Bonneagar Iompair Éireann
Transport Infrastructure Ireland

Sustainable Earthworks – Mass Haul Analysis

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Sustainable Earthworks

Background

Ongoing research to identify opportunities at Phase 2 and 3 for greater consideration of earthworks factors which influence sustainability.

Purpose

A well-considered Mass Haul analysis during the early-stage planning and design can help mitigate ground risks, reduce potential waste, and reduce the need for reactive and less sustainable engineering solutions at subsequent project phases.

Objective & Deliverable

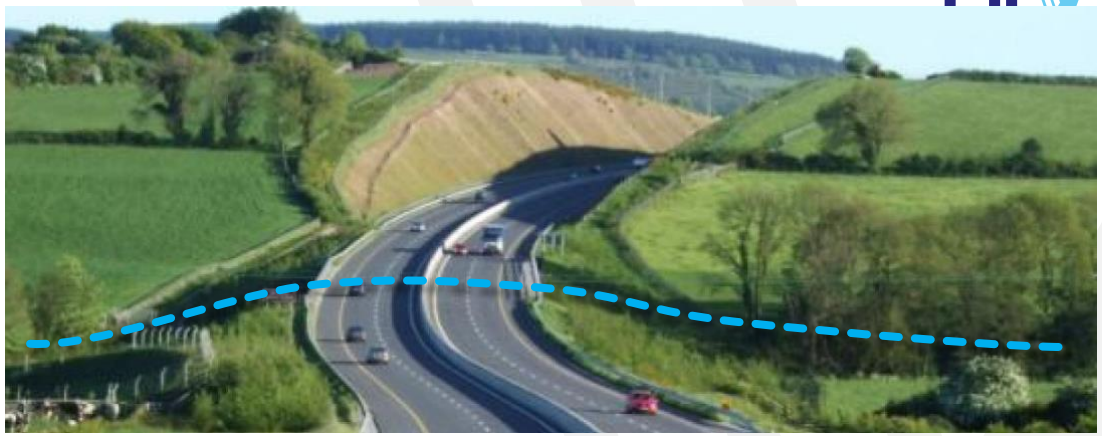
Identify the main principles that influence Mass Haul and develop a tool which would facilitate Mass-Haul analysis at Phase 2 and Phase 3

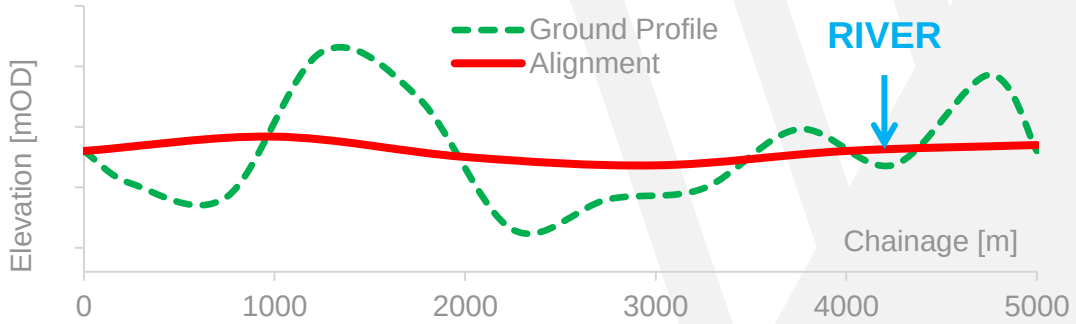
What is Mass Haul in this context?

Basic Definition:
Volume of Material ***x*** Transport Distance

Accurate mass haul is also influenced by the following:

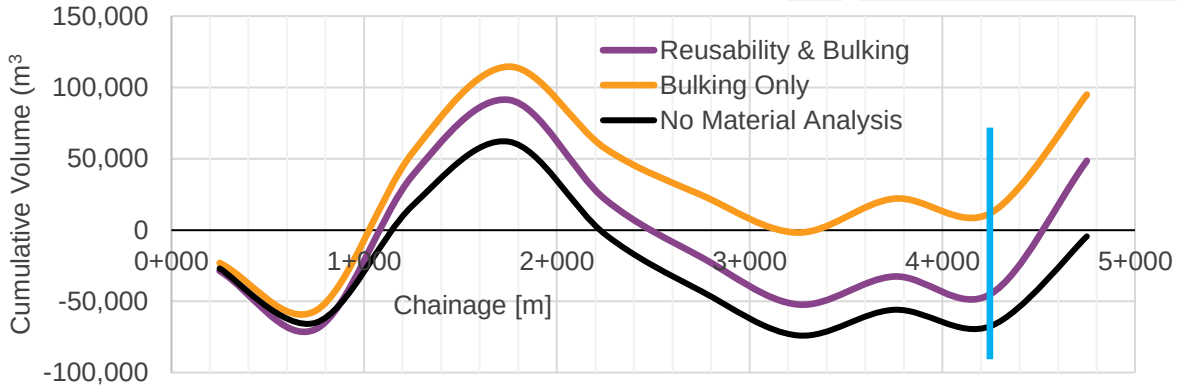
- material classification
- material acceptability
- material value
- source and destination of material
- material handling and construction practices
- haulage constraints
- haulage / extraction equipment
- programme





What is a Mass Haul Diagram?

A **Mass Haul Diagram** is a graphical representation of the material moved and facilitate investigation of material allocation and optimised haulage



What are the benefits of Mass Haul as part of Phase 2 & Phase 3?

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Phase 2 Option Selection Process

- More ***considered comparison*** of options in terms of earthworks
- Optimised earthworks design when options at their ***most flexible***
- Facilitate ***identification of deposition and/or borrow areas*** much earlier in the process
- Increased likelihood of achieving a ***more balanced*** (earthworks) preferred option

Phase 3 Planning Design

- ***Reduced risk of unforeseen ground conditions*** which result in expensive, time-consuming and disruptive engineering solutions
- Allocation and re-use of material at its ***highest value***
- ***Reduces reactive design*** to deal with unbalanced preferred option

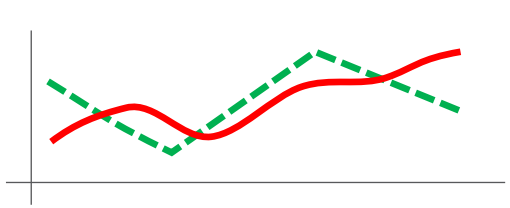
Phase 4 Statutory Process

- ***Quantitative and qualitative assessment*** of factors which influence sustainability (from concept stage)
- Shows ***stronger link*** between option selection process, sustainability and land required
- ***Evidence to support land acquisition***, particularly in terms of borrow areas and material deposition areas

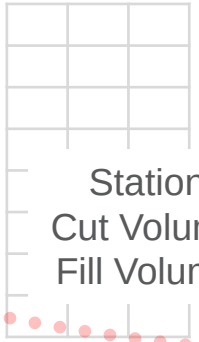
Phase 5 & Phase 6

- ***Greater cost certainty*** in terms of earthworks quantities and movement
- Optimised earthworks considerations will likely result in ***less reliance on natural / scarce resources***
- ***Localised balances*** which reduce works and cost associated with long or unsustainable haulage
- ***Reduction in claim costs and programme overrun*** due to improved consideration of material movements and allocation e.g. sourcing acceptable material, disposal of unacceptable material

How can Mass Haul be incorporated?

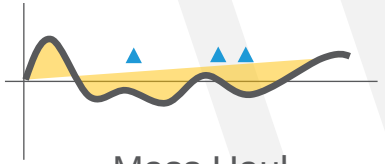


Ground Profile
Vertical Alignment
Horizontal Alignment



Station
Cut Volume
Fill Volume

Mass Haul
Development



Mass Haul
Analysis

Identification of possible optimisation options

Original Objective
Create a mass haul diagram spreadsheet

Evolved Objective
Create a tool which directs and highlights opportunities for a more sustainable design through optimisation with respects to earthworks

Project Phase	Scope *(based on)*	Geometry & Volumes	Earthworks Analysis	Project Characteristics	Visualisation	Conclusions & Opportunities
Phase 2	Geological Description (e.g. Overburden, Rock)	• Geometry: ○ Chainage/Stations ○ Alignment Levels ○ Ground Levels • Volumes: ○ Cut	• Volumes: ○ Cut (Bulked) ○ Fill (Uncompacted) • Reusability Analysis	• Constraints • Material Deposition Areas • Borrow Areas	• Overall Mass Haul Diagram • Mass Haul Diagram per Material Type (as per Phase &	• Earthworks Balance • Haulage Gradient • Haulage Distance (freehaul vs overhaul) • Haulage
Phase 3	TII Material Classification (e.g. Class 1, Class 2, Class					

Tab	User Input	Analysis & Output
Longsection	• Chainage/Stations • Alignment Levels • Ground Levels • Total Cut & Fill /Station	• Earthworks Areas • Gradient
Unbulked Cut Volumes	• Cut volumes • % per earthworks area & material type	• Unbulked cut volumes per earthworks area and material
Compacted Fill Volumes	• Fill volumes • % per earthworks area & fill type	• Compacted (*in situ*) fill volumes per earthworks area and material

Input								Analysis				
Chainage		Ground Level		Road Alignment		Earthwork Volume		Average Elevation		Average Gradient		Total Volume
From	To	Levels		Levels		Cut	Fill	Ground	Alignment	Ground	Alignment	
-	-	mOD		mOD		m³	m³	mOD	mOD	%	%	m³
-190	-150	36.933	37.537	36.933	37.638	44	2	37.24	37.44	1.5%	1.6%	42
-150	-100	37.537	38.244	37.638	38.551	223	11	37.89	38.22	1.4%	1.6%	212
-100	-50	38.244	38.837	38.551	38.865	183	9	38.54	38.70	1.2%	0.9%	174

Topsoil	Assumed	*Where assumed, based on percentage of*	Overburden
Made Ground	Assumed		Overburden
Peat	Submitted		Total
Overburden	Submitted		Total
Rock	Submitted		Total

Input														
Chainage			Submitted Cut Volumes							Assumed Cut Volumes				
From	To	Status	Total	Topsoil	Made Ground	Peat	Overburden	Rock	Topsoil		Made Ground		Peat	
-	-	-	-	m³	m³	m³	m³	m³	%	m³	%	m³	%	m³
-190	50	CUT				0	25620	1245	5%	1281	10%	2562	0%	

Topsoil	Assumed	*Where assumed, based on percentage of*	Total	20%
General Fill	Assumed		Total	20%
Select Fill	Assumed		Total	10%
Capping (6F)	Assumed		Total	10%
Subbase	Assumed		Total	10%

Input															
Chainage			Submitted Compacted Fill Volumes							Assumed Compacted Fill Volu					
From	To	Status	Total	Topsoil	General Fill	Select Fill	Capping	Subbase	Topsoil		General Fill		Select Fill	
-	-	-	m³	m³	m³	m³	m³	m³	%	m³	%	m³	%	m³
-190	50	CUT	26						5%	1	30%	8	25%	6

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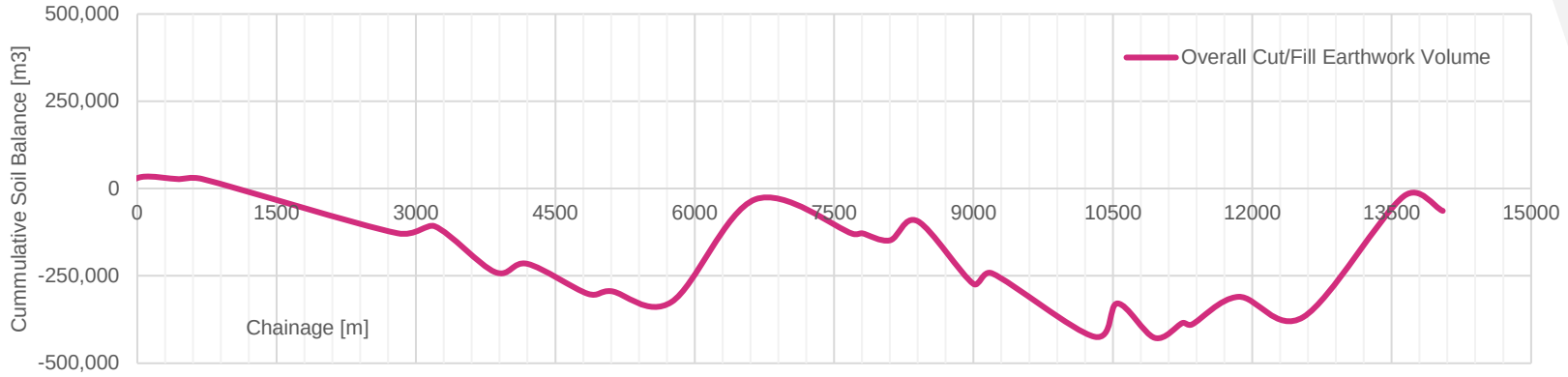

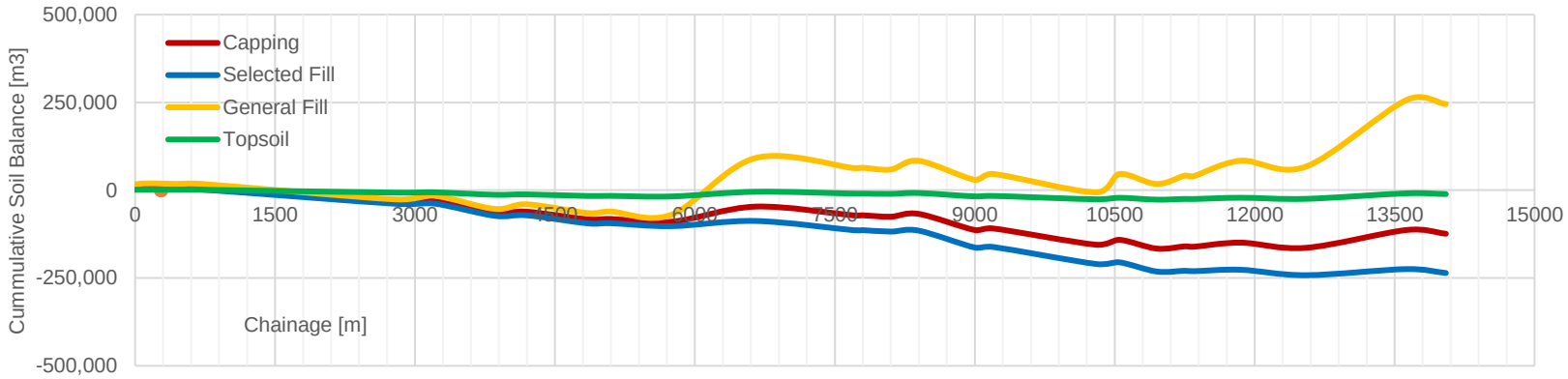

Mass Haul Diagrams –

- Overall
- Detailed per material type or classification
- Automatically updated based on inclusion of material deposition areas and/or borrow areas

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Haulage Analysis Summary –

- Earthworks balance as total and according to material designation
- Haulage summary per material designation:
  - Haulage volume in terms of freehaul and overhaul
  - Haulage distance in terms of freehaul and overhaul
  - Volume and total distance for uphill movements
- Haulage summary per earthworks area per material type, highlighting following impacts:
  - Gradient (uphill)
  - Constraints
  - Distance (over freehaul)
  - Two iterations of movements, both in forward and backward direction

	Topsoil	General Fill	Selected Fill	Capping	Subbase	Total
Haulage Deficit (m^3)	26,700	72,563	236,044	155,085	118,607	
Haulage Surplus (m^3)	15,631	317,329	0	31,202	9,395	

Haulage Volume (m^3)		Topsoil		General Fill		Selected Fill		Capping		Subbase	
	Overall	31,584		242,493		51,829		119,869		50,843	
	Freehaul	25,819	82%	184,966	76%	49,666	96%	102,750	86%	48,499	95%
	Overhaul	5,766	18%	57,526	24%	2,163	4%	17,119	14%	2,344	5%

				Topsoil															
				FORWARD MOVEMENT								BACKWARD MOVEMENT							
Chainage				To the 1st Next Fill Section				To the 2nd Next Fill Section				To the 1st Next Fill Section				To the 2nd Next Fill Section			
From	To			Gradient	Constraints	Volume	Distance	Gradient	Constraints	Volume	Distance	Gradient	Constraints	Volume	Distance	Gradient	Constraints	Volume	Distance
-190	50	CUT		0.27%	YES	164	320	0.55%	YES	1381	1820								
50	450	FILL																	
450	700	CUT		0.63%	NO	23	1175												
700	2800	FILL																	
2800	3200	CUT		-0.72%	NO	462	525					-0.74%	NO	462	1250				
3200	3850	FILL																	
3850	4200	CUT		0.04%	YES	541	500					0.86%	NO	541	500				
4200	4850	FILL																	
4850	5100	CUT		0.23%	NO	172	450					0.07%	YES	172	450				
5100	5750	FILL																	
5750	6650	CUT		0.48%	YES	5263	975					-0.50%	NO	1498	775	-0.29%	YES	3899	1675
6650	7700	FILL																	
7700	7800	CUT		1.84%	NO	36	200					-0.65%	YES	36	575				
7800	8100	FILL																	
8100	8400	CUT		0.18%	NO	1626	450					-1.22%	NO	832	300				
8400	9000	FILL																	
9000	9200	CUT		0.25%	NO	695	650					0.10%	NO	695	400				

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Considerations for Use on Projects

- Tools are intended to support the Phase 2 and Phase 3 design process and identification of opportunities for sustainability in earthworks
- Tools allow for flexibility in terms of the level of geotechnical information available at each Phase
- However, an appropriate level of geotechnical information is required in order to obtain value from Mass Haul Analysis – designers need to consider this at the outset of the project and throughout each Phase
- Essential that Mass Haul Analysis is an integral part of the design process
- Mass Haul needs to be considered holistically along with all relevant aspects – it may not be possible to apply all the optimisations identified
- Tools are not intended to replicate the Mass Haul analysis which is undertaken by contractors at Phase 6

Baseline earthworks analysis developed into excel-based tool

Arbitrary Volumes

Assumed / Submitted Volumes	Increase flexibility for user to input assumptions
Breakdown Percentage per Class	Need to account for variations in material type / value
Constraints	Need to identify potential issues with movement
MDA & Borrow Pits	Account for alternative sources and destinations
Gradient	Need to account for gradient within movements
Haulage Analysis (Fwd & Bkwd)	Identify optimisation opportunities

FIRST CHECK

Case Study Data

Automatic Breakdown into Earthworks Areas	Significant analysis required due to number of stations
Multiple Fwd & Bkwd Movements	Allocation & balance sometimes requires longer movements

SECOND CHECK

Current Tools

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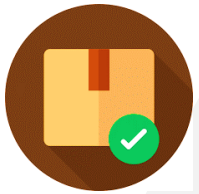
2no. Beta Excel-Based Earthwork Analysis Tools with Draft User Manual

Next Steps

Pilot Trial (N17 Knock to Collooney) with in-house trial of Phase 2 tool and independent project team trial of Phase 3 tool

Final Steps



Release of 2no. Excel-Based Earthwork Analysis Tools with User Manual