Appendix C
Evaluation of Short-list Remedial Options

General Remedial Action	Remedial Option	Description	Remedial Approach and Application to Site Area/ Material Type	Evaluation of Remedial Approaches		Outcome
				Advantages	Disadvantages	
No action	No Action	No remedial action undertaken.	A no action remedial approach for: • Southern Gasholder - this site area would require application of a management plan and access restrictions. • Remaining site area	• Minimal cost expenditure.	• Does not reduce, remove or control exposure risks to human health or ecological receptors and does not address Significant Risk Of Harm (SRoH) issues. • Is not aligned with RailCorp's decision to enter into a Voluntary Remediation Agreement with the NSW EPA. • Would not be accepted by regulators or the local community as a 'do nothing approach'. • Incompatible with RailCorp's long term objectives for future site use and an ongoing groundwater management plan (GMP). • Not aligned with future land use aspirations.	Not preferred: • Overall does not meet the long term objectives for the Site.
Institutional Controls	Environmental Management Plan (EMP)	EMP is designed to minimise exposure risks posed by residual contamination.	An ancillary remedial approach for: • Entire site – subject to active/passive remediation.	• Controls exposure risks to human health and ecological receptors by managing (disrupting) exposure pathways to residual contamination. • Short term timeframe to prepare. • Regulatory acceptance. • Compatible with future site use and incorporates/outlines a GMP. • Cost effective. • Defines procedures and company policies for ongoing site management.	• Enforcing management plan if the Site is divested.	Preferred (in combination with preferred active/passive approach): • Overall provides ongoing management of contamination risks.
	Site access restrictions	Security fencing is installed to limit site access or limit access to specific site areas.	An ancillary remedial approach for: • Entire site – to control exposure risks to general public and community. • Retained Southern Gasholder heritage item – to protect historical importance.	• Controls exposure risks to human health and ecological receptors by disrupting exposure pathways. • Short term timeframe to implement. • Regulatory acceptance. • Compatible with future site use. • Cost effective. • Minimal maintenance required.	• Controlling site access of a 24hr facility from illegal trespassing. • Enforcing access restrictions if the Site is divested	Preferred (in combination with preferred active/passive approach): • Overall provides security and protection of historic items.

General Remedial Action	Remedial Option	Description	Remedial Approach and Application to Site Area/ Material Type	Evaluation of Remedial Approaches		Outcome
				Advantages	Disadvantages	
Insitu Physical/ Chemical Treatment	Passive Insitu Chemical Oxidation	Oxidizing reagent converts hazardous organic contaminants to compounds that are more stable, less mobile or inert.	A passive remedial approach for: • Primary Source Areas at excavation depth limits – Treating residual organic compounds in deep soils, where excavation is limited by machinery capability or deeper excavation is not feasible. Used to promote mass reduction of residual organic contaminants as well as promote groundwater plume treatment over the long term.	• Reduces exposure risks to human health and ecological receptors by reducing residual organic contamination levels (and vapour generation) in soil and groundwater over time. • Short term application provides a long term benefit to enhance biodegradation depending on distribution and volume of residual organic contaminants and quantity of reagent. • Preliminary investigations (CH2M HILL, 2000) indicate that natural attenuation is occurring; therefore enhancing microbial action is feasible. • Is likely to get regulatory acceptance and no adverse impacts to community. • Would be compatible with active (i.e. excavation) remedial approach and management plan. • Would be compatible with GMP to reduce residual organic contaminant levels and enhance natural attenuation and plume reduction. • Would be cost effective when considering costs to excavate deeper/wider areas to chase out residual organic contamination beyond practicable extent. • Would not require ongoing maintenance, although ongoing groundwater monitoring would be required as part of GMP/EMP.	• Effectiveness may be limited on target organic material by the existence of non-target organic material that consumes large quantities of the oxidizing reagent (i.e. organic carbon in soils). • Stiff and highly plastic clay at application depth (i.e. low permeability) may limit the effectiveness to localised areas. • Depth and distribution of residual impact may limit the effectiveness.	Preferred (in combination with preferred active approach): • Overall enhances biodegradation of residual sources
	Soil Vapour Extraction (SVE)	Gas/vapour-phase volatile organic compounds (VOC) are removed from soil through extraction wells applying a vacuum.	An active in-situ remedial approach for: • Primary Source Areas – Treating residual organics in deep soils, where active remedial excavation is limited by machinery capability or deeper excavation is not feasible.	• Controls human health exposure risks by reducing risk posed by the residual organic contaminants and reduces generation of vapours. • Would provide a short to medium timeframe for treating VOCs only.	• Applicable only to VOCs including BTEX and some PAH of low molecular weight (particularly naphthalene). • Limited or ineffective on residual SemiVOCs (i.e. heavier molecular weight PAH). • Stiff and highly plastic clay (i.e. low permeability) would hinder extraction and treatment rates. • Does not work in saturated zones (i.e. below the groundwater). • A uniform treatment may be unachievable given the nature of the clays and weathered shale rock underlying the source areas. These conditions include intermittent, discontinuous and preferential conduit pathways provided by fractures in shale. • Minimal reduction of ecological risks posed by the residual organics because it only treats VOCs, and not SVOCs which may continue to impact groundwater. • Would require an extended timeframe for SVOCs and non-volatiles as most are in a liquid or solid phase at depth and may not volatilise. • Is unlikely to achieve regulatory or community acceptance given requirement for establishing treatment infrastructure on site and the sensitivity of neighbouring residents, considering noise and potential vapour releases. • Is incompatible and may limit future redevelopment based on timeframe and locations of treatment structures. • Is relatively inflexible once established on site. • Provides only partial treatment of residual/potential sources. • May be unnecessary if the active remedial approach achieves remedial goals. • Is likely to be costly for lengthy O&M required to meet specific remedial goals.	Not preferred: • Overall is unlikely treat recalcitrant compounds in source material

General Remedial Action	Remedial Option	Description	Remedial Approach and Application to Site Area/ Material Type	Evaluation of Remedial Approaches		Outcome
				Advantages	**Disadvantages**	
Insitu Thermal Treatment	Thermal Treatment	Increases volatilisation rate to facilitate and enhance SVE.	An active remedial approach for: • Primary Source Areas – Treating residual organics in deep soils, where source removal by active remedial excavation is limited by machinery capability or deeper excavation is uneconomical.	Similar advantages as SVE above. May also have an increased effect on SVOC, but non volatiles (i.e. tar source) would remain insitu.	Similar disadvantages as SVE above. This option would not be appropriate alone and usually undertaken with SVE.	Not preferred: • Overall is unlikely treat recalcitrant compounds in source material
Exsitu Biological Treatment	Biopiles	Excavated soils are mixed with soil amendments and placed in aboveground enclosures or constructed bioremediation cells.	An active remedial approach for: • Excavated soil impacted by tar beneath the Retort area and surrounding source zones. For VOCs and lighter fraction PAHs.	• Removes exposure risks to human health and ecological receptors at the Site by disrupting the exposure pathway and reducing the volume of contamination. • A proven technique accepted by regulators for materials impacted with low levels of volatile and lighter fraction PAH contamination. • May get community acceptance at the former gasworks site if alternative site used for treatment (i.e. contamination will be removed). • Is compatible with future site use and GMP and may be flexible to consider alternative approaches.	• Limited site area would require an alternative site to treat large volumes of soil. Short term exposure risks would exist at the alternative site. • The high sensitivity of the neighbouring residential properties may preclude any treatment being undertaken on site (i.e. noise, dust and odour issues). • Transport of potentially hazardous wastes to alternative treatment site would require approval. • An alternative treatment site would require all necessary environmental safeguards particularly vapour emissions requiring treatment, construction of concrete slab/s. • The process is unsuitable for grossly impacted materials such as free tar. • Limited effectiveness in reducing the multi-ring (4 ring and greater) PAHs, such as chrysene and benzo(a)pyrene, to acceptable regulatory levels. • Additional/alternative treatment may be necessary if remedial goal not achieved. • Treatment trials would be necessary. • High clay content of the soil would require pre-treatment to breakdown the physical structure. • Requires an extended timeframe to treat the impacted material. Although grossly impacted material (i.e. free tar) would require an alternative treatment. Considering substantial portion of material is likely to contain free tar source, then this approach may have limited success. • Is incompatible with potential reuse of the impacted materials because it is unlikely to have a significant effect on PAH contaminants with 4 or greater rings. • Is likely to become costly considering timeframe, establishment and maintenance of an alternative treatment site, and if additional treatment using a different technique is required.	Not preferred: • Overall is unlikely treat recalcitrant compounds in source material
	Composting	Excavated soils are mixed with bulking agents and organic amendments, such as wood chips, hay, manure, and vegetative wastes.	An active remedial approach for: • Excavated soil impacted by tar beneath the Retort area and surrounding source zones. For VOCs and lighter fraction PAHs.	Similar advantages as Biopiles above.	Similar disadvantages as Biopiles above. The addition of compost bulking agents would substantially increase the volume of the material being treated.	Not preferred: • Overall is unlikely treat recalcitrant compounds in source material
	Landfarming	Excavated soils are applied into lined beds, and periodically turned over or tilled.	An active remedial approach for: • Excavated soil impacted by tar beneath the Retort area and surrounding source zones. For VOCs and lighter fraction PAHs.	• Relatively simple and cheap as does not require construction of cells as with ex-situ bioremediation or composting options above.	Similar disadvantages as Biopiles above. • Unlikely to gain regulatory acceptance, as known to be ineffective on more complex PAHs and other SVOCs, and due to aesthetic and environmental (dust, odours, erosion) control issues. • Requires greater surface area as soil needs to be thinly spread to effect biological treatment. • Would require amendment (nutrients) and regular tilling over longer timeframe.	Not preferred: • Overall is unlikely treat recalcitrant compounds in source material

General Remedial Action	Remedial Option	Description	Remedial Approach and Application to Site Area/ Material Type	Evaluation of Remedial Approaches		Outcome
				Advantages	Disadvantages	
Exsitu Physical/ Chemical Treatment	Solidification / Stabilisation/ Immobilisation	Contaminants are physically bound or enclosed within a stabilised mass.	An active remedial approach for: • Excavated soil impacted by tar beneath the Retort area and surrounding source zones. This material can be stabilised then would qualify for general immobilisation approval from the DEC. • Ash and coke fill material. Where PAH contamination can be demonstrated to be immobile without treatment within ash and coke then it would qualify for general immobilisation approval from the DEC.	• Removes exposure risks to human health and ecological receptors at the Site by disrupting the exposure pathway and reducing the volume of contamination. • Enables off site disposal of former gasworks waste materials and ash/coke fill materials classified on TCLP alone using the NSW DEC general approval for immobilisation. Therefore liability of the contamination is passed onto the licensed disposal facility, which is designed to contain such materials. • Provides a short timeframe to achieve the desired goals. • A proven technique accepted by regulators for gasworks waste material and ash/coke fill. • Likely to get community acceptance at the former gasworks site (i.e. contamination will be removed). • Is compatible with future site use and GMP. • Is incompatible with potential reuse of the impacted materials.	• Limited site area may require an alternative site to treat a large volume of soil. Short term exposure risks would exist at the alternative site. • The high sensitivity of the neighbouring residential properties may preclude any treatment being undertaken on site (i.e. noise, dust and odour issues). • Transport of potentially hazardous wastes to an alternative treatment site for stabilisation of some material would require approval. • High clay content of the soil would require pre-treatment to breakdown the physical structure and to improve handling.	Preferred (in combination with off site disposal): • Overall a proven technique that addresses inherent financial risk posed by other approaches
	Chemical Extraction	Wastes and extractant are mixed, thereby dissolving the contaminants. The extracted solution is then placed in a separator, where the contaminants and extractant are separated for treatment.	An ancillary remedial approach for: • Residual tar material within old gasworks pipes and underground services.	• Removes some exposure risks to human health and ecological receptors at the Site by disrupting the exposure pathway and reducing the volume of contamination. • Can be undertaken in a relatively short timeframe; however effectiveness for this application is unknown.	• The high sensitivity of the neighbouring residential properties may preclude any treatment being undertaken on site (i.e. noise, dust and odour issues). • Transport of potentially hazardous wastes would require approval. • Unknown treatment history for gasworks wastes and is a relatively new technology and effectiveness would be judged on treatment trials. • Generates a waste liquid that would require treatment/ disposal at completion. • Treated pipes may be recycled if technique is effective, however may ultimately require disposal at a landfill. • Would have a cost dependency on the quantity of material requiring treatment, which is unknown. • Regulatory acceptance would be based on proof of effectiveness and ultimate destination of wastes.	Potential ancillary approach: • Can be used specific to old pipe work waste
	Segregation	Segregation techniques concentrate contaminated (or non-contaminated) solids through physical and chemical means.	An ancillary remedial approach: • Specific for retaining oversize materials in general fill such as bricks, footings, concrete, metal pipe and other building rubble for off site recycling, which should exclude asbestos containing material (ACM), ultimately reducing material volumes.	• Would be beneficial in reducing the volume of contamination in combination with active remedial approaches. • Short time frame. • Minor costs on top of those to undertake active remediation.	• The presence of Asbestos Containing Material (ACM) in fill materials may preclude this as an appropriate option (i.e. OH&S issues).	Preferred (in combination with active approach): • Overall does not affect the preferred active approach, but can reduce treatment volumes and overall costs • Proven approach • Follows the regulatory framework for managing wastes under the *Waste Avoidance and Resource Recovery Act 2001.*
Exsitu Thermal Treatment	Incineration or Co-burning	Utilises the high operating temperatures of industrial processes (between 870-1,200°C) to combust organic constituents in hazardous wastes.	An active remedial approach for: • Primary tar source material including - Tar Well contents, Gasholder base annulus contents and gross tar materials (i.e. high tar content and low soil material). The material must comprise a high calorific content. This approach would only address a portion of the impacted soils.	• Would be effective in reducing the exposure risks to human health and ecological receptors at the Site posed by highly contaminated materials. • Would be completed in a relatively short timeframe. • Would be effective for a portion of the tar impacted material.	• Potential issues with gaining regulatory approval or acceptance of wastes by potential facilities. • Limited facilities that would accept wastes to mix with coal/oil feedstock. • Tar materials would require pre-treatment to improve handling and transport. • Transport of potentially hazardous wastes would require approval. • Regulatory acceptance (if approved) would delay the approach. • Treatment trials may be necessary to demonstrate effectiveness. • Only applicable to material with high tar content (high calorific value) and low soil content. Therefore deals with only a portion of contaminated material.	Not preferred: • Overall unknown effectiveness, which can be addressed by other, cost effective, approaches

General Remedial Action	Remedial Option	Description	Remedial Approach and Application to Site Area/ Material Type	Evaluation of Remedial Approaches		Outcome
				Advantages	Disadvantages	
Exsitu Thermal Treatment	Thermal Desorption	Wastes are heated to volatilise organic contaminants. A carrier gas or vacuum system transports volatilised water and organics to the gas treatment system.	An active remedial approach for: • Primary tar source material and tar impacted soils.	• Removes exposure risks to human health and ecological receptors at the Site by disrupting the exposure pathway and reducing the volume of contamination. • May require disposal after treatment at a licensed facility, therefore liability of the contamination is passed onto the licensed disposal facility. • Is compatible with the future site use and management of groundwater issues. • Is a proven technique for destroying organic contaminants including PAHs. • Treatment technique has had regulatory and community acceptance in other locations in Sydney. • Relatively short timeframe for remediation once approved and set up.	• Given the limited site area, it is likely to require an alternative site to treat large volumes of soil in order to set up the thermal treatment plant and associated infrastructure. Short term exposure risks would exist at the alternative site. • The high sensitivity of the neighbouring residential properties may preclude any treatment being undertaken on site (i.e. noise, dust and odour issues). • Transport of potentially hazardous wastes to alternative treatment site would require approval. • An alternative treatment site would require all necessary environmental safeguards particularly vapour emissions requiring treatment. • Is a proven technique, however there is currently no approved off site thermal desorption facility available and onsite treatment with a portable plant would present logistical problems and regulatory and community issues. • Stiff and highly plastic clay with high moisture content would require pre-treatment to improve handling. • Potential issues with effectiveness on high tar content materials. • Additional/alternative treatment may be necessary if the remedial goal is not achieved.	Preferred (in combination with off site disposal): • Overall a proven technique that addresses inherent financial risk posed by other approaches
Containment	Insitu Capping	Provides a physical barrier and prevents site users being exposed to the contaminated material. Also may reduce contaminant migration from leaching by mitigating surface water infiltration.	An ancillary remedial approach for: • Specific to relatively shallow impacts of non leaching material (i.e. ash/coke surface fill) in the northeast, southwest and western lot portions of the Site.	• Reduces exposure risks to human health and perhaps ecological receptors at the Site by disrupting the exposure pathway. • Can be applied in a short timeframe to those specific areas and materials of the Site • Would be relatively cost effective if applied to those specific areas of the Site and would not require off site treatment or disposal costs. • Would require a management and maintenance policy as part of the SMP.	• Is a partial remedial approach that does not address the issue of localised buried wastes and tar impacted primary source zone areas and potential tar source hotspot areas. • Does not prevent migration of groundwater carrying contaminants away from source areas beneath the cap. • Is unlikely to achieve regulatory and community acceptance to address immobile surface contamination, and an alternative approach would be necessary to address potential deeper source areas. • Unknown compatibility with future site development. May only be an advantage if site levels are to be raised. • May be incompatible with an ongoing groundwater management strategy.	Not preferred: • Overall ongoing regulatory acceptance issues and unknown redevelopment aspirations
	Capping in Prescribed Onsite Containment Area	Contaminated soil is consolidated and capped in one area of the site.	An ancillary remedial approach for: • Specific to non-leaching material (i.e. ash/coke surface fill) in the northeast, southwest and western lot portions of the Site.	• Reduces exposure risks to human health and ecological receptors at the Site by disrupting the exposure pathway. • Can be applied in a short timeframe to those specific areas and materials of the Site • Would be relatively cost effective if applied to those specific areas of the Site and would not require off site treatment or disposal costs. • Would require a management and maintenance policy as part of the SMP.	• A partial remedial approach that does not address primary tar sources. • The limited site area is unlikely to accommodate a designated containment area. • Future redevelopment would be limited and some areas of the Site would be unused. • Potential for ongoing groundwater impacts. • Is unlikely to achieve regulatory and community acceptance and an alternative approach would be necessary to address potential deeper source areas. • Management and monitoring costs would be ongoing. • May be incompatible with future redevelopment aspirations for the Site, considering levels and finished grade. • May be incompatible with an ongoing groundwater management strategy.	Not preferred: • Overall ongoing regulatory acceptance issues and unknown redevelopment aspirations

General Remedial Action	Remedial Option	Description	Remedial Approach and Application to Site Area/ Material Type	Evaluation of Remedial Approaches		Outcome
				Advantages	Disadvantages	
Off-Site Disposal	Disposal at an existing off-site facility	Material is transported to an existing licensed off-site disposal facility.	An active remedial approach for: • Treated soils • Asbestos impacted demolition waste • Ash/coke fill material • General fill material	• Controls exposure risks to human health and ecological receptors at the Site by disrupting exposure pathways and reduces the source volume at the Site and vapour generation. • Can be implemented in a short timeframe to achieve the desired goal. • Is a proven technique that, when implemented in combination with other treatment technologies such as stabilisation, is likely to achieve regulatory and community acceptance. • Would enable the NSW EPA general approval for immobilisation to be applied to gasworks wastes subject to treatment of the material. • Enables the NSW EPA general approval for immobilisation to be applied directly to ash/coke impacted material without treatment. • Would be compatible with other preferred remedial approaches. • Would be compatible with GMP to remove sources, promote natural attenuation and promote plume reduction. • Would not require ongoing maintenance as the liability of the contamination is passed onto the licensed disposal facility, which may also accept liability at the site boundary prior to transporting the waste to the disposal site. • Is comparatively cost effective. • Is compatible with future redevelopment and site use.	• Tar impacted soil would require pre-treatment to apply the NSW DEC general approval for immobilisation specific for gasworks waste materials. • An alternative treatment site would be required given the limited site area and local sensitivity of the adjoining residencies. • High clay content of the soil would require pre-treatment to breakdown the physical structure.	Preferred (in combination with other preferred approaches): Overall - • Limited unknowns and disadvantages • Proven approach. • Meets long term objectives
		A specially constructed mono-cell within a landfill is used to dispose untreated hazardous contaminated materials.	An active remedial approach for: • Hazardous gasworks tar wastes. • Old gasworks tar pipes.	• Can be implemented in a short timeframe to achieve the desired goal. • Construction of a mono-cell at an approved waste landfill would enable disposal of potentially hazardous wastes without treatment. • Would be compatible with GMP to remove sources, promote natural attenuation and promote plume reduction. • Would not require ongoing maintenance as the liability of the contamination is passed onto the licensed disposal facility, which may also accept liability at the site boundary prior to transporting the waste to the disposal site. • Is compatible with future redevelopment and site use.	• Transport of potentially hazardous wastes would require approval. • Construction of a mono-cell within the licensed landfill would be required to accept potentially hazardous gasworks tar wastes. • Is unlikely to achieve regulatory approval.	Not preferred: • Overall ongoing regulatory acceptance issues
		Liquid wastes require disposal at approved facilities.	An active remedial approach for: • Hazardous liquid tar waste contents in Tar Wells, old gasworks tar pipes, and base annulus of Gasholder. • Other impacted liquid waste.	• Controls exposure risks to human health and ecological receptors at the Site by disrupting exposure pathways and reduces the source volume at the Site and vapour generation. • Can be implemented in a short timeframe to achieve the desired goal. • Is a proven technique that is likely to achieve regulatory and community acceptance. • Would be compatible with other preferred remedial approaches. • Would be compatible with GMP to remove sources, promote natural attenuation and promote plume reduction. • Would not require ongoing maintenance as the liability of the contamination is passed onto the licensed disposal facility, which may also accept liability at the site boundary prior to transporting the waste to the disposal site. • Is comparatively cost effective. • Is compatible with future redevelopment and site use.	• Transport of potentially hazardous wastes would require approval.	Preferred (in combination with other preferred approaches): Overall - • Limited unknowns and disadvantages • Proven approach • Meets long term objectives
Beneficial Reuse and Recycling	Materials retained on site and reused or removed off-site for reuse/recycling by other appropriate facilities	Some materials will have physical and chemical properties that enable beneficial reuse at the site. Some materials have value to other processing plants and may be removed from site.	An ancillary remedial approach for: • Material meeting the land use criteria. • Material meeting the site specific risk-based criteria for soils at depth. • Demolition wastes	• Would be beneficial in reducing the volume of contamination in combination with active remedial approaches. • Would reduce costs associated with importing backfill material. • Can be integrated into the remedial program timeframe. • Minor costs and time on top of those to undertake active remediation to recover recyclables.	• Fill materials associated with the main gasworks operations area that are impacted with tar would be suitable for reuse, even after treatment. • The presence of asbestos containing materials in some fill materials may limit the availability for reuse/recycle.	Preferred (in combination with other preferred approaches): • Proven approach • Meets long term objectives for the site • Follows the regulatory framework for managing waste and avoidance.

Appendix D
RailCorp Infrastructure Engineering Standards – Geotechnical Guidelines

TMC 411

EARTHWORKS MANUAL

Version 1.0

Issue Date September 2006

Owner Principal Engineer Geotechnical

Approved By:	John Stapleton Group Leader Standards	Authorised By:	Jee Choudhury Principal Engineer

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Table of Contents

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Revision Control Table

Revision	Date of Approval	Summary of change
1		Original Issue

Current Subsection Revision

Subsection	Current Revision	Summary of change
Title page	1	Original Issue
Revision Control	1	Original Issue
Table of Contents	1	Original Issue
Ch 1	1	Original Issue
Ch 2	1	Original Issue
Ch 3	1	Original Issue
Ch 4	1	Original Issue
Ch 5	1	Original Issue
Ch 6	1	Original Issue
Ch 7	1	Original Issue
Ch 8	1	Original Issue
Ch 9	1	Original Issue
App 1	1	Original Issue
App 2	1	Original Issue
App 3	1	Original Issue
App 4	1	Original Issue

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Chapter 1 General

C1-1 Purpose

This document specifies procedures for the construction and maintenance of cuttings, embankments and formation for RailCorp tracks.

The procedures apply to all main lines and sidings.

Guidelines for the rehabilitation of existing track formation are given in TMC 403 “Track Reconditioning Guidelines”.

C1-2 How to read the Manual

When you read this manual, you will not need to refer to RailCorp Engineering Standards.

Any requirements from standards have been included in the sections of the manual and shown shaded. The shaded sections are extracts from RailCorp Standard ESC 410 “Earthworks and Formation”.

Reference is however made to other Manuals.

C1-3 References

AS 1141	Methods for sampling and testing aggregates
AS 1289	Methods for testing soils for engineering purposes
SPC 411	Earthworks Materials Specification
TMC 403	Track Reconditioning Guidelines
TMC 421	Track Drainage Manual
RailCorp	Asset Management Group Workplace Safety Manual
RailCorp	Environmental Management System

C1-4 Definitions, abbreviations and acronyms

Earth:	All materials such as earth, clay, sand gravel, weathered or loose rock which could normally be removed by ripping by a bulldozer of 290 kilowatt brake power (382 h.p.) with heavy duty tynes.
Rock:	Any other material which cannot be so removed and shall include boulders greater than 1 cubic metre in volume.
Dispersive soil:	Soil that has the ability to pass into suspension in the presence of water
Highly dispersive soil:	Soil that has the ability to pass rapidly into suspension in the presence of water and has an Emerson Class number of 1.
Earthworks level:	The level at the centre of the earthworks prior to placing of the capping layer.
Formation level:	The finished level at the centre of the formation preparatory to laying ballast. It includes the required capping layer.
Capping layer:	Layer of compacted material that provides an impermeable seal to the earthworks.
Structural zone:	The upper zone of the embankment. Thickness varies from 500mm to 1000mm, depending on the CBR of the general fill.
General fill:	The lower zone of the embankment.

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CBR:	Soaked California Bearing Ratio, Standard Compaction.
Scarp:	Bench formed by excavating down the slope perpendicularly
Geotechnical Engineer:	RailCorp's Principal Geotechnical Engineer or a competent person with delegated engineering authority for geotechnical design activities relating to earthworks.
Site Supervisor:	A qualified civil engineer or a competent person with delegated engineering authority for earthworks supervision.

C1-5 Competencies

Design of earthworks is to be approved by a Geotechnical Engineer.

Earthworks shall only be carried out under the supervision of a Site Supervisor.

Some aspects of the earthworks may require the approval of a Geotechnical Engineer.

Certification of the track during earthworks or after earthworks has been completed may only be undertaken by persons with the following competency:

– TDT B38 01A - Maintain track geometry.

C1-6 Safety and Environmental

Safe work method statements shall be prepared for earthworks construction work.

Earthworks shall be carried out so as not to undermine any adjacent track structure.

An environmental management plan is required for all earthworks construction sites. The plan is to include control measures for erosion and sedimentation.

The disposal of unsuitable material shall be in accordance with the requirements specified in RailCorp's Asset Management Group Workplace Safety Manual and Environmental Management System.

Service searches shall be conducted to identify all underground services.

The location of the services shall be marked on site prior to the commencement of any earthworks.

Services that are located within the construction zone may require relocation so as not to adversely affect the performance of the completed earthworks.

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Chapter 2 Earthworks & Formation

C2-1 General

The formation for single track mainlines and single track sidings shall comply with the appropriate dimensions shown on Drawing SP 521 in Appendix 1.

The formation for multiple track mainlines and multiple track sidings shall comply with the appropriate dimensions on Drawing SP 522 in Appendix 2.

C2-2 Formation Shoulder Distance

Earthworks are to be constructed to achieve the formation shoulder distance as detailed in Appendix 3.

Where reduced shoulder distances exist due to physical constraints, an assessment is to be made of the need for safety refuges, handhold devices and limited clearance signs. The requirements are specified in ESC 350 “Retaining Walls and Platforms”.

C2-3 Train Examination Areas

Where nominated, train examination areas are to be provided. The minimum requirement is to cover these areas with a 50mm layer of 10mm single sized aggregate as shown on Drawings SP 521 and SP 522.

The train examination area is not to be assumed as available for road access purposes.

C2-4 Walkways

Where nominated, walkways are to be provided for staff to walk along the track cess. The minimum requirement is to cover walkways with a 50mm layer of 10mm single sized aggregate as shown in Drawings SP 521 and SP 522.

C2-5 Drainage

The basic requirements for drainage are shown on Drawings SP 521 and SP 522.

Cess drains, sub-surface drains and top drains to cuttings shall be designed and installed in accordance with TMC 421 Track Drainage Manual.

C2-6 Compaction

Compaction standards shall be as follows:

Compaction A:	-	Cohesive soils - Not less than 100% Relative Compaction as determined by AS 1289 Tests 5.1.1 and 5.3.1 (Standard Compaction)
	-	Rock fill or cohesionless soils - No visible deflection of surface under 10 tonne vibratory rollers after 6-8 passes. Relative density shall not be less than 75%.
Compaction B:		Not less than 95% Relative Compaction as determined by AS 1289 Tests 5.1.1 and 5.3.1 (Standard Compaction).

C2-7 Non-compliance with Compaction Standards

Material not complying with the specified compaction standard shall only be used with the approval of the Principal Engineer Geotechnical.

Chapter 3 Preparation for Earthworks

C3-1 General

Prior to commencing earthworks, the Site Supervisor shall determine proposed work methods, taking into account the physical conditions at the site.

C3-2 Site Clearing

The whole area to be occupied by the completed works is to be cleared and grubbed plus a clearance of 2m from tops of cuttings and toes of embankments.

Clearing includes removal and disposal of all trees, stumps, logs, timber, scrub, vegetation, rubbish and other material unsuitable for incorporation in the work. Unsuitable material includes topsoil, peat and other highly organic soils, logs, stumps, perishable material, material susceptible to spontaneous combustion, free draining materials susceptible to scouring, very fine sand, silt, organic clay, highly dispersive soils and material with a CBR < 1%.

Dispersive soils can be used only in accordance with guidelines provided by a Geotechnical Engineer.

Where unsuitable material exists in excessive depths the advice of a Geotechnical Engineer is required.

Grubbing is to be carried out to the level of 0.5m below natural surface or 1.5m below finished earthworks level.

Holes left after grubbing under proposed embankments are to be filled with sound material and compacted in layers as for embankments.

Topsoil shall be removed over the area that will be occupied by the completed works plus a clearance of 2 metres.

Where required for re-use in landscaping and revegetation, topsoil shall be placed in a stockpile clear of the work.

All material unsuitable for incorporation in the work shall be disposed off-site, unless approved for re-use on site e.g. noise barriers.

Chapter 4 Embankments

C4-1 Preparation of embankment base

Preparation includes clearing, grubbing, removal of topsoil and removal of unsuitable material and subsequent restoration as described in C3-2.

It also includes cutting of terraces into slopes, scarifying and compaction of embankment base and provision of drainage works as specified below.

Where embankments are to be constructed on a natural slope or on the slope of an existing embankment steeper than 4 to 1 (horizontal to vertical), the existing slope is to be cut in horizontal terraces at least 1.5m wide.

The terraces are to be cut progressively as the embankment is constructed (refer to Appendix 4).

Suitable material excavated in cutting the terraces may be incorporated in the embankment but unsuitable material must be disposed off-site.

The area of the base of the embankment shall be scarified to a depth of 100mm, parallel to the embankment axis.

A layer of general fill 100mm thick shall be spread over the scarified area, and the whole area shall be compacted to Compaction B standard as detailed in C1-8.

C4-2 Drainage Blanket

Where shown on the drawings a drainage blanket is to be provided at the base of the embankment.

It will comprise a geotextile fabric (as approved by the Geotechnical Engineer) laid along the base and around a layer of free draining filter material to a depth of 300mm, and spall protection provided at the outlet.

Manufacturer's instructions concerning installation of the fabric shall be followed.

The free draining filter material shall be crushed rock, river gravel or slag composed of hard, strong and durable particles, and complying with SPC 411.

The filter material shall be spread in uniform layers to give the specified compacted thickness in such a manner as to avoid damage to the fabric.

Compaction is to be obtained using at least 8 passes of a vibratory roller of static drum load of 6 tonnes.

Bad ground, seepage or springs encountered during embankment preparation may require additional special treatment (refer to Appendix 4). Advice of the Geotechnical Engineer should be sought.

C4-3 Embankment material

Embankment materials shall comply with Engineering Specification SPC 411 Earthworks Materials.

The embankment shall consist of two zones of embankment material:

- Structural Zone
- General Fill

The zones of the embankment shall be defined by the thickness of the structural zone (H) at the top of the embankment as determined by the following relationship with the general fill in the embankment:

For general fill with CBR 3-8%, H = 500mm

For general fill with CBR 1-3%, H = 1000mm.

Material for use in the structural zone shall comply with SPC 411.

Unsuitable material as defined in C3-2 shall not be used as general fill.

Material not complying with the above requirements is only to be used with the approval of the Geotechnical Engineer.

C4-4 Placing embankment material

Embankments shall be constructed in full width horizontal layers.

Normally layers should not exceed 200mm thickness unless it can be shown that the specified compaction can be obtained for a thicker layer.

Layers or pockets of substantially varying material should be avoided.

The maximum particle size should be less than 2/3 of the compacted layer thickness.

Construction shall be carried out in such a manner as to ensure adequate drainage of the works, and to avoid scour and erosion.

C4-5 Compaction of embankment material

Compaction shall be carried out at a moisture content that will allow the specified compaction to be achieved, normally within 2 per cent of optimum moisture content.

Where necessary water shall be added uniformly or drying carried out.

Bond between layers is to be ensured, if necessary by wetting or scarifying.

Embankments shall be compacted to:

General Fill:	Below Structural Zone = Compaction B
Structural Zone:	To 500mm or 1000mm below formation layer (i.e. Earthworks Level) = Compaction A

The earthworks in embankments shall be placed and compacted to a level 30 millimetres above the base of the capping layer.

Immediately prior to the placement of the capping, the fill shall be trimmed by grading to the final profile and compacted by a minimum of three passes of a smooth steel drum roller which has a static mass not less than 10 tonnes.

The finished, rolled surface shall be true to profile to a tolerance of +0 to -30mm, and shall be free of depression and ruts.

No traffic shall be allowed on the finished surface.

Field testing for Relative Compaction control shall be carried out for every 500 cubic metres (minimum) of fill placed, or more frequently as determined by the Geotechnical Engineer or Site Supervisor.

C4-6 Embankment profile

Embankment batter slopes shall be as shown on the Drawings. Unless shown otherwise, the standard batter slope for embankments shall be 2:1 (horizontal:vertical), subject to confirmation by site specific stability analysis taking account of materials, height and foundation conditions.

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