrinkage is adopted, such as:

Team and slip work	*Nil*
Wheeler and wagon work.	5%
Dumpcar and wheelbarrow...	10%

and from a consideration of the fact that earth, when first moved by these several methods, expands about that same percentage, it would appear that the old expedient of putting on shrinkage and paying for neat embankment quantities is not very wide of the mark after all.

TABLE No. 1.

Fill Ht. in ft.	Slopes	R.B.	Cubic yds.	5% Fig. 1 Cub. yds.	Slopes	Actual %	10% Fig. 1 Cub. yds.	Slopes	Actual %
10	1.5	16	1148	28	1.425	2	55	1.35	5
20	1.5	16	3407	111	1.425	3	222	1.35	6
30	1.5	16	6778	250	1.425	4	500	1.35	7

TABLE No. 2.

Fill Ht. in ft.	Slopes	R.B. for setting stakes	R.B. used in figuring X sect.	Cubic yds.	Nominal shrinkage 5%—Fig. 2 Cub. yds.	Actual percentage increased quantities over a 16' roadbed 1.5—1
10	1.6—1	16	17.5	1185	30+ 37= 67	6%
20	—	—	10	3555	118+148=266	8%
30	—	—	20.5	7111	266+333=599	9%
					10% Fig. 2	
10	1.7—1	16	19	1222	63+ 74= 137	12%
20	—	—	22	3703	252+296= 548	16%
30	—	—	25	7444	566+666=1232	18%

TABLE No. 3.

Fill	Slopes	R.B. for X section and setting stakes	Cubic yds.	Nominal shrinkage 5% Fig. 3 Cub. yds.	Actual percentage increased quantities over 16' roadbed 1.5—1
10	1.4	17.5	1166	18	1%
20	—	19.0	3481	74	2%
30	—	20.5	6944	166	3%
				10% Fig. 3	
10	1.3	19	1185	37	3%
20	—	22	3555	148	4%
30	1.3	25	7111	333	5%

Overhaul.—Here, again, the first question that arises is, "What is the contractor to be paid for, theoretical or actual overhaul?"

If paid for actual overhaul, it often happens that through some extraneous conditions as, for instance, down-hill haul, by the method of handling the work, or perhaps on acount of a structure not being built in time, the most economical distribution of the material, from the company's point of view, is not followed out.

When, however, the material expands considerably, as in a rock cut, the contractor would get the worst of the bargain unless the actual haul is used.

Another point in connection with the actual haul made by contractor is the case where borrow is made between two hauls; generally this borrow is put in by slip work, all in the bottom of the fill, and the actual haul made difficult of determination without elaborate figuring and close watching of the work, as the two hauls close on completion, and is often impossible under these circumstances.

In this case it is necessary to give the theoretical overhaul, unless, in cases of rock, when the method shown in Fig. 5 should be used, assuming some equitable percentage of expansion as found by measurements or taking actual haul.

Fig. 5 illustrates the method (which is self-explanatory) of figuring expansion in overhaul.

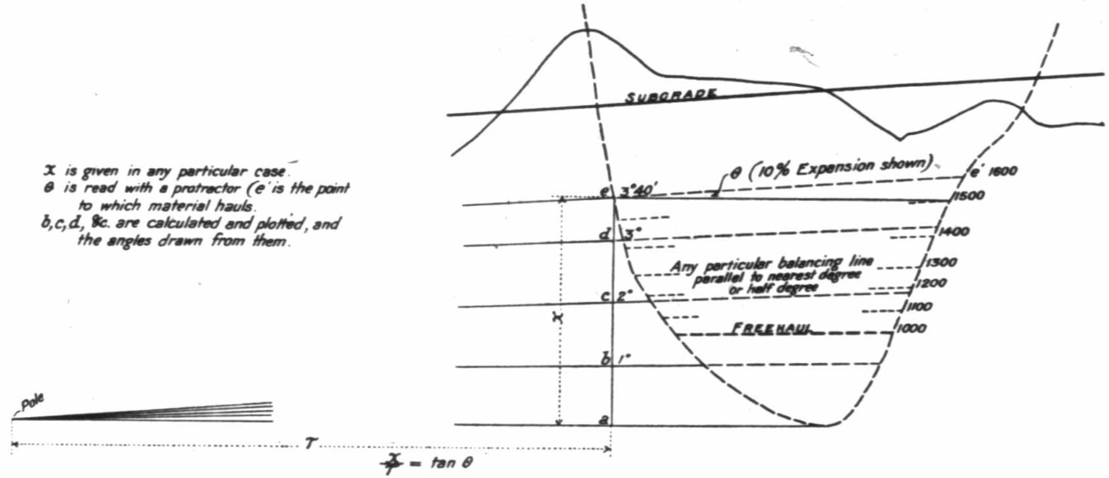
Fig. 6 is a typical cut hauling both ways, and serves to illustrate some of the points raised, but on account of the small quantities of overhaul, does not bring out very forcibly the discrepancies in the various methods of calculating.

From this figure it is evident that the c.g. of cut is not the most economical distribution point, but the point that such a cu. yd. can be hauled either way at the same cost is the point wanted.

Considering the many assumptions necessary in preparing the overhaul diagram on account of shrinkage and expansion, it would appear that the large scale diagrams are not offset by increased accuracy sufficiently to warrant their use, and that a diagram on the field profile (Fig. 6) will give the information to as great a degree of accuracy as the method warrants, besides being always available for giving the contractor his points for distribution of material on the ground.

By using the planimeter various methods of distribution can be easily computed. Set the index to read square inches and ascertain the area of diagram under balancing line drawn in accordance with the method noted above. This, multiplied by the proper factor according to scale (Fig. 6—2000 cu. yds. to 1" and 400 ft. to 1" = 8000 cu. yds.) gives the total yards hauled to 100 ft. Ascertain area of free haul, and to this add the number of cubic yards hauled 10 stations. Subtracting these two from the whole area of diagram gives the pay overhaul.

With a small outfit, without variety of equipment, it often pays the contractor to waste and borrow (freehaul limit, 1000 feet) rather than haul, the extra price for overhaul enabling him to do this. Care must be exercised, or one is apt to pay him for material wasted at his own expense.



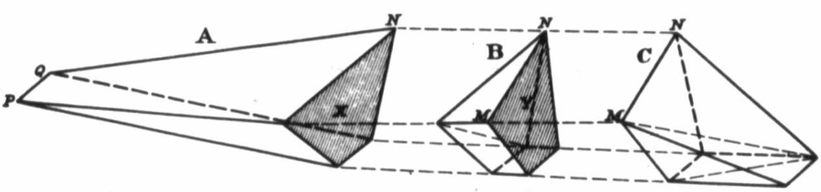
X is given in any particular case.
θ is read with a protractor (e' is the point to which material hauls.
b, c, d, &c. are calculated and plotted, and the angles drawn from them.
Pole
T
X/T = tan θ
SUBGRADE
θ (10% Expansion shown)
e' 1600
1500
1400
1300
1200
1100
1000
e 3°40'
d 3°
c 2°
b 1°
a
X
Any particular balancing line parallel to nearest degree or half degree
FREEHAUL

Fig. 5.

Road Crossings.—These, although relatively unimportant, yet having to be established on prescribed lines and at regular intervals, often occur in places where the quantities involved are considerable. Also as they frequently cross the roadbed at an oblique angle, a method of figuring them may be of service, although open to criticism from its being an approximation only.

Figs. 7 and 8 show a road crossing on a skew. M. N. P. Q.,

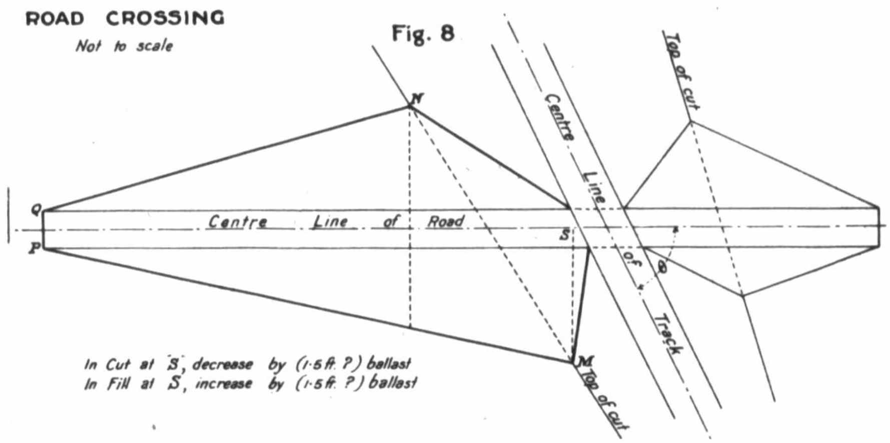
Fig. 7



ROAD CROSSING

Not to scale

Fig. 8



are the most important points to establish on the ground. P. and Q. should be laid out to give the requisite grade on road crossing between P.—Q. and the point S., otherwise the grade has to be steepened. Although a detail, this is often overlooked.

A (Fig. 7) is calculated from ordinary cross sections. Area of

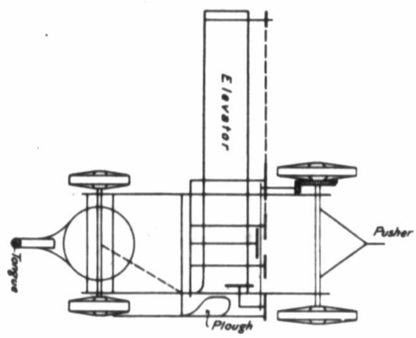
$$Y = \frac{\text{Area } X}{\cos \theta}$$

B (Fig. 7) can be divided into two truncated triangular prisms, whose solidities are given by the following formulae: Area of right section $\times \frac{1}{3}$ sum of lateral edges.

C (Fig. 7) can be divided into pyramid and tetrahedron:

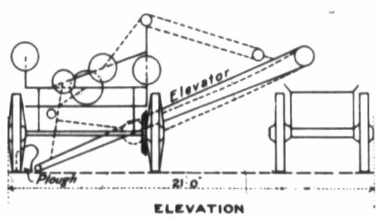
$$\text{Solidity of Pyramid} = \frac{\text{Area } X}{\cos\theta} \times \tfrac{1}{3} \text{ (half breadth} - \tfrac{1}{2} \text{ roadbed)}$$

$$\text{Solidity of Tetrahedron} = \tfrac{1}{3} \text{ depth at M} \times \text{(half breadth} - \tfrac{1}{2} \text{ roadbed)} \times \tfrac{1}{2} \text{ roadbed of road crossing.}$$



PLAN

Fig. 9



ELEVATION

Fig. 10

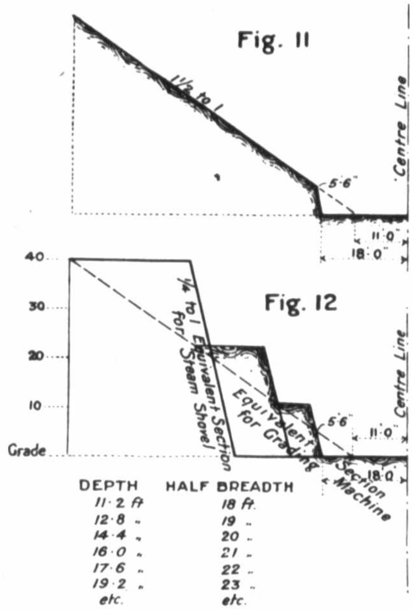
Grading Machines.—Figs. 9 and 10 are diagramatic plan and rear elevation of a grading machine, manufactured in Chicago.

This machine requires 42 ft. to work in, but has a 3 ft. extension section on the elevator, so that when required, this can be removed, making it capable of working in a 36 ft. cut. With sand or loose material, however, the extra height to which the elevator has to be raised to properly clear wagons, exceeds the workable angle of repose of the material, and it refuses to elevate.

With the short elevator the cut requires to be taken down very uniformly, or the wagons catch on the underside of elevator, even when used with one side board removed.

Working in a 36 ft. cut with a full length elevator, about 6 furrows in the centre have to be thrown to the sides of cut and rehandled at a disadvantage, as the loose material will not throw a good furrow and is, besides, in the way of the wagons.

On the Medicine Hat section, in order to give the required width for these machines to work in, cuts were staked, as shown



in Fig. 11, and in the cross-hatched section of Fig. 12. This increased the cut quantities slightly (as in Fig. 12 at ends of cut only), but the material being required in the fill, the overhaul only was increased. This cutting away of the toe of slope would be objectionable, if not impossible, in some instances, but here the banks caved back to a natural slope very quickly.

With six pairs of horses the machine could be turned in 36 ft. by crowding, but to turn quickly more room is required.

With a cut, say, 1232 ft. long, the lost time turning, at 2½ min. per turn, amounts to 1 hour and 30 minutes per day, while the lost time ploughing furrows to waste for the lower 5·6 of cut was two hours. Whilst actually at work a wagon was loaded on an average every 65 seconds, including stop for next wagon. This gives an output for the main part of cut, 404 wagons = 505 cu. yds. per day, and for the lower 5·6, 307 wagons, at, say, 1.25 cu. yds = 384 cu. yds. per 10-hour day, which is a very poor showing for the number of teams required.

Whilst of great service in shallow borrow pit, street grading, and open work of that nature, this machine is all that is claimed by the makers, the writer is of opinion that money can easily be lost by trying to use it where boulders or hardpan are encountered, or where cuts are limited in width. Its chief drawbacks are: Too many delicate parts, frame not heavy or rigid enough, and consequently too much lost time for minor repairs, and as there is usually a big outfit waiting on account of the repairs, a series of short stoppages soon make a big loss.

Steam Shovel Work.—Fig. 12 shows the diagram used to stake cuts for this work, giving equivalent quantities to the roadbed used, viz., 22 ft. slopes 1½—1. It is advisable to stake these cuts to a 1½—1 also, and cut a grip along this line to induce the bank to break back to the correct lines. If this is not done it breaks away in pockets.

Fig. 13 will be found useful in determining what a given size of shovel will do, and enable one to lay out the most economical lifts which should be taken in making a thorough cut.

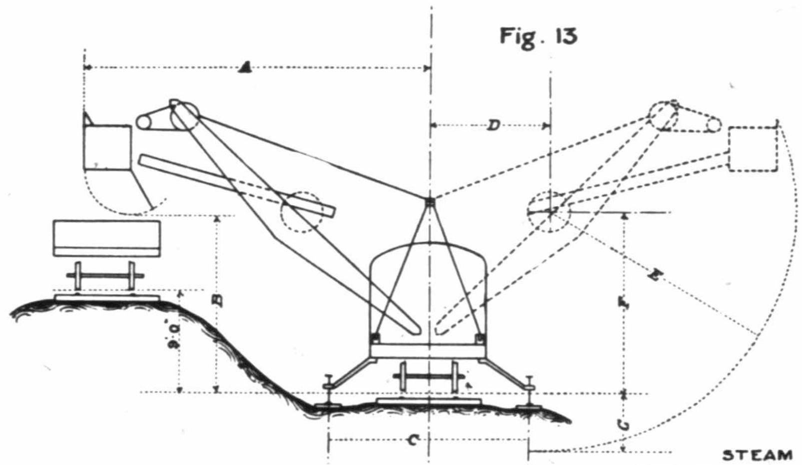
The question of water supply for the shovel, its quality and quantity, should never be overlooked, as it materially affects the cost of the work.

The use of heavier steel than the dinkeys and dump cars call for, is not economical, as it costs too much to move around and handle.

An all around shovel on traction wheels with a 1½ or 2 yd. dipper, and 2½ yd. cars on 30 lb. steel, would often be more serviceable than the heavier types of shovels, where the frequency and distance of moves is considered, and if it could be operated by a gasoline motor to solve the fuel difficulty, an almost ideal machine for railway work would be available.

General Notes.—On deep cuts and high fills it is very convenient for purposes of running fence stakes, etc., to have these set out before ground is broken, as great trouble is experienced in setting them afterwards, particularly around curves.

Fig. 13



STEAM SHOVEL

STEAM SHOVEL DATA

STYLE	A	B	C	D	E	F	G
90 Ton Shovel	31·9	17·0	20·3	10·0	21·9	18·6	3·3
70 " "	30·0	15·0	17·9	9·6	20·6	16·0	4·6
45 " "	26·0	14·0	17·0	7·0	19·0	13·8	5·4

HAUL FROM EQUIDISTANT POINTS

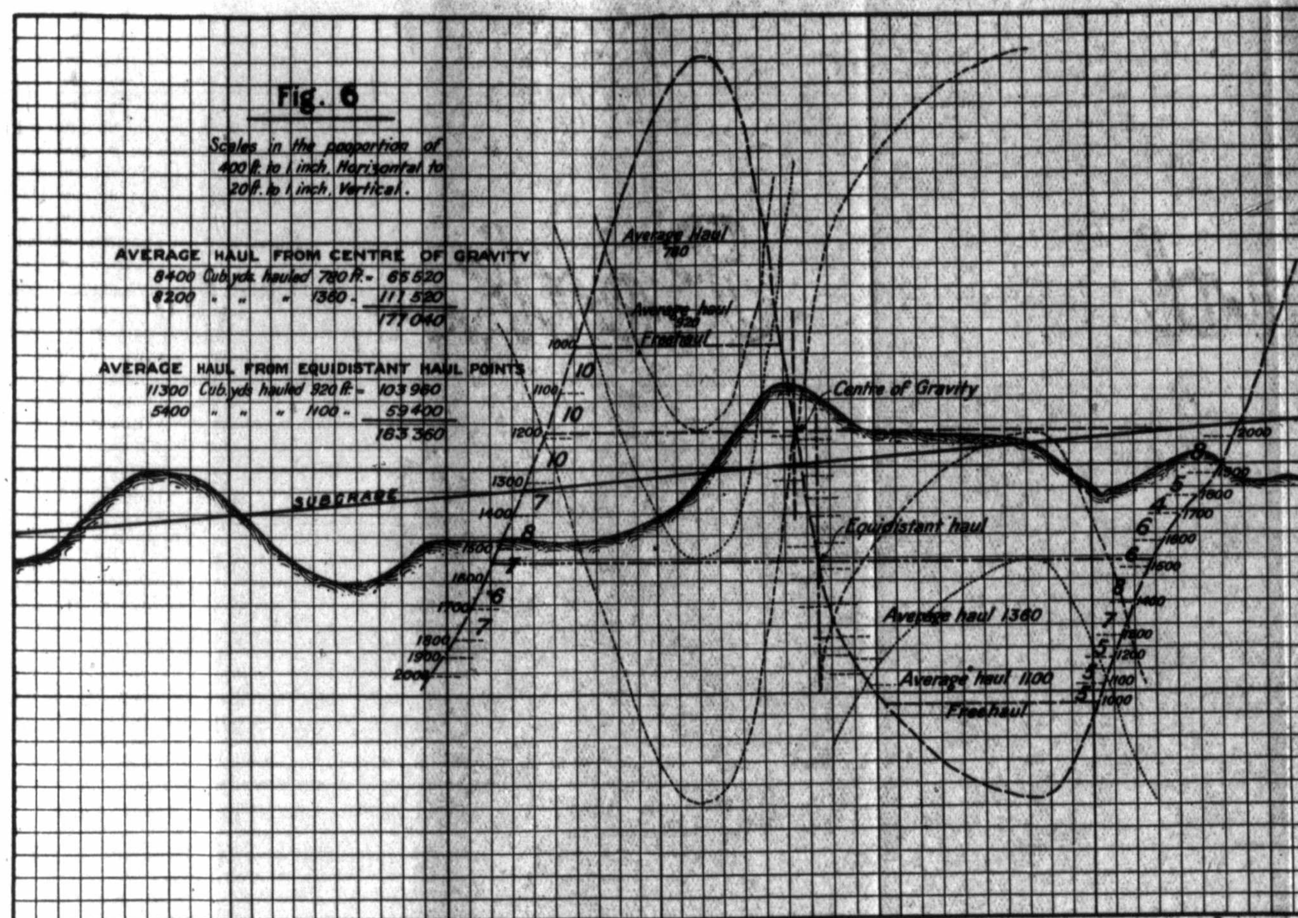
1000	50	500	100
1000	150	1500	"
1000	250	2500	"
700	350	2450	"
800	450	3600	"
300	520	1560	"
4800		12110	

HAUL FROM CENTRE OF GRAVITY

1000	50	500	100
900	145	1305	"
1900		1805	"

FOR COMPARISON

1000	50	500	100
1000	150	1500	"
1000	250	2500	"
700	350	2450	"
800	450	3600	"
700	550	3850	"
600	650	3900	"
700	750	5250	"
6500		23530	



HAUL FROM EQUIDISTANT POINTS

500	50	250	100
500	150	750	"
500	250	1250	"
700	350	2450	"
800	450	3600	"
200	520	1040	"
3200		9340	
		12110	
		21450	

HAUL FROM CENTRE OF GRAVITY

500	50	250	100
500	150	750	"
500	250	1250	"
700	350	2450	"
800	450	3600	"
600	550	3300	"
600	650	3900	"
400	750	3000	"
500	850	4250	"
800	950	7600	"
200	1010	2020	"
6100		32370	
		1805	
		34175	

FOR COMPARISON

500	50	250	100
500	150	750	"
500	250	1250	"
1500		2250	
		23550	
		25800	