Office of Rail and Road and Network Rail

Mandate L3AR005: CP5 Asset Data Quality Assurance - Earthworks and Structures Asset Data

Final Report

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General

Arup was appointed by the Office of Rail and Road (ORR) and Network Rail (NR) to undertake an assessment of NR's earthworks and structures asset data quality, in its role of Independent Reporter – Lot 3.

Mandate

The ORR specified that asset data quality for NR's earthworks and structures assets should be at 'A2'[1] by April 2017. During CP5, NR further developed its Asset Data Governance Management System (ADGMS). When assessed by the ORR and NR, the 'system reliability' aspect was allocated an 'alpha' Confidence Grade of 'A' for all the relevant asset types. This assessment therefore concerns the 'numeric' Accuracy Grade, the target being '2'. The ORR and NR considered it more beneficial to base the assessment on a recent dataset to provide a more contemporary picture of the data quality, a dataset extracted February 2019 was therefore assessed.

The dimensions considered for the data accuracy grade were both the accuracy and completeness of the asset data, as defined below:

- Data Accuracy to evaluate the correctness of the data at attribute level. Accuracy is assessed from a comparison of data record attributes with independent data or review of the real-world assets. Where such comparisons do not produce equivalence, then an error is recorded i.e. a Fail result.
- Data Completeness Assessment to evaluate how well the data set reflects the assets in the real world. Completeness is assessed based on the three types of potential error:
    - No record (i.e. the asset exists in the real world but not in the database / asset register)
    - Spurious record (i.e. the asset exists in the system but not in the real world)
    - Duplicate record (i.e. two system records relate to the same physical asset).

[1] The target confidence grade of A2 is set by asset type and based on a component for system reliability (the 'alpha') and data accuracy (the 'numeric').

The Asset Types, Sub-Asset Types and Attributes tested are set out in Table 1, Data Accuracy assessment took place at attribute level and Data Completeness assessment at sub-asset type level. The ORR and NR decided that the attributes greyed out should not be assessed[2].

Table 1: Assets and Attributes Tested

Asset Type	Sub Asset Types	Attributes	
Structures	Overline Bridges Underline Bridges	ID	CMI score (PLBE)
		Start Mileage	CMI date
		Primary ELR	Detailed Exam Date
		Owning Party	Underwater examination date (underline bridges only)
		Operational Status	Number of decks
		Primary Material	HCE examination date
		CMI score (Asset level)	
Earthworks	Embankments Rock Cuttings Soil Cuttings	Asset ID	Last Evaluation Date
		Currently included in Adverse / Extreme Weather Plan	Last Examination Date
		EACB	Operational Status
		Asset Examination Status	Owning Party
		EHC	Route
		Asset Type	Side
		ELR	Start Easting
		End Easting	Start Mileage
		End Mileage	Start Northing
		End Northing	Track Name

Dataset Assessment Findings

Completeness

The completeness assessment produced very good findings, with each sub-asset type and therefore asset type exceeding the required numeric grading of '2'.

Accuracy

The accuracy of the majority of attributes assessed for both structures and earthworks were well within the parameters required. The numeric accuracy

[2] The attributes Currently included in Adverse / Extreme Weather Plan and Owning Party are not currently maintained by NR centrally, pending the implementation of the CSAMS system. An independent verification source was not identified for EACB, Asset Examination Status and EHC, as these are maintained via the field data capture aspects of the earthworks application.

Confidence Gradings of both structures and earthworks asset data are marred by issues, affecting a sub-set of the attributes under assessment, which reduce the overall grade. It is considered that if these issues were addressed, systemically, then the expected numeric accuracy Confidence Gradings would be achieved within the parameters of this assessment.

The main issue identified during the structures accuracy dataset assessment, was that the multiple databases, used to support this asset type, are on occasions misaligned, particularly in relation to cyclical examinations.

These misalignments apply to both of:

1. Attributes within databases having different values for the same examination cycle; and

2. Attributes within databases being from different examination cycles.

The principal issue with the earthworks attributes under accuracy assessment, is the start and end co-ordinate pairings and their relationship to the linear location references (start and end mileages). In a significant number of cases, the start co-ordinate pairings were associated with the end mileage and vice versa, i.e. the spatial and linear references were inverted against each other.

This referencing inversion may consequentially have an impact on other aspects of the linear referencing system, particularly the Side and Track Name attributes under assessment.

Confidence Grading

The results of the tests were collated to provide scores, on a pass/fail basis. These scores were then converted into gradings, in accordance with the ADCGAM, as shown in Table 2.

Table 2: Grading Derivation from Scores

Dataset Evaluation Gradings	1	2	3	4	5	6
Accuracy Score	>=99%	>=95%	>=90%	>=75%	>=50%	<50%
Completeness Score	>=99%	>=95%	>=90%	>=75%	>=50%	<50%

The results of the combined accuracy and completeness gradings are shown at Table 3.

Table 3: Asset Type and Sub-Asset Type Gradings

Asset Type Grading		Sub-Asset Type Grading		Accuracy	Completeness
Structures	3	Overline Bridges	2	Score 95.7% Grading 2	100.0% 1
		Underline Bridges	3	Score 94.6% Grading 3	100.0% 1
Earthworks	3	Embankments	3	Score 90.6% Grading 3	100.0% 1
		Rock Cuttings	3	Score 93.1% Grading 3	99.5% 1
		Soil Cuttings	3	Score 90.0% Grading 3	99.0% 1

Recommendations, Observations and Suggestions

A set of recommendations has been prepared based on the findings of the study. These are included in Table 4. An observation and suggestion for improving the nature of future independent assessments is also made, at Table 5, as a result of undertaking this assessment.

Table 4: Assessment Recommendations

Number	Recommendations to Network Rail	Benefits	Location in Text
2019ADQ01	NR should define and migrate to a single combined linear and spatial location referencing system. The definition should include the data requirement, the relationship between the linear and spatial facets, the accuracy and tolerance and the purpose and use of the linear and spatial facets.	1. Valid cross comparisons can be made between asset types, via location reference. 2. The data is prepared for migration to NR's ambition of a single central integrated asset management system (CSAMS). 3. Supports a 'horses for courses' approach in the field, including where applicable modern mobile technologies.	**4.2.1.2**
2019ADQ02	NR should produce and implement a consolidated set of asset data requirements, including their data quality parameters. Currently the source of these is diverse including guides and manuals, conventions and derivation from sources of other purposes, for example, engineering standards	1. Clarity and focus, 2. Maintenance and control as a discipline	Phase 1 duration and Phase 2 start-up
2019ADQ03	NR should strengthen their processes, procedures and controls for maintaining the alignment of multiple central databases with overlapping datasets and data delivery into them. They should consider automation, to identify misalignment on an ongoing basis.	1. NR can rely on a, logical, single version of the truth. 2. The data is prepared for migration to NR's ambition of a single central integrated asset management system (CSAMS).	**4.2.1.1**
2019ADQ04	NR should undertake an assurance programme of its own asset data quality. The ORR, or Reporter on their behalf, may then audit the results of the assurance programme.	1. Is pro-active and ongoing rather than retrospective. 2. Is adaptable to emerging needs. 3. More cost-effective use of the Reporter.	Derived from 2019ADQ03

Table 5: Assessment Observation/Suggestion

Number	Recommendations to Network Rail	Benefits	Location in Text
2019ADQObs01	The ORR and NR should consider the nature of future independent data quality assessments for the master source comparison aspects of this assessments, considering factors such as; clarity of data requirements, communication of requirement, training, controls, routine monitoring of compliance and improvement of the data management system.	1. Considers modern data capture methods, where there is no independent source of comparison. 2. Is pro-active and ongoing rather than retrospective. 3. Is adaptable to emerging needs, rather than driving an 'A2' behaviour.	Various, deviations from the Mandate

Acknowledgements

The Independent Reporter Team would like to thank both NR and ORR staff for their assistance with this study.

1 Introduction

1.1 Background

Arup was appointed by the Office of Rail and Road (ORR) and Network Rail (NR) to undertake an assessment of NR's earthworks and structures asset data quality, in its role of Independent Reporter – Lot 3. The scope of the assessment is defined in Mandate L3AR005 (dated 3 May 2018) and as clarified by the ORR over the course of the assessment as described in this report. A copy of the Mandate is included at Appendix A.

The assessment was undertaken in two phases.

- Phase 1: Discovery and Definition; and
- Phase 2: Implementation of Review.

1.2 Mandate Requirements

This assessment of the asset data was commissioned as a result of a NR licence requirement and previous ORR determinations.

Condition 1.20 of Network Rail's licence states:

"1.20 The licence holder shall maintain appropriate, accurate and readily accessible information about the relevant assets, including their condition, capability and capacity."

Furthermore, in its PR13 Final Determination[3], the ORR specified that asset data quality for NR's earthworks and structures assets should be at 'A2'[4] for the datasets held by April 2017 –see Figure 1 and Figure 2 below.

[3] ORR Periodic Review 2013: Final determination of Network Rail's outputs and funding for 2014-19 October 2013

[4] The target confidence grade of A2 is set by asset type and based on a component for system reliability (the 'alpha') and data accuracy (the 'numeric').

Figure 1: Extract ORR PR13 Final Determination[1] – ORR Decisions (pages 23, 24)

Table 1: Summary of regulated outputs for CP5

Area	Outputs
Train service reliability	• Annual target for the percentage of trains on time (measured by PPM) for England & Wales and Scotland, with 92.5% on time by March 2019. • All franchised operators in England & Wales to reach 90% PPM by March 2019, except Virgin Trains which has a combined target of 88% PPM and 2.9% CaSL and East Coast which has a combined target of 88% PPM and 4.2% CaSL. First Great Western will have a minimum of 88% PPM for its long distance services.
	• Annual target for the percentage of trains cancelled or very late in England & Wales (measured by CaSL), with no more than 2.2% in this category by March 2019.
	• Annual target of 92.5% of freight trains on time (measured by the Freight Delivery Metric[14]).
Enhancements	• Wide range of improvement projects completed. Delivery milestones will be published in March 2014 delivery plan alongside development milestones for early stage projects. Includes funding for initial ETCS[15] cab fitment.
Safety	• Network Rail required to deliver a plan to maximise the reduction in risks of accidents at level crossings, using £99m ring-fenced fund[16]. This fund combines £67m from the DfT HLOS and £32m of further funding.
Disruption to passengers and freight caused by engineering works	• Disruption reduced by 8% for passengers and 17% for freight in 2019 compared to 2014, supported by an extension of funding for '7 day railway' projects.
Network capability	• Track mileage and layout, line speed, gauge, route availability, electrification at least maintained, and improved where there are enhancement works.
Stations	• Average condition maintained.
Asset management	• Asset management capability excellence achieved.
	• Asset data quality standards for all asset types.
	• Milestones for 'ORBIS' data improvement project.

Figure 2: Extract ORR PR13 Final Determination – ORR Decisions (pages 106, 107)

Table 3.8: Our decisions on asset data quality outputs

Asset Groups	May 2013 ARUP Scores	Output (April 2017)
Track		
Plain Line	B3	A2
Switches & Crossings	B3	
Signalling		
Interlockings	A2	A2
Signals	A3	
Train Detection Equipment	A3	
Point Operating Equipment	A3	
Level Crossings	A2	

Asset Groups	May 2013 ARUP Scores	Output (April 2017)
Telecomms	-*	A2
Electrical Power		
High Voltage Switchgear	-*	A2
Transformers	-*	
Overhead Line Equipment	B2	
Conductor Rail	B4	
High Voltage Cables	-*	
Buildings	B1	A2
Structures		
Underline Bridges	B5	A2
Overline Bridges	B5	
Earthworks	-*	A2

*The data quality of these asset types has not been fully assessed at the time of publication.

Audit of asset data quality, Arup, May 2013, http://www.rail-reg.gov.uk/pr13/publications/consultants-reports.php.

During CP5, NR further developed its ADGMS and implemented the regime at route level. This has led to the 'system reliability' aspect achieving an 'alpha' Confidence Grade of 'A' for all the relevant asset types when assessed by NR / ORR.

The Accuracy Grading system presented in the Mandate is reproduced below in Table 6. It was noted that the accuracy bands are different to those on which the scores presented in the CP5 Final Determination were based. For example, Band '2' in the table below requires an accuracy within 5%, while the agreed approach used in the 2013 review required an accuracy with 4%. During Phase 1 of this assessment (Kick-Off Tripartite meeting on 14th November 2018) it was agreed that equivalent measurements to the 2013 review would be used.

Table 6: Confidence Grading Assessment Matrix (from Mandate)

Accuracy Band	Description
1*	Data used to calculate the measure is accurate to within 0.1%
1	Data used to calculate the measure is accurate to within 1%
2	Data used to calculate the measure is accurate to within 5%
3	Data used to calculate the measure is accurate to within 10%
4	Data used to calculate the measure is accurate to within 25%
5	Data used to calculate the measure is accurate to within 50%
6	Data used to calculate the measure is inaccurate by more than 50%
X	Data accuracy cannot be measured

Notes:
1. Accuracy is a measure of the closeness of the data used in the system to the true values.
2. Accuracy is defined at the 95% confidence level - i.e. the true value of 95% of the data points will be in the accuracy bands defined above.

The scope of the review set out in the Mandate solely focuses on the data accuracy of the Earthworks and Structures assets based on information held at March 2017. During Phase 1, ORR and NR agreed and advised Arup[5] that they considered it more beneficial to base the assessment on an Assessment Dataset more current than March 2017, to provide a more contemporary picture of the data quality. The Assessment Dataset was therefore based on the NR Corporate and Regulatory Reporting datasets, which they secure monthly, using the one from the month of commencement of Phase 2 of the assessment.

The Mandate requires the assessment to be based on a statistical evaluation of how well the Assessment Dataset represents the real world, using a statistically significant sample. This assessment is required to be completed at the attribute level for each asset type under consideration. The assessment is to cover all routes and central functions, but only report at national level. The asset attributes by asset and sub-asset type to be considered are summarised below:

Table 7: Asset Attributes to be Tested (from the Mandate)

Asset Type	Sub Asset Type	Attributes	
Structures	Overline Bridges	ID	CMI score (Asset Level)
		Start Mileage	CMI score (PLBE)

[5] ORR, NR and Arup Tripartite meeting 14th November 2018.

Asset Type	Sub Asset Type	Attributes	
		Primary ELR	CMI Date
		Owning Party	Detailed Exam Date
		Operational Status	HCE examination date
		Primary Material	Number of Decks
	Underline Bridges	ID	CMI score (PLBE)
		Start Mileage	CMI date
		Primary ELR	Detailed Exam Date
		Owning Party	Underwater examination date
		Operational Status	Number of decks
		Primary Material	HCE examination date
		CMI score (Asset level)	
Earthworks	Embankment	Asset ID	Last Evaluation Date
		Currently included in Adverse / Extreme Weather Plan	Last Examination Date
		EACB	Operational Status
		Asset Examination Status	Owning Party
		EHC	Route
		Asset Type	Side
		ELR	Start Easting
		End Easting	Start Mileage
		End Mileage	Start Northing
		End Northing	Track Name
	Soil Cutting	Asset ID	Last Evaluation Date
		Currently included in Adverse / Extreme Weather Plan	Last Examination Date
		EACB	Operational Status
		Asset Examination Status	Owning Party
		EHC	Route
		Asset Type	Side
		ELR	Start Easting
		End Easting	Start Mileage
		End Mileage	Start Northing
		End Northing	Track Name
	Rock Cutting	Asset ID	Last Evaluation Date

Asset Type	Sub Asset Type	Attributes	
		Currently included in Adverse / Extreme Weather Plan	Last Examination Date
		EACB	Operational Status
		Asset Examination Status	Owning Party
		EHC	Route
		Asset Type	Side
		ELR	Start Easting
		End Easting	Start Mileage
		End Mileage	Start Northing
		End Northing	Track Name

During the course of Phase 1 of the assessment, it was agreed with the ORR that a sub-set of the earthworks attributes would not be tested for accuracy. This was because it was found that independent comparative data did not exist or limits to the data held had been agreed between the ORR and NR. This sub-set of earthworks attributes is described at Table 8.

Table 8: Earthwork Attributes Not Tested

Attribute	Reason Not Tested
Included in Adverse / Extreme Weather Plan?	Not assessed, as not maintained by NR pending the introduction of the NR CSAMS application, agreed at the meeting 3rd May 2019.
Earthwork Asset Criticality Band	Not assessed, no independent source of verification identified as this is maintained by the in-field aspects of the NR earthworks (JBA) application, agreed at the meeting 3rd May 2019.
Asset Examination Status	Not assessed, no independent source of verification identified as this is maintained by the in-field aspects of the NR earthworks (JBA) application, agreed at the meeting 3rd May 2019.
Earthwork Hazard Category	Not assessed, no independent source of verification identified as this is maintained by the in-field aspects of the NR earthworks (JBA) application, agreed at the meeting 3rd May 2019.
Owning Party	Not tested for accuracy, currently all assets in the data set are assumed to be owned by NR. There is work underway, to acquire data about third party earthworks which pose a risk to the railways which is being marshalled outwith the current data set, for inclusion in the CSAMS system but this is not yet maintained.

The dimensions considered for the data accuracy score are both the accuracy and completeness of the asset data, as defined below:

- Data Accuracy to evaluate the correctness of the data at attribute level. Accuracy is assessed from a comparison of data record attributes with independent data or review of the real-world assets.
- Data Completeness Assessment to evaluate how well the data set reflects the assets in the real world. Completeness is assessed based on the three types of errors:
    - No record (i.e. the asset exists in the real world but not in the database / asset register)
    - Spurious record (i.e. the asset exists in the system but not in the real world)
    - Duplicate record (i.e. two system records relate to the same physical asset).

1.3 Report Structure

The report structure, summarised at Table 9, has been designed to replicate the methodology which was adopted to deliver the commission. It recognises the Phase 1 work done to determine a methodology, identify the nature of the samples, and then describes the principle workstreams of accuracy and completeness achieved by the application of the methodology under Phase 2. It then progresses from the application of the methodology to the delivery of the assessment results, and the subsequent outcomes and recommendations.

Table 9: Report Structure

Section	Title	Purpose
Section 2	Methodology	A description of the methodology adopted for both Phase 1 and Phase 2 of the assessment.
Section 3	Dataset Assessment	A description of the application of the methodology to the assessment. The main body is split between the two major workstreams during the implementation of the assessment, of accuracy and completeness.
Section 4	Conclusions	Draws together the results of the application of the methodology and the two major workstreams, to provide an overview and detail of the assessment findings.
Section 5	Recommendations	Recommendations arising from the definition of the methodology and its application.

Appendices are included that provide additional detail in support of the main text. They are used to simplify the flow of the report, while retaining the detail generated during the course of the assessment.

1.4 Glossary of Terms

Term	Meaning
ADCGAM	Asset Data Confidence Grading Assessment Measure, version used Network Rail ADCGAM Methodology and Toolkit Apr 2012
ADGMS	Asset Data Governance Management System
BCIM	Bridge Condition Marking Index, see also CMI, previously known as SCMI
CARRs	Civils Asset Register and Reporting System
CMI	Condition Marking Index for bridges, also known as BCMI and previously SCMI
CP4 or 5	Control Period 4 (*2009/10 -2013/14*) or 5 (*2014/15-2018/19*)
CSAMS	Civil Structures Asset Management System
CSV	Comma Separated Variable, file format
EACB	Earthworks Asset Criticality Band
EHC	Earthwork Hazard Category
ELR	Engineers Line Reference, used to segment the NR network into extents
GUID	Globally Unique Identifier
HCE	Hidden Critical Element of a bridge
HDD	Hard Disk Drive
LiDAR	Light Detection and Ranging
NAO	National Audit Office
ORBIS	Offering Rail Better Information Services

Term	Meaning
OS	Ordnance Survey
PLBE	Principal Load Bearing Element of a bridge
RINM	Railway Infrastructure Network Model
SCMI	Structures Condition Marking Index (forerunner to BCMI)

2 Methodology

2.1 Introduction

This section describes the methodology used to carry out both the accuracy and completeness assessments of the five sub asset types and to provide an overall grade for the datasets of each asset sub-type.

2.2 Overview

The approach is set out below, reflecting the requirements of the Mandate and building upon the Independent Reporter experience gained in CP4 and CP5.

At the highest level, the assessment was undertaken in two phases.

- Phase 1 Definition and Discovery; and
- Phase 2 Implementation of Review.

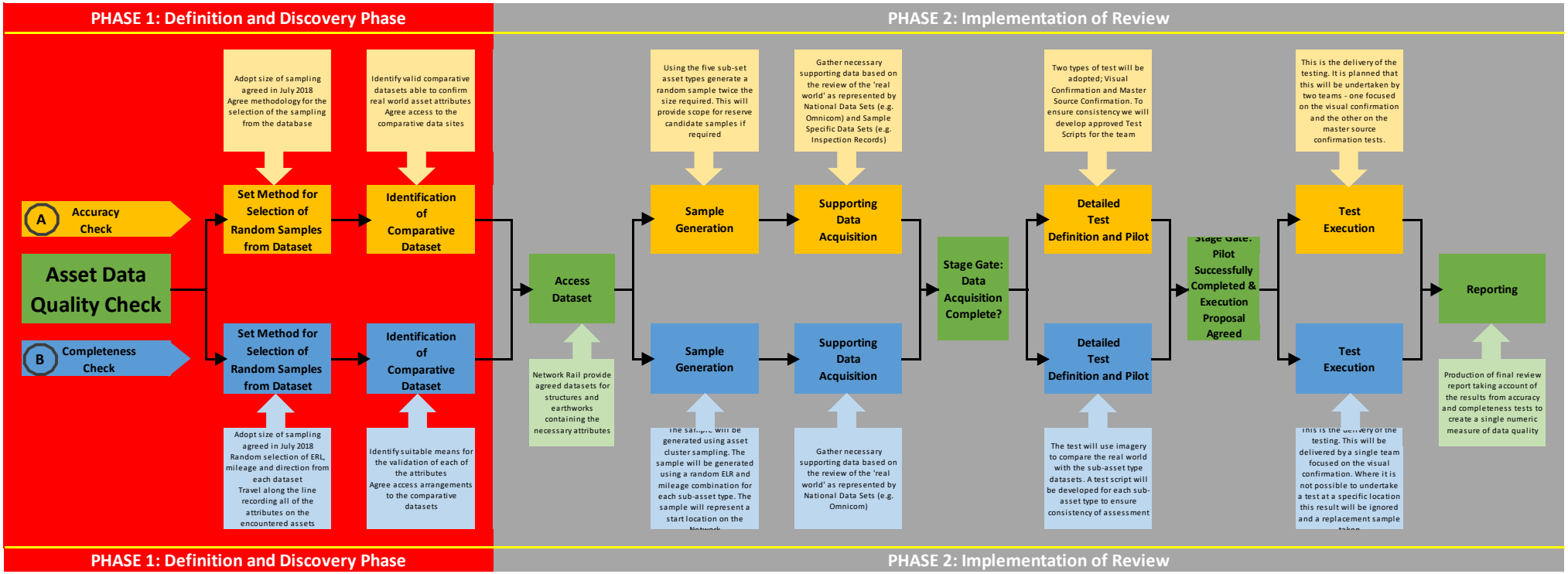
The findings under Phase 1 informed the detail of Phase 2 and the aspects of this methodology specific to this assessment.

The Phase 2 approach comprises four elements, described pictorially at Figure 3 below and in the subsequent sections of this methodology:

- Access Assessment Dataset;
- Data Accuracy Measurement;
- Data Completeness Measurement; and
- Reporting and Refinement.

The approach allowed the main streams of Data Accuracy Measurement and Data Completeness Measurement to run in parallel. There were measures to prevent conflation of the two measurements.

Figure 3: Methodology - High Level View



2.3 Phase 1 Approach – Definition and Discovery

2.3.1 Data Gathering

NR and ORR provided core data sets and background information in consultation with the Independent Reporter, this included:

- Network Rail Asset Data Governance Management System;
- Network Rail's statistical methods for sampling its assets to be stratified and cluster sampling;
- Details of the approach to the measurement of data accuracy adopted already for Track, Signals, Operational Property, Telecoms, Electrification and any associated reports;
- Details of the ORBIS project for standardising asset data upload;
- Latest revision of ADCGAM methodology;
- Asset Data Quality Improvement Plan (ADQIP) and baseline.
- Contemporary assessment datasets, including a description of how extracts were obtained.
- Details of the roles and responsibilities of the Routes and Central Functions in respect of Asset Data.
- Most suitable independent data sources for validating data sets.

2.3.2 Data Background Analysis

On collation and assimilation of the initial data, the study team met with ORR and NR representatives to ensure an understanding of:

- Previous Data Accuracy gradings for Earthworks and Structures and how they were assessed;
- *'….The independent reporter graded the quality of civils asset data required for licence compliance B5, reflecting the incomplete records for datasets which Network Rail has recently started collecting. It assessed the quality of civils asset data for SBP planning purposes to be B4.'*[6];
- Baseline for Network Capability in CP5 set out by ORR in the Final Determination;
- NR work to date for other assets to take advantage of improvements in the use of remote sensing and other information sources; and
- Other pertinent information.

The meeting also identified contacts (NR Central and Routes) as part of the work in Phase 1 or Phase 2.

[6] ORR Final Determination 8.434 page 100

2.3.3 Define Phase 2 Methodology

The review developed a clear, unambiguous methodology for Phase 2. This was clear about the baseline data, the assessment process and how results / findings would be assessed and reported.

This was achieved by analysis of the data and information received, together with further input from ORR and NR representatives.

The Phase 2 methodology considered:

- Alignment with ADGCAM approach;
- Data flows;
- Approach to assessing contemporary datasets;
- Sampling approach to satisfy required levels of accuracy;
- Overall approach to completeness assessment;
- Use of remote sensing and other visual means to “ground truth” asset records;
- Overall approach to accuracy determination;
- Rules and tolerances for validating each asset attributes;
- Validation “pass / fail” criteria for each asset attribute;
- Weighting of scores for individual attributes; and
- Aggregation of completeness and accuracy scores into a single numeric confidence grading for each asset group.

The Phase 2 methodology was agreed with ORR and NR. Critically this saw agreement between all parties on the datasets to be used, the data to be audited, the tests to be carried out, the pass / fail criteria to be applied, and the weighting of parameters.

2.4 Phase 2 Approach – Implementation of Review

2.4.1 Access Assessment Dataset

Phase 2 commenced on the receipt from NR of contemporary asset data, for the five sub asset types to be assessed; overline bridges, underline bridges, embankments, soil cuttings and rock cuttings.

On receipt, the data was secured and, by reference to the Phase 1 data discovery work, was verified that it was:

- In the format expected;
- Solves the issues notified to NR against the corresponding asset data supplied during Phase 1;
- Of similar volume to previous; and
- Has similar ranges of values to previous.

Where there were issues identified with the data set, these were raised immediately with NR for discussion and remedy.

2.4.2 Data Accuracy Measurement

The aim of the data accuracy measurement is to confirm the attribute values, for approximately two hundred assets of each sub asset type, in order to meet the confidence requirement.

The following sub-sections describe how this was delivered:

- Generate the sample to be assessed;
- Gain the supporting data, in addition to the asset data necessary to undertake the accuracy measurement;
- Define the detailed test procedures that were used to determine accuracy, at an attribute level and pilot-test these procedures; and
- Execute the full test set.

2.4.2.1 Sample Generation

Using each of the five sub asset types as strata, a random sample of assets was generated of approximately twice the size of the number to be assessed. The random sample members were then secured, so that subsequent manipulation of the data did not affect it e.g. through sorting, filtering.

The random sample size was larger than the number to be assessed so that there were reserve candidates to use if the assessment was unable to undertake an attribute test against a random sample member. This allowed the achievement of execution of the requisite number of tests per attribute, per asset type to satisfy the required sampling confidence level. Given the samples were being tested in two independent streams, this meant that different attributes of an asset may be tested against different sub-sets of the random sample.

Examples of when it may be necessary to use reserve candidates are:

- Using the asset attribute information, inability to locate a random sample member within imagery to undertake visual confirmation tests. Therefore, move on to a reserve candidate and prevent conflation of the accuracy and completeness assessments; or
- The quality of imagery is insufficient to undertake visual confirmation tests, for example the images are taken in poor light. Therefore, move on to a reserve candidate, as the imagery is not being directly tested; it is supporting data.

2.4.2.2 Supporting Data Acquisition

Supporting data acquisition took place in parallel with detailed definition and consisted of:

- National data sets; and

- Sample specific data sets.

National data sets were intended to be used to undertake visual confirmation of attribute values against alternative sources. Phase 1 identified the following NR data sets, to be provided:

1. High resolution aerial imagery, as exposed in the RINM system, for the ELRs in the random samples;
2. Oblique imagery (provided via access to the NR Route Viewer application);
3. Processed LiDAR, as exposed in the RINM system, for the ELRs in the random samples; and
4. A spatial representation of all routes, sub-divided to ELRs, with attribution including start and end mileages for the ELRs.

During the course of the assessment other data sources were used which were not supplied by NR. These included:

1. NR detailed route and ELR specifications, from the National Electronic Sectional Appendix, at https://www.networkrail.co.uk/industry-commercial-partners/information-operating-companies/national-electronic-sectional-appendix/
2. Google earth and street view;
3. OS mapping; and
4. OS OpenStreetMap.

Images in the sample specific data sets were also used, to aid visual confirmation.

The sample specific supporting data sets were used to undertake master source confirmation of attribute values. This data was needed for the random sample members, by asset type.

The assessment agreed with NR that the provision of the sample specific data sets would be in close temporal proximity to the core data for assessment. This lowered the potential for mis-matches between the sets due to changes over time intervals.

During the course of Phase 1 the following NR data sets were identified to provide the random sample members, in relation to overline and underline bridges:

1. Detailed examination cycle interval, by bridge;
2. Bridges subject to HCE examinations and the HCE examination cycle interval by bridge;
3. Bridges subject to underwater examination and the underwater examination cycle interval by bridge;
4. Latest inspector / engineer detailed examination report, by bridge;

5. Latest inspector / engineer HCE examination report, by bridge;
6. Latest inspector / engineer underwater examination report, by bridge;
7. Listing of principal load bearing element, by bridge, using the same coding as in the detailed examination reports; and
8. Written agreements of bridge ownership, by bridge, for the sample members not owned by NR.

Phase 1 identified the following NR data sets for the random sample members, in relation to embankments, soil cuttings and rock cuttings:

1. Latest inspector / engineer detailed examination report, by earthwork asset;
2. Latest inspector / engineer evaluation report, by earthwork asset;
3. Examination cycle, by earthwork asset;
4. Evaluation cycle, by earthwork asset; and
5. Adverse / Extreme Weather Plans, covering all earthwork assets in the sample.

The commencement of test execution, both pilot and full, was dependent on the receipt of all the supporting data.

2.4.2.3 Detailed Test Procedure Definition

During Phase 1, two principal test types for accuracy measurement were identified:

- Visual confirmation; and
- Master source confirmation.

Visual confirmation used imagery to confirm the value of an attribute and/or its measurement.

Master source confirmation used an alternative, original source of data to confirm the value of an attribute.

The principle test types, supporting data, tests outlines, and pass criteria for the assets and their attributes, is as described in Table 10 and Table 11 below.

Table 10: Bridges Test Type, Supporting Data and Processes

Attribute	Test Type	Supporting Data Set	Primary Test Process	Pass Criteria	Secondary Test Process	Pass Criteria
ID	Master Source Confirmation	Core Data Set only	Format and uniqueness	Binary	-	-
Start Mileage	Visual Confirmation	National Data Sets	Repeat the measurement made by NR engineering, via remote surveying	Binary to +/- 25m	-	-
Primary ELR	Master Source Confirmation	National Data Sets	Cross check to NR detailed route and ELR maps	Binary	For rail over rail, confirm against rules and cross check asset type	Binary
Owning Party	Master Source Confirmation	Sample Specific Data Set, Agreement of Ownership (non-NR owned)	Conditionally, for ownership is prefixed 'Network Rail' cross check operational status and detailed examination date combination	Binary	Conditionally, for ownership not prefixed 'Network Rail' written confirmation of ownership with other party exists	Binary
Operational Status	Visual Confirmation	National Data Sets	Does the visible operational status match that in the data set?	Binary	-	-
Primary Material	Master Source Confirmation	Sample Specific Data Set, Detailed Examination Report	Does the primary material in the examination report imagery match that in the data set?	Binary	-	-
Condition Marking Index Score (Asset Level)	Master Source Confirmation	Sample Specific Data Set, Detailed Examination Report, Detailed Examination Cycle	Conditionally, for NR responsibility does the BCMI score in the latest detailed examination report match that in the data set?	Binary	Conditionally, for non-NR responsibility, is this null?	Binary
Condition Marking Index Score (PLBE)	Master Source Confirmation	Sample Specific Data Set, Detailed Examination Report, Detailed Examination Cycle, PLBE Identities	Conditionally, on NR responsibility does the CMI score in the latest detailed examination report match that in the data set?	Binary	Conditionally, for non-NR Responsibility, is this null?	Binary

Attribute	Test Type	Supporting Data Set	Primary Test Process	Pass Criteria	Secondary Test Process	Pass Criteria
Condition Marking Index Date	Master Source Confirmation	Sample Specific Data Set, Detailed Examination Report, Detailed Examination Cycle	Conditionally, for NR responsibility: On or after the detailed examination date, within tolerance? Within range of the examination cycle?	Binary to +/- 3.5 or 5 Months	Conditionally, for non-NR responsibility, is this null?	Binary
Detailed Examination Date	Master Source Confirmation	Sample Specific Data Set, Detailed Examination Report, Detailed Examination Cycle	Conditionally, for NR responsibility: Does this reflect the latest detailed examination report? Within range of the examination cycle?	Binary Binary to +/- 3.5 or 5 Months	Conditionally, for non-NR responsibility, is this null?	Binary
Underwater Examination Date (underline bridges only)	Master Source Confirmation	Sample Specific Data Set, Underwater Examination Report, Underwater Examination Cycle, Underwater Examination Members	Conditionally, for NR responsibility and the asset subject to underwater examination: Does this reflect the latest underwater examination report? Within the currency range of the examination cycle?	Binary Binary to +/- 3.5 or 5 Months	Conditionally, for non-NR responsibility, is this null? Conditionally, for NR responsibility but not subject to underwater examination, is this null?	Binary
Hidden Critical Element Examination Date	Master Source Confirmation	Sample Specific Data Set, HCE Examination Report, HCE Examination Cycle, HCE Examination Members	Conditionally, for NR responsibility and the asset subject to HCE examination: Does this reflect the latest HCE examination report? Within range of the HCE examination cycle?	Binary Binary to +/- 3.5 or 5 Months	Conditionally, for non-NR responsibility, is this null? Conditionally, for NR responsibility but not subject to HCE examination, is this null?	Binary
Number of Decks	Visual Confirmation	National Data Sets	Does the number of decks match that in the data set?	Binary	Is the relationship between the number of decks and asset type correct?	Binary

Table 11: Earthworks Test Type, Supporting Data and Processes

Attribute	Test Type	Supporting Data Set	Primary Test Process	Pass Criteria	Secondary Test Process	Pass Criteria
Asset ID	Master Source Confirmation	Core Data Set only	Format and uniqueness, this is the combination of Start Mileage, End Mileage, Side and Track ID	Binary	-	-
Asset Type	Visual Confirmation	National Data Sets	Does the visible asset type match that in the data?	Binary	-	-
ELR	Master Source Confirmation	National Data Sets	Cross check to NR detailed route and ELR maps	Binary	-	-
End Mileage	Not tested for accuracy, earthworks are divided into five chain, track relative, lengths. Each length constitutes an asset record, there are therefore no visible, earthwork relative, real world markers. Mileages were used as part of the completeness assessment.					
End Easting	Visual Confirmation	National Data Sets	Does the co-ordinate pairing equate to the End Mileage measurement?	Binary to +/- 25m[7]	-	-
End Northing						
Last Evaluation Date	Master Source Confirmation	Sample Specific Data Set, Latest Evaluation Report, Evaluation Cycle	Conditionally if subject to evaluation, then does the data in the Evaluation Report, match that in the data set? Within the currency range of the evaluation cycle?	Binary Binary to +/- 3, 6 or 12 months	Conditionally if not subject to evaluation, is this null?	Binary

[7] There is not a definition of the precision and tolerance required of co-ordinate pairings in the NR engineering standards, it was agreed at the meeting 7th June 2019 that the same tolerance should be used as with bridges as discussed between ORR and NR.

Attribute	Test Type	Supporting Data Set	Primary Test Process	Pass Criteria	Secondary Test Process	Pass Criteria
Last Examination Date	Master Source Confirmation	Sample Specific Data Set, Detailed Examination Report, Examination Cycle	Does this reflect the latest examination report? Within range of the examination cycle?	Binary Binary to +/- 3, 6 or 12 months	-	-
Operational Status	Visual Confirmation	National Data Sets	Does the visible asset status match that in the data?		-	-
Route	Visual Confirmation	National Data Sets	Does the asset lie within the route quoted in the data set?	Binary	-	-
Side	Visual Confirmation	National Data Sets	Does the asset appear on the side quoted in the data set?	Binary	-	-
Start Mileage	Not tested for accuracy, see End Mileage considerations.					
Start Easting	Visual Confirmation	National Data Sets	Does the co-ordinate pairing equate to the Start Mileage measurement?	Binary to +/- 10m	-	-
Start Northing						
Track Name	Visual Confirmation	National Data Sets	Does the asset appear on the track quoted in the data set?	Binary	-	-

In addition to the principal test type, aspects of the basic data structure of the entries were considered, for example valid value range and uniqueness. Some tests contained conditional elements, for example last examination date should exist where NR is responsible for the asset but not where it is not.

Detailed test procedures were developed containing:

- Test Reference;
- Test Description;
- Attributes(s) to be confirmed;
- Reference materials;
- Test steps; and
- Expected results of test steps.

The procedures supported, during test execution, the recording of:

- Asset IDs tested
- Test step results;
- Actual result where other than expected;
- Testers notes; and
- Derivation of the overall test result from the step results.

A detailed test procedure typically considered a discrete attribute, but directly related attributes were combined, for example co-ordinate pairings. The aim was not to create dependencies between different tests, particularly between the principal test types, so that tests could be executed in parallel.

The detailed test procedures were submitted to ORR and NR for comments, for resolution between the authors and reviewers. Any unresolved comments were considered by a joint meeting with ORR and NR, to determine an agreed way forward. Pilot versions were then issued.

2.4.2.4 Test Pilot

Test execution of around 15% of the required sample were undertaken (i.e. ~30 tests) in the pilot test as described in section 2.4.2.5 below. This allowed the proving of the testing procedures, asset and supporting data and de-risked full test execution.

On completion of the pilot tests, consolidated results were provided to ORR and NR and any remedial actions agreed prior to full test execution via a tri-partite meeting, which considered:

1. Any refinement of detailed test procedures;
2. Adjustments to asset or supporting data needs; and/or
3. Repetition of parts of the pilot.

On completion of actions following the pilot and its review agreement was then reached with ORR and NR to proceed into full test execution.

The pilot exercise provided ORR and NR with an early indication of outcome, albeit at a low confidence level. At this point, full and summary reports were not produced as set out in section 2.4.4 below.

2.4.2.5 Test Execution

Tests were split between two teams, a visual confirmation test team (delivered by Geospatial Insight) and a master source confirmation test team (delivered by Arup). A tester undertook multiple tests concurrently against a random sample member, for example if a visual confirmation tester located a bridge from the random sample within the imagery then all visual confirmation tests were undertaken. This reduced the location overhead.

If a test or tests could not be undertaken against a random sample member, then the tester moved on using the reserve candidates as described at section 2.4.2.1 above. This avoided the need to take time out to gain additional or alternative information. If unable to undertake a test against a random sample member then the test results were put to null. Such null results were not included in the analysis contributing to the scoring during the Reporting and Refinement stage.

Testers undertook the test steps set out in the detailed test procedures defined at section 2.4.2.3 above and recorded the test results.

The results, per random sample member, recorded at a test step level were:

- **Pass**, if the actual result matched the expected result;
- **Fail**, if the actual result did not match the expected result, in which case the actual result and any testers notes were also recorded; and
- **Not Proven**, if the tester was unable to determine pass or fail, in which case the testers notes of why this result was given was also recorded.
- **Not Applicable**, where the conditions of a conditional test did not apply to the random sample member. Not Applicable results were not used in the derivation of overall test results to scores.

Test results for conditional tests between two or more attributes, were recorded against the attribute which was the subject of the test, not each attribute used in the test. This meant that an issue was only attributed once. Similarly, this assessment considered asset data accuracy, not root cause identification of matters arising. An example of such a conditional test is that if a bridge is subject to detailed examination, by NR, then the CMI date should be on or after the detailed examination date where both of these dates are included in this assessment, if the CMI date is not on or after the detailed examination date then it is the CMI date check that fails not both date checks.

The Not Proven test step outcome was intended to be used sparingly and was monitored, to ensure its use did not get out of hand. However, it allowed the review to continue through test execution, then revisit these outcomes potentially

in conjunction with NR during the refinement period of the Reporting and Refinement stage, at section 2.4.4 below.

An example of where a Not Proven result occurs was, the identification of a random sample bridge successfully within the imagery, but there being insufficient imagery available at that point to assess the Primary Material. Thus, the Primary Material result is Not Proven, at this point.

The derivation of overall test result from the step results of its detailed test procedure steps, for each random sample member, was the first of the following to be satisfied:

1. If all test steps for that test and random sample member were recorded as Pass, then the test for that random sample member is Pass;
2. If any test step for that test and random sample member is recorded as Not Proven, then the test for that random sample member is Not Proven; or
3. If any test step for that test and random sample member is recorded as Fail, then the test for that random sample member is Fail.

Test execution continued until there were sufficient test results to achieve the required confidence level, approximately two hundred assets of each sub asset type tested.

2.4.3 Data Completeness Measurement

The aim of the data completeness measurement was to make a bi-directional comparison between the assets of each asset sub-type in the real world and the asset data, to determine:

- Assets which exist in the real world, which have corresponding entries in the asset data;
- Assets which exist in the real world, which do not have corresponding entries in the asset data; and
- Assets which exist in the data, which do not exist in the real world.

Approximately two hundred real world assets, of each asset sub-type, were assessed in order to achieve the confidence requirement.

The data completeness assessment took place at the asset level. Within the assessment, the accuracy of attribute values was not tested to prevent conflation of the accuracy and completeness assessments. The asset attributes were used within the assessment, to check locations and sub-types.

The following paragraphs describe how the study:

- Generated the sample to be assessed;
- Gained the supporting data, in addition to the asset data necessary to undertake the data completeness measurement;

- Defined the detailed test procedures that would be used to determine data completeness at an asset level; and
- Executed those tests.

2.4.3.1 Sample Generation

An asset cluster sampling approach was used for data completeness assessment, each cluster being determined by a rail network extent.

A set of random ELR/mileage combinations were generated, each ELR/mileage combination being the start location of a rail network extent.

The end location of a rail network extent would then be determined during test execution, see section 2.4.3.5 below. Broadly test execution remotely surveyed the network, using imagery, in ascending milepost direction from the start location identifying pertinent real-world assets until the first of:

i) five pertinent real-world assets of each sub-asset type had been found, or

ii) the ELR ends.

The end location was then the location of the twenty-fifth pertinent real-world asset, or the end of the ELR respectively.

This meant that the asset cluster size for a rail network extent was zero to five times five real-world assets, plus any asset data records within the rail network extent which did not have a real-world equivalent, per sub-asset type.

In an ideal situation, therefore around forty-two random ELR/mileage combinations would be needed, to undertake a data completeness assessment of about two hundred assets per sub-asset type, to achieve the confidence requirement.

One hundred and twenty random ELR/mileage combinations would be generated and used in turn until the achievement of the confidence requirement, to cater for factors such as:

- Reaching the end of the ELR;
- Sparsity of some sub-asset types in some areas e.g. rock cuttings; and
- Poor light quality imagery, rendering remote surveying unreliable.

It should be noted that this sampling approach means that an asset could exist in more than one rail network extent, for that sub-asset type and therefore its remote survey could be repeated. This is a result of cluster sampling at random locations. It was believed that this was a minor matter, given the volume of each sub asset type nationally. Recording the Asset IDs was included in the assessment during test execution, hereby monitoring any repetitions.

2.4.3.2 Supporting Data Acquisition

See section 2.4.2.2 above, national data sets.

2.4.3.3 Detailed Test Procedure Definition

To carry out the data completeness assessment, imagery was used to compare the real world with the sub asset type data sets.

Detailed test procedures were developed, for each sub asset type which set out how the completeness assessment was to be conducted within a rail network extent. The procedures defined the steps for the identification of:

- Assets which exist in the real world and once in the data set (Correct Record);
- Assets which exist in the real world and more than once in the data set (Duplicate Record);
- Assets which exist in the real world, but do not exist in the data set (No Record); and
- Assets which exist in the data set, but do not exist in the real world (Spurious Record).

Detailed test procedures were developed which contained comparable content and recording capabilities to those for accuracy at 2.4.2.3 above.

Attribute values were not tested in the completeness assessment, but location attributes were used to compare the real world with the data. The same tolerances on location attributes were used to compare the real world with the data, as with the accuracy assessment.

There are two earthwork specific considerations, factored into the detailed test procedures:

1. Earthworks are modelled in the data as a series of assets of up to five chains in length, so for example an embankment a mile long would appear in the data as approximately sixteen assets. To prevent this model perverting the completeness assessment, the first asset record encountered was used for the overall earthwork feature as a proxy for the whole earthwork.
2. The definition of an earthwork in the NR engineering standards, allows for engineering judgement to be applied where the earthwork elevation is less than three metres, as to whether that asset should be recorded. It was assumed that this judgement had been applied when considering such data, as an engineering matter not a data matter.

The detailed test procedures were submitted to ORR and NR for comments, for resolution between the authors and reviewers. Any unresolved comments were considered jointly with agreed versions then adopted.

2.4.3.4 Test Pilot

Test execution of around 15% of the required sample was undertaken, as described in section 2.4.3.5 below. This allowed for the proving of the testing procedures, asset and supporting data and de-risked full test execution.

On completion of the pilot tests, consolidated results were provided to ORR and NR and actions agreed to modify any deficiencies undertaken prior to full test execution, via a tri-partite meeting, which included:

1. Refinement of detailed test procedures; and
2. Adjustments to asset or supporting data needs.

Following the successful delivery of the pilot agreement was reached with ORR and NR to proceed into full test execution.

As with the accuracy exercise this provided ORR and NR with an early indication of the study's completeness outcome, albeit at a lower confidence level than that finally required.

2.4.3.5 Test Execution

If unable to undertake a test or tests from the start of a rail network extent, then the tester moved on using the alternate candidates as described at section 2.4.3.1 above. This avoided the need to take time out to gain additional or alternative information. If unable to undertake a test against a rail network extent, then the test results were put to null. Null results were not included in the analysis leading to scoring during the Reporting and Refinement stage.

The testers undertook the test steps set out in the detailed test procedures defined at section 2.4.3.3 above and recorded the test results.

The results, per asset of sub asset type per rail network extent, recorded at a test level were:

- Pass, if the result is Correct Record and the Asset ID is recorded; and
- Fail, if the result is Duplicate Record, No Record or Spurious Record. In these cases the actual result, testers notes, and Asset ID was recorded. In the No record case, then Asset ID is derived from the real-world location, using the same location referencing approach as if it had been in the data set.

Test execution continued until there were sufficient test results to achieve the required confidence level.

2.4.4 Reporting and Refinement

The following were undertaken:

- Results consolidation and summation;
- Not proven result refinement; and
- Full and summary report generation and agreement.

Results consolidation and summation and Not Proven result refinement were undertaken in parallel. On completion of both, full and summary report generation and agreement took place.

2.4.4.1 Results Consolidation and Summation

Two results models were created, one for each of the accuracy and completeness assessments. Individual testers results were combined into these models to produce a consolidated set of results, resolving any results set anomalies and format glitches. The models included the summarisation from the test results, ultimately to an accuracy and a completeness score per sub asset type.

For the accuracy tests, the results were presented at an attribute level and therefore the summation, in the first instance, lead to attribute accuracy and then aggregate to sub asset type accuracy. Each attribute, within each sub-asset type, was treated as being of equal importance.

For completeness tests the results were produced at asset level, so the summation went straight to sub asset type completeness. It identified any test failures by type.

Not Proven results were not included in the summation, as they were subject to the refinement tasks below. These results were modified from Not Proven to either Pass or Fail during refinement and thereafter included.

Consolidated results and summation were shared with ORR and NR as soon as the models were stable and internally verified.

2.4.4.2 Not Proven Result Refinement

The aim of this activity was to convert any Not Proven accuracy results to either Pass or Fail. This was carried out working collaboratively with NR using the following sources to refine the results:

- Photographs from NR reports or assessments;
- Drawings; and
- Discussions with NR engineers with local knowledge.

3 Dataset Assessment

3.1 Introduction

This section describes how the methodology defined at section 2 above was applied during the assessment.

3.2 Application of Methodology – Phase 1

3.2.1 Data Gathering

3.2.1.1 Core Datasets

The Core Datasets contain the attribute values which were evaluated for accuracy. The records within these datasets constitute the recorded inventory, the extent of which was evaluated for completeness.

Trial versions, for discovery purposes, of these datasets were obtained from NR, from their monthly extracts for corporate and regulatory reporting purposes. The sets for bridges were from April 2017 and for earthworks from November 2018. Section 3.3.2.1 below provides a description of these datasets and their mapping to the mandate, for the later versions formally reviewed under this assessment.

3.2.1.2 Background Data

Background data supports the definition of tests to assess the accuracy and completeness of the core datasets. It is used in the data background analysis activity to identify the systems and business rules that apply to the data under assessment.

General background data obtained was:

- Network Rail ADCGAM Methodology and Toolkit Apr 2012;
- Supporting Evidence on Data Accuracy to March 2017; and
- Asset Data Governance and Assurance Framework V1.

Bridges background data obtained was:

- Structures core data specification;
- A2 Structures Core Data Methodology Rev04;
- NR_BS_LI_167 - Requirements for the exposure of HCE;
- NR_L1_CIV_032 - Management of Structures;
- NR_L2_CIV_035 - Structural Assessments;

- NR_L3_CIV_006_1A - Examination of Structures Purpose, Scope and Definitions;
- NR_L3_CIV_006_1B – Examination of Structures Types of Regime;
- NR_L3_CIV_006_1C - Determining the Examination Regime; and
- NR_L3_CIV_006_2C - Condition Marking of Bridges.

Earthworks background data obtained was:

- NR_L2_CIV_086 - Management of Earthworks;
- NR_L2_CIV_086_Mod01 - Earthwork Evaluations;
- NR_L2_CIV_086_Mod12 Definition of Earthwork Criticality;
- NR_L3_CIV_065 - Examination of Earthworks;
- NR_L3_CIV_065_Mod02 Soil Cutting Hazard Index;
- NR_L3_CIV_065_Mod04 Soil Embankment Hazard Index; and
- TIDs – Earthwork Track Identification.

3.2.2 Data Background Analysis

The assessment attributes within the core datasets were profiled to establish:

- Data types;
- Ranges;
- Coding;
- Mandatory/optional conditions; and
- Coverage of the mandate.

The profile was combined with an analysis of the background data to formulate sets of questions, by asset type, about the system and business rules governing the data. Responses to the questions were gathered in meetings with NRs representatives of the Professional Heads for structures and earthworks, the Asset Information Group and route representatives for structures and earthworks.

The analysis also drew out the availability of independent comparative datasets, to be used for verification purposes. A meeting was held with NRs spatial data teams, to understand the availability, currency and coverage of imagery, LiDAR and network model datasets to support remote visual surveying of the assets.

3.2.3 Define Phase 2 Methodology

In parallel with the activities above, the Phase 2 methodology was defined and refined from the results of the analysis. Particularly, this covered the nature of the

tests to be undertaken and the supporting data sets for these tests, defined at sections 2.4.3.3 and 2.4.3.2 of the Phase 2 methodology respectively.

The Phase 2 methodology was presented to the ORR and NR at the Tripartite meeting 12th February 2019 for review, then approved through its commissioning.

3.3 Application of Methodology – Phase 2

3.3.1 Sample Generation

The assessment was based upon studying samples of the data against the real world, or master source data, with the sample sizes statistically designed to meet the Accuracy Grading required by the Mandate, as set out in the methodology sections 2.4.2.1 and 2.4.3.1 above.

The selection of sample size to appropriately assess these data quality parameters was determined using statistical sampling theory appropriate for proportionality sampling. The appropriate sample size was determined based on the required precision (or vice versa). The formulae used to calculate sample size and sample precision are derived from statistical sampling theory. The process is described in the ADCGAM and summarised in the boxed text below. The method is also described by the NAO in their current sampling guidance[8].

[8] A Practical Guide to Sampling, NAO; 2001.

Sample Size and Precision Calculations (from the ADCGAM toolkit)

The sample size needs to be determined based on the required precision (or vice versa). The formulas that were used to calculate sample size and sample precision were derived from statistical sampling theory.

FORMULAE

Sample Size

$$ss = \frac{Z^2 * (p) * (1-p)}{c^2} \quad \text{and rearranging for c;} \quad c = Z * \sqrt{\frac{p*(1-p)}{ss}}$$

Where:
ss = sample size
Z = Z value (1.96 for 95% confidence level, 1.65 for 90% confidence level, 2.58 for 99% confidence level)
p = percentage picking a choice, expressed as decimal (0.5 used for sample size needed)
c = precision, expressed as decimal (e.g., .04 = ±4%)
√ = square root

Correction for Finite Population

$$\text{new ss} = \frac{ss}{1 + \frac{ss-1}{pop}}$$

pop = population

For this review 'Finite Population' calculations were used. At the point of calculating the required sample size, the number of assets recorded in the asset database most likely gives a fair indication of the number of assets in the population (at least an order of magnitude). The 'Infinite Population' calculations need to be used if:

- The number of assets recorded in the asset database is not a true reflection of the number of physical assets; or
- For a new asset types when the number of assets is unknown and very large

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SAMPLE SIZE AND PRECISION

TO CALCULATE REQUIRED SAMPLE SIZE

Population Size	1,000
Required Precision (±)	5%

Sample Size

FINITE POPULATION		
99% Conf	95% Conf	90% Conf
400	278	214

TO CALCULATE PRECISION WITH A FIXED SAMPLE SIZE

Population Size	1,000
Sample Size	300

Precision (±)

FINITE POPULATION		
99% Conf	95% Conf	90% Conf
±6.23%	±4.74%	±3.99%

Interpretation
On a population of 1000 with ±5% required Precision, a sample size of 278 is required for 95% confidence level.

Similarly, using a sample of 300 will provide a precision value of ±4.74% at a 95% confidence level

For example:

- Assume there is an asset population of 1,000 and we want to achieve a +5% precision at a 95% confidence level;
- The Sample Size calculator tells us to take a sample of 278 assets;
- If during subsequent assessment we found 250 (of 278) were recorded correctly then this represents an accuracy of 90%;
- Thus, in the total population, between 85% and 95% will be accurate with a probability of 95%.

Therefore, the 95% confidence interval for accurate assets is between 850 and 950 assets have accurate information.

The sample sizes for each of the accuracy and completeness exercises were determined taking into consideration the previous assessment of asset data accuracy and completeness carried out during 2013. In these assessments the considered opinion was that the data quality was at least 90%. This hypothesis was used to inform the sample sizes. To determine appropriate sample sizes the calculations were based on the assumed incidence of pass / fail to be 90/10. For example, and based on the above example, this reduces the required sample to 121 assets (population of 1000 assets with a +5% precision at a 95% confidence level).

For the assessment the agreed parameters were a 95% confidence and 4% precision (allowing an accuracy grading of '2', or better, to be awarded if the sample demonstrates suitable compliance). Based on this approach the review was undertaken based on producing approximately 200 results (e.g. 207 samples for a population of 5000 assets for accuracy results) as being appropriate for an "infinite" population with this expected pass / fail incidence.

Two sets of random samples were produced, as described in the sub-sections below, for the following purposes:

1. Random Asset Samples were generated for each of the five sub-asset types under assessment. The accuracy of the attributes of these Asset Samples was then evaluated, under the accuracy assessment; and
2. A random Network Location Sample was generated, providing the start points for remote surveying the network and clusters of assets, under the completeness assessment.

The details of how the samples were generated is provided at Appendix C.

3.3.2 Supporting Data Acquisition

The types of dataset were identified for use within the assessment. These are described in the sub-sections below:

- Core Datasets;
- National Datasets; and
- Sample Specific Datasets.

3.3.2.1 Core Datasets

The Core Datasets contain the attribute values which were to be evaluated for accuracy. The records within these datasets constitute the recorded inventory, the extent of which is evaluated for completeness. These datasets were supplied by NR and are from the data sets which they use internally for corporate and regulatory reporting.

The acquisition of the core datasets is identified in the methodology at section 2.4.1 above.

The relationship between the Core Datasets and the Mandate, their volumes and initial checks are detailed at Appendix D.

3.3.2.2 National Datasets

National Datasets are imagery data sets, used to visually evaluate applicable attribute values from the Core Datasets and to undertake the completeness assessment. Both assessment types used remote visual surveying, as cheaper, less dangerous and less disruptive method than physical surveying. The National Datasets were supplied by NR, via extracts from or access to their spatial and imagery systems, in use within their business.

The acquisition of national datasets is described in the methodology at sections 2.4.2.2 and 2.4.3.2 above.

The details of the National Datasets used are described at Appendix E.

3.3.2.3 Sample Specific Datasets

Sample specific data sets, were used either as an independent source of data to confirm the values of the core data against or to confirm that the business rules determining the value in the core data were being adhered to.

The sample specific data sets were supplied by NR as either:

- Sets specifically for the candidates in the accuracy random samples;
- National datasets containing sufficient information to link them to candidates in the accuracy random samples; or
- Access to NR asset management systems with guidance on how to look up the information relevant to the accuracy random samples.

The acquisition of national datasets is described in the methodology at sections 2.4.2.2 and 2.4.3.2 above.

The suitability of the sample specific datasets, to undertaking the assessment, was gauged via their use within the execution pilot as described in the methodology at sections 2.4.2.4 and 2.4.3.4 above.

The details of the Sample Specific Datasets used are described at Appendix E.

3.3.3 Data Accuracy Measurement

3.3.3.1 Detailed Test Procedure Definition

A detailed test procedure as a set of test steps was developed for each attribute of each sub-asset type, subject to assessment. These were assembled into test sets, split by test type as defined in Table 10 and Table 11 above, to aid execution by multiple test teams and their skill sets.

A summary and mapping of the detailed test procedures to the Mandate is included at Table 12, the procedures are included in full at Appendix F. The versions of the procedures are those used in the full test execution, including any refinement to the procedures undertaken as part of the piloting exercise.

The test procedures were provided and presented to the ORR and NR at the meeting 3rd May 2019. Their decision was to review these via the results and outcomes of the test execution pilot at section 3.3.3.2 below.

Table 12 - Mandate to Test Procedure Cross Reference for Structures

Mandate Reference			Test Cross Reference	
Asset Type	**Sub Asset Type**	**Attributes**	**Test Set**	**Test Procedure**
Structures	Overline Bridges	ID	L3 AR005 - Overline Bridges Accuracy Test Procedures v1 3	OB-ID
		Start Mileage	L3 AR005 - GSI Overline Bridges Accuracy Test Procedures v1 3	OB-SM
		Primary ELR	L3 AR005 - GSI Overline Bridges Accuracy Test Procedures v1 3	OB-PE
		Owning Party	L3 AR005 - Overline Bridges Accuracy Test Procedures v1 3	OB-OP
		Operational Status	L3 AR005 - GSI Overline Bridges Accuracy Test Procedures v1 3	OB-OS
		Primary Material	L3 AR005 - Overline Bridges Accuracy Test Procedures v1 3	OB-PM
		CMI score (Asset Level)	L3 AR005 - Overline Bridges Accuracy Test Procedures v1 3	OB-CMI(AL)
		CMI score (PLBE)	L3 AR005 - Overline Bridges Accuracy Test Procedures v1 3	OB-CMI(PLBE)
		CMI Date	L3 AR005 - Overline Bridges Accuracy Test Procedures v1 3	OB-CMID
		Detailed Exam Date	L3 AR005 - Overline Bridges Accuracy Test Procedures v1 3	OB-DED

Mandate Reference			Test Cross Reference	
Asset Type	**Sub Asset Type**	**Attributes**	**Test Set**	**Test Procedure**
		HCE examination date	L3 AR005 - Overline Bridges Accuracy Test Procedures v1 3	OB-HCED
		Number of Decks	L3 AR005 - GSI Overline Bridges Accuracy Test Procedures v1 3	OB-ND
	Underline Bridges	ID	L3 AR005 - Underline Bridges Accuracy Test Procedures v1 3	UB-ID
		Start Mileage	L3 AR005 - GSI Underline Bridges Accuracy Test Procedures v1 3	UB-SM
		Primary ELR	L3 AR005 - GSI Underline Bridges Accuracy Test Procedures v1 3	UB-PE
		Owning Party	L3 AR005 - Underline Bridges Accuracy Test Procedures v1 3	UB-OP
		Operational Status	L3 AR005 - GSI Underline Bridges Accuracy Test Procedures v1 3	UB-OS
		Primary Material	L3 AR005 - Underline Bridges Accuracy Test Procedures v1 3	UB-PM
		CMI score (Asset level)	L3 AR005 - Underline Bridges Accuracy Test Procedures v1 3	UB-CMI(AL)
		CMI score (PLBE)	L3 AR005 - Underline Bridges Accuracy Test Procedures v1 3	UB-CMI(PLBE)
		CMI date	L3 AR005 - Underline Bridges Accuracy Test Procedures v1 3	UB-CMID

Mandate Reference			Test Cross Reference	
Asset Type	**Sub Asset Type**	**Attributes**	**Test Set**	**Test Procedure**
		Detailed Exam Date	L3 AR005 - Underline Bridges Accuracy Test Procedures v1 3	UB-DED
		Underwater examination date	L3 AR005 - Underline Bridges Accuracy Test Procedures v1 3	UB-UED
		Number of decks	L3 AR005 - GSI Underline Bridges Accuracy Test Procedures v1 3	UB-ND
		HCE examination date	L3 AR005 - Underline Bridges Accuracy Test Procedures v1 3	UB-HCED

Table 13 - Mandate to Test Procedure Cross Reference for Earthworks

Mandate Reference			Test Cross-Reference	
Asset Type	**Sub Asset Type**	**Attributes**	**Test Set**	**Test Procedure**
Earthworks	Embankment	Asset ID	L3 AR005 - Earthworks Embankments Accuracy Test Procedures v1 1	EM-ID
		Currently included in Adverse / Extreme Weather Plan	Not assessed, as not maintained by NR pending the introduction of the NR CSAMS application, agreed at the meeting 3rd May 2019.	
		EACB	Not assessed, no independent source of verification identified as this is maintained by the in-field aspects of the NR earthworks (JBA) application, agreed at the meeting 3rd May 2019.	
		Asset Examination Status	Not assessed, no independent source of verification identified as this is maintained by the in-field aspects of the NR earthworks (JBA) application, agreed at the meeting 3rd May 2019.	
		EHC	Not assessed, no independent source of verification identified as this is maintained by the in-field aspects of the NR earthworks (JBA) application, agreed at the meeting 3rd May 2019.	
		Asset Type	L3 AR005 – GSI Earthworks Embankments Accuracy Test Procedures v1 1	EM-AT
		ELR	L3 AR005 – GSI Earthworks Embankments Accuracy Test Procedures v1 1	EM-ELR
		End Easting	L3 AR005 – GSI Earthworks Embankments Accuracy Test Procedures v1 1	EM-EM

Mandate Reference			Test Cross-Reference	
Asset Type	**Sub Asset Type**	**Attributes**	**Test Set**	**Test Procedure**
		End Mileage	Not tested for accuracy, earthworks are divided into five chain, track relative, lengths. Each length constitutes an asset record, there are therefore no visible, earthwork relative, real world markers. Mileages were used as part of the completeness assessment. The relationship between end easting and northing and end mileage was tested.	
		End Northing	L3 AR005 – GSI Earthworks Embankments Accuracy Test Procedures v1 1	EM-EM
		Last Evaluation Date	L3 AR005 - Earthworks Embankments Accuracy Test Procedures v1 1	EM-LEvD
		Last Examination Date	L3 AR005 - Earthworks Embankments Accuracy Test Procedures v1 1	EM-LExD
		Operational Status	L3 AR005 – GSI Earthworks Embankments Accuracy Test Procedures v1 1	EM-OS
		Owning Party	Not tested for accuracy, currently all assets in the data set are assumed to be owned by NR. There is work underway, to acquire data about third party earthworks which pose a risk to the railways which is being marshalled outwith the current data set, for inclusion in the CSAMS system but this is not yet maintained.	
		Route	L3 AR005 – GSI Earthworks Embankments Accuracy Test Procedures v1 1	EM-RO
		Side	L3 AR005 – GSI Earthworks Embankments Accuracy Test Procedures v1 1	EM-SI
		Start Easting	L3 AR005 – GSI Earthworks Embankments Accuracy Test Procedures v1 1	EM-SM

Mandate Reference			Test Cross-Reference	
Asset Type	**Sub Asset Type**	**Attributes**	**Test Set**	**Test Procedure**
		Start Mileage	Not tested for accuracy, earthworks are divided into five chain, track relative, lengths. Each length constitutes an asset record, there are therefore no visible, earthwork relative, real world markers. Mileages were used as part of the completeness assessment. The relationship between start easting and northing and start mileage was tested.	
		Start Northing	L3 AR005 – GSI Earthworks Embankments Accuracy Test Procedures v1 1	EM-SM
		Track Name	L3 AR005 – GSI Earthworks Embankments Accuracy Test Procedures v1 1	EM-TN
	Rock Cutting	Asset ID	L3 AR005 – Earthworks Rock Cuttings Accuracy Test Procedures v1 1	RC-ID
		Currently included in Adverse / Extreme Weather Plan	Not assessed, as not maintained by NR pending the introduction of the NR CSAMS application, agreed at the meeting 3rd May 2019.	
		EACB	Not assessed, no independent source of verification identified as this is maintained by the in-field aspects of the NR earthworks (JBA) application, agreed at the meeting 3rd May 2019.	
		Asset Examination Status	Not assessed, no independent source of verification identified as this is maintained by the in-field aspects of the NR earthworks (JBA) application, agreed at the meeting 3rd May 2019.	
		EHC	Not assessed, no independent source of verification identified as this is maintained by the in-field aspects of the NR earthworks (JBA) application, agreed at the meeting 3rd May 2019.	

Mandate Reference			Test Cross-Reference	
Asset Type	**Sub Asset Type**	**Attributes**	**Test Set**	**Test Procedure**
		Asset Type	L3 AR005 – GSI Earthworks Rock Cuttings Accuracy Test Procedures v1 1	RC-AT
		ELR	L3 AR005 – GSI Earthworks Rock Cuttings Accuracy Test Procedures v1 1	RC-ELR
		End Easting	L3 AR005 – GSI Earthworks Rock Cuttings Accuracy Test Procedures v1 1	RC-EM
		End Mileage	Not tested for accuracy, earthworks are divided into five chain, track relative, lengths. Each length constitutes an asset record, there are therefore no visible, earthwork relative, real world markers. Mileages were used as part of the completeness assessment. The relationship between end easting and northing and end mileage was tested.	
		End Northing	L3 AR005 – GSI Earthworks Rock Cuttings Accuracy Test Procedures v1 1	RC-EM
		Last Evaluation Date	L3 AR005 – Earthworks Rock Cuttings Accuracy Test Procedures v1 1	RC-LEvD
		Last Examination Date	L3 AR005 – Earthworks Rock Cuttings Accuracy Test Procedures v1 1	RC-LExD
		Operational Status	L3 AR005 – GSI Earthworks Rock Cuttings Accuracy Test Procedures v1 1	RC-OS
		Owning Party	Not tested for accuracy, currently all assets in the data set are assumed to be owned by NR. There is work underway, to acquire data about third party earthworks which pose a risk to the railways which is being marshalled outwith the current data set, for inclusion in the CSAMS system but this is not yet maintained.	

Mandate Reference			Test Cross-Reference	
Asset Type	**Sub Asset Type**	**Attributes**	**Test Set**	**Test Procedure**
		Route	L3 AR005 – GSI Earthworks Rock Cuttings Accuracy Test Procedures v1 1	RC-RO
		Side	L3 AR005 – GSI Earthworks Rock Cuttings Accuracy Test Procedures v1 1	RC-SI
		Start Easting	L3 AR005 – GSI Earthworks Rock Cuttings Accuracy Test Procedures v1 1	RC-SM
		Start Mileage	Not tested for accuracy, earthworks are divided into five chain, track relative, lengths. Each length constitutes an asset record, there are therefore no visible, earthwork relative, real world markers. Mileages were used as part of the completeness assessment. The relationship between start easting and northing and start mileage was tested.	
		Start Northing	L3 AR005 – GSI Earthworks Rock Cuttings Accuracy Test Procedures v1 1	RC-SM
		Track Name	L3 AR005 – GSI Earthworks Rock Cuttings Accuracy Test Procedures v1 1	RC-TN
	Soil Cutting	Asset ID	L3 AR005 – Earthworks Soil Cuttings Accuracy Test Procedures v1 1	SC-ID
		Currently included in Adverse / Extreme Weather Plan	Not assessed, as not maintained by NR pending the introduction of the NR CSAMS application, agreed at the meeting 3rd May 2019.	
		EACB	Not assessed, no independent source of verification identified as this is maintained by the in-field aspects of the NR earthworks (JBA) application, agreed at the meeting 3rd May 2019.	

Mandate Reference			Test Cross-Reference	
Asset Type	**Sub Asset Type**	**Attributes**	**Test Set**	**Test Procedure**
		Asset Examination Status	Not assessed, no independent source of verification identified as this is maintained by the in-field aspects of the NR earthworks (JBA) application, agreed at the meeting 3rd May 2019.	
		EHC	Not assessed, no independent source of verification identified as this is maintained by the in-field aspects of the NR earthworks (JBA) application, agreed at the meeting 3rd May 2019.	
		Asset Type	L3 AR005 – GSI Earthworks Soil Cuttings Accuracy Test Procedures v1 1	SC-AT
		ELR	L3 AR005 – GSI Earthworks Soil Cuttings Accuracy Test Procedures v1 1	SC-ELR
		End Easting	L3 AR005 – GSI Earthworks Soil Cuttings Accuracy Test Procedures v1 1	SC-EM
		End Mileage	Not tested for accuracy, earthworks are divided into five chain, track relative, lengths. Each length constitutes an asset record, there are therefore no visible, earthwork relative, real world markers. Mileages were used as part of the completeness assessment. The relationship between end easting and northing and end mileage was tested.	
		End Northing	L3 AR005 – GSI Earthworks Soil Cuttings Accuracy Test Procedures v1 1	SC-EM
		Last Evaluation Date	L3 AR005 – Earthworks Soil Cuttings Accuracy Test Procedures v1 1	SC-LEvD
		Last Examination Date	L3 AR005 – Earthworks Soil Cuttings Accuracy Test Procedures v1 1	SC-LExD

Mandate Reference			Test Cross-Reference	
Asset Type	**Sub Asset Type**	**Attributes**	**Test Set**	**Test Procedure**
		Operational Status	L3 AR005 – GSI Earthworks Soil Cuttings Accuracy Test Procedures v1 1	SC-OS
		Owning Party	Not tested for accuracy, currently all assets in the data set are assumed to be owned by NR. There is work underway, to acquire data about third party earthworks which pose a risk to the railways which is being marshalled outwith the current data set, for inclusion in the CSAMS system but this is not yet maintained.	
		Route	L3 AR005 – GSI Earthworks Soil Cuttings Accuracy Test Procedures v1 1	SC-RO
		Side	L3 AR005 – GSI Earthworks Soil Cuttings Accuracy Test Procedures v1 1	SC-SI
		Start Easting	L3 AR005 – GSI Earthworks Soil Cuttings Accuracy Test Procedures v1 1	SC-SM
		Start Mileage	Not tested for accuracy, earthworks are divided into five chain, track relative, lengths. Each length constitutes an asset record, there are therefore no visible, earthwork relative, real world markers. Mileages were used as part of the completeness assessment. The relationship between start easting and northing and start mileage was tested.	
		Start Northing	L3 AR005 – GSI Earthworks Soil Cuttings Accuracy Test Procedures v1 1	SC-SM
		Track Name	L3 AR005 – GSI Earthworks Soil Cuttings Accuracy Test Procedures v1 1	SC-TN

Note: Start easting/northing and end easting/northing are both indivisible as co-ordinate pairings, from an accuracy perspective in comparison to the start and end mileages. Each co-ordinate pairing therefore has a single test procedure.

3.3.3.2 Test Pilot

The test procedures were executed against random sample members, working sequentially through the member until 34 results were achieved for each attribute of each sub-asset type.

On completion, the results were aggregated from attribute level to sub-asset type level. Two scenarios of outcome were presented, based on Not Proven results, the first assuming the Not Proven results resolved to Pass and the second to Fail to give a range of outcome. The results were presented to the ORR and NR at a tri-partite meeting 5th May 2019 and subsequent conference call 17th May 2019.

Prior to the tri-partite meeting an analysis of the pilot execution and results was undertaken and between the meeting, sessions held with the NR representatives of the Professional Heads for structures and earthworks. This identified the following improvements to the test procedures, which were agreed by the tri-partite meetings and the test procedures and pilot test results subsequently updated accordingly.

For Structures:

1. Last detailed examination pre-dates the implementation of the CARRs system. The CARRs system was implemented during 2008, so a small number of bridges with detailed examination intervals of 12 years or greater do not have their last detailed examination report, including BCMI content within it. It was decided that these would be disregarded under the affected tests.
2. Refinement of PLBE identification. The algorithm used to identify which element of a bridge constitutes the PLBE was refined and clarified, to prevent false test results.
3. BCMI exempt structures. There are a small number of structures which are exempt from BCMI calculations, as they have construction characteristics which are not covered by the calculations. It was decided that these structures would therefore also be exempt from the BCMI checks in the assessment, NR provided an additional supporting dataset of BCMI exempt structures.

For Earthworks:

1. Last evaluation date check refinement. An improvement to the EHC of an earthwork should lead to either an evaluation or not result in a change to the inspection regime. The corresponding test was improved to consider the latter as well as the former.
2. The tolerance for mileage measurement on bridges had been agreed as +/- 25 meters, there was no corresponding agreement for earthwork although using the same tolerance had been discussed. It was agreed that 25 meters would be used in both cases.

In addition to the general cases above, there were a few individual cases where additional evidence or information was needed on a case by case basis, which did not warrant changing the test procedures. These were addressed with the NR representatives of the Professional Heads for structures and earthwork either during the pilot review or in parallel with the full execution.

At the conference call 17th June 2019, it was agreed that the pilot review had concluded, and that full test execution should proceed. The detailed test results from the pilot are contained in Appendix G, as the first 34 results in each test set.

3.3.3.3 Test Execution

On completion of the pilot, test execution continued sequentially through the random samples, using the test procedures enhanced by the pilot, until 207 test results were obtained for each attribute within each sub-asset type. The detailed results of test execution are included in Appendix G, as those subsequent to the pilot results.

3.3.4 Data Completeness Measurement

3.3.4.1 Detailed Test Procedure Definition

A detailed test procedure is a set of test steps which were developed for each sub-asset type, subject to assessment. The data completeness measurement makes a bi-directional comparison between the assets of each asset sub-type in the real world and the asset data, to determine:

- Assets which exist in the real world, which have corresponding entries in the asset data;
- Assets which exist in the real world, which do not have corresponding entries in the asset data; and
- Assets which exist in the data, which do not exist in the real world.

The procedures, therefore, allow for the identification of assets which exist in the real world and once in the data set (Correct Records), as well as the 3 types of completeness error set out in the mandate included at Appendix A:

- Assets which exist in the real world and more than once in the data set (Duplicate Record);
- Assets which exist in the real world, but do not exist in the data set (No Record); and
- Assets which exist in the data set, but do not exist in the real world (Spurious Record).

Although attribute values were not being tested in the completeness assessment, location attributes were used to compare the real world with the data.

There are two earthwork specific considerations, which have been factored into the detailed test procedures, as follows:

1. Earthworks are modelled in the data as a series of assets of up to five chains in length, for example an embankment a mile long would appear in the data as approximately sixteen assets. To prevent this model perverting the completeness assessment, we used the first asset record encountered for the overall earthwork feature as a proxy for the whole earthwork.

2. The definition of an earthwork in the NR engineering standards, allows for engineering judgement to be applied where the earthwork elevation is less than three meters, as to whether that asset should be recorded. We assumed that this judgement had been applied when considering such data, as an engineering matter not a data matter.

The procedures are included in full in Appendix F. The versions of the procedures are those used in the full test execution, including any refinement to the procedures undertaken as part of the piloting exercise.

3.3.4.2 Test Pilot

The test procedures were executed against random sample members, working sequentially through the asset until 34 results were achieved for each sub-asset type.

Prior to the tri-partite meeting an analysis of the pilot execution and results was undertaken and between the meetings, sessions held with the NR representatives of the Professional Heads for structures and earthworks. This identified the following improvements to the test procedures, which were agreed by the tri-partite meetings and the test procedures and pilot test results subsequently updated accordingly.

For Structures:

1. Overline Bridges – Footbridges. When searching along an ELR for overline bridges, false test results were produced where a bridge was recorded as a footbridge as opposed to an overline bridge. NR provided an additional supporting dataset showing bridges recorded as footbridges, meaning these were disregarded from the overline bridges data completeness measurements.

2. Underline Bridges – Culverts. Similar to above, when searching along an ELR for underline bridges, false test results were produced where a bridge was recorded as a culvert as opposed to an underline bridge. As these scenarios were encountered specific further information was provided by NR confirming, if in fact it was a culvert at these locations, meaning these could be disregarded from the underline bridges data completeness test results.

For Earthworks it was not necessary to make changes to the methodology used in the pilot.

In addition to the general cases above, there were a few individual cases where additional evidence or information was needed on a case by case basis, such as bridge detailed examination reports, which did not warrant changing the test

procedures. These were addressed with the NR representatives of the Professional Heads for structures and earthwork either during the pilot review or in parallel with the full execution.

At the weekly conference call, it was agreed that the pilot review had concluded, and that full test execution should proceed. The detailed test results from the pilot are contained in Appendix G, as the first 34 results for each sub-asset type.

3.3.4.3 Full Execution

On completion of the pilot, full test execution continued sequentially through the random ELR/Mileage combinations (start points), using the test procedures enhanced by the pilot, until 207 test results were obtained for each sub-asset type.

For the completeness assessment the review then "ran along the line" in the real-world data until five of each of the five sub asset types were found within the ELR. If less than five assets were located before the end of the ELR, then an additional ELR was reviewed. In each case, when a candidate was found in the real-world data, the Asset Register was analysed to locate the occurrence of the asset.

The completeness test results are a listing of the assets found by ID and ELR/Mileage and marked with one of the four scores. If there was any uncertainty over the results for an asset this was flagged, the record ignored and then reviewed during the refinement stage of the project.

The detailed results of test execution are included in Appendix G, as those subsequent to the pilot results.

3.3.5 Reporting and Refinement

3.3.5.1 Not Proven Result Refinement

During pilot execution and full execution, accuracy test step results were marked as Not Proven, if there were insufficient evidence to either Pass or Fail them as set out in the methodology. Similarly, completeness test step results were marked as Not Proven, if there was insufficient evidence to mark as Correct Record or otherwise. Additional evidence was then sought, for these items in parallel with and after full execution, to refine these results to either Pass or Fail

At the end of the refinement period, all Not Proven results had been resolved to another value and therefore no account needs to be made of this setting in the results consolidation below.

Refinement took place in a series of sessions; three for structures and two for earthwork with representation from the Professional Heads of the respective disciplines. Additional evidence was provided, which took the form of:

1. Additional outside party ownership information in the form of documents correspondence and screenshots;

2. Additional detailed and underwater examination reports, for recently approved or historic examinations;
3. Information about in-progress examinations, from the examinations works management system;
4. Additional information about BCMI applicability to individual structures and where pertinent additional BCMI data;
5. Construction information for assets managed under a different class, particularly those managed as culverts rather than underline bridges;
6. Additional imagery, typically photographs from detailed or visual examination reports to augment the aerial and oblique imagery and LiDAR data sets;
7. Additional data about the management regime applied to items and points in time when changes to the engineering standards had affected the regimes; and
8. Point cases on the management of items with unusual design properties.

3.3.5.2 Results Consolidation and Summation

This section describes how the fully executed and refined results were used to generate scores and gradings.

For the assessment the required parameters were a 95% confidence and 4% precision (allowing an accuracy grading of '2', or better, to be awarded if the sample demonstrates suitable compliance). This requirement was used to drive the sample size, as described in section 3.3.1 above. The scores and gradings are therefore only accurate to this confidence and precision level.

3.3.5.2.1 Completeness Score and Grading

The completeness test procedure results allowed the following counts to be made, by summing the Spurious Record, Missing Record and Duplicate Record results respectively, by sub-asset type:

N_S - The number of spurious records found in the assessment data, i.e. those with no corresponding asset in the real world.

N_U - The number of unrecorded assets in the assessment data, i.e. assets which exist in the real world with no corresponding record in the assessment data.

N_D - The number of duplicate records found in the assessment data, i.e. those that exist in the real world and are recorded more than once in the assessment data.

The total number of mismatched records for the completeness assessment of an asset group sample, **N_{MC}**, was defined as:

$$N_{MC} = N_S + N_U + N_D$$

The corresponding completeness score for a sub-asset type is:

$$S_C = (1 - (N_{MC} / N_R)) \times 100\%$$

Where $\mathbf{N_R}$ is the total number of results, the sum of Correct Record, Spurious Record, No Record and Duplicate Record results.

These scores were carried forward to the overall completeness and accuracy score, via their gradings.

The completeness grading, by sub-asset type was derived from the completeness scores, in accordance with the ADCGAM, as set out in Table 14.

Table 14: Grading Derivation from Scores

Dataset Evaluation Gradings	1	2	3	4	5	6
Accuracy Score	>=99%	>=95%	>=90%	>=75%	>=50%	<50%
Completeness Score	>=99%	>=95%	>=90%	>=75%	>=50%	<50%

Applying the above, generates the scores and grading by sub-asset type shown in Table 15.

Table 15: Completeness Scores and Gradings by Sub-Asset Type

Mandate Reference		Sub-Asset Type Results						
Asset Type	**Sub-Asset Type**	**Results**	**Correct Record**	**No Record**	**Spurious Record**	**Duplicate Record**	**Completeness Score**	**Completeness Grading**
Structures	Overline Bridges	208	208	0	0	0	100.0%	1
	Underline Bridges	212	212	0	0	0	100.0%	1
Earthworks	Embankment	211	211	0	0	0	100.0%	1
	Rock Cutting	208	207	0	0	1	99.5%	1
	Soil Cutting	207	205	1	0	1	99.0%	1

3.3.5.2.2 Accuracy Score and Grading

The ADCGAM accuracy evaluation approach considers the way in which a data field within a record represents the attributes of a particular asset, using two basic tests:

- Was the field populated? Note: Some of the attributes under assessment may be legitimately blank under some conditions. For example, a bridge for which NR is not responsible and therefore not subject to detailed examination should have blank BCMI and detailed examination attributes, whereas a bridge for which NR is responsible should not have blank BCMI and detailed examination attribute values. These conditional aspects were built into the detailed test procedures at section 3.3.3.1 above as conditional steps; and,
- Does the observed value in the dataset field correctly represent the expected properties of the attribute when compared with an independent reference dataset or the real-world asset? Note that pre-defined criteria specific to the attribute were determined for this test, in the detailed test procedures at section 3.3.4.1 above.

In undertaking the assessment of accuracy, it must be clear what reference is being used to make the accuracy comparison as there is a limit to the extent of the checks that can be made. There needs to be an assumption made that the properties of the reference dataset, or the real-world asset, used for comparison are 100% accurate, i.e. they represented a "gold standard". For example, when checking whether a site observation in a detailed examination report had been correctly reflected in a data system, it is assumed that the observation in the detailed examination report is accurate. The detailed test procedures for this assessment are split between master source confirmation tests together with independent references and visual confirmation tests for comparison with the real-world, as set out in Table 10 and Table 11.

The following counts were established for each attribute within each sub-asset type for the members of the random sample tested:

N_{IR} = Total number results of tests for each attribute. The results are taken from the Overall Result row in each set of results, derived from the test step results as defined in the methodology at section 2.4.2.5 above; and

N_{IC} = Number of 'Fail' results of accuracy tests for each attribute.

Under the methodology, all attributes were considered to be of equal importance and therefore weightings, as set out in the ADCGAM, were not used. This was agreed by the ORR and NR at the tri-partite meeting 5th December 2018.

The percentage score for an attribute, within a sub-asset type, S_{IA}, was calculated from:

$$S_{IA} = (1 – (N_{IC} / N_{IR})) \times 100\%$$

The overall results and incorrect results for all (n) of the attributes within a sub-asset type sample, N_{IR}^{group} and N_{IC}^{group} respectively, were calculated from:

$$N_{IR}^{group} = \Sigma\ (N_{IR}^{i})^{i=1\ to\ n};\ and$$

$$N_{IC}^{group} = \Sigma\ (N_{IC}^{i})^{i=1\ to\ n}$$

The resulting accuracy score (S_A) of all of the attributes considered in a sub-asset type sample is:

$$S_A = (1 - (N_{IC}^{group} / N_{IR}^{group})) \times 100\%$$

These scores were carried forward to the overall completeness and accuracy score, via their gradings.

Accuracy gradings were derived from the attribute and sub-asset type scores, using the same method as completeness gradings described at section 3.3.5.2.1 above.

Applying the above to the results, from the accuracy detailed test procedures, generates the attribute scores and gradings for each sub-asset type shown in Table 16 to Table 20 inclusive; and scores and gradings by sub-asset type at Table 21.

Table 16: Structures, Overline Bridges Attribute Accuracy Scores and Gradings

Attributes	Results	Pass	Fail	Accuracy Score	Accuracy Grading
ID	207	205	2	99.0%	1
Start Mileage	207	184	23	88.9%	4
Primary ELR	207	207	0	100.0%	1
Owning Party	207	205	2	99.0%	1
Operational Status	207	205	2	99.0%	1
Primary Material	207	190	17	91.8%	3
CMI score (Asset Level)	207	190	17	91.8%	3
CMI score (PLBE)	207	199	8	96.1%	2
CMI Date	207	186	21	89.9%	4
Detailed Exam Date	207	197	10	95.2%	2
HCE examination date	207	207	0	100.0%	1
Number of Decks	207	202	5	97.6%	2

Table 17: Structures, Underline Bridges Attribute Accuracy Scores and Gradings

Attributes	Results	Pass	Fail	Accuracy Score	Accuracy Grading
ID	207	205	2	99.0%	1
Start Mileage	207	197	10	95.2%	2
Primary ELR	207	206	1	99.5%	1
Owning Party	207	207	0	100.0%	1
Operational Status	207	206	1	99.5%	1
Primary Material	207	205	2	99.0%	1
CMI score (Asset level)	207	164	43	79.2%	4
CMI score (PLBE)	207	184	23	88.9%	4
CMI date	207	185	22	89.4%	4
Detailed Exam Date	207	201	6	97.1%	2
Underwater examination date	207	195	12	94.2%	3
Number of decks	207	189	18	91.3%	3
HCE examination date	207	201	6	97.1%	2

Table 18: Earthworks, Embankments Attribute Accuracy Scores and Gradings

Attributes	Results	Pass	Fail	Accuracy Score	Accuracy Grading
Asset ID	207	207	0	100.0%	1
Currently included in Adverse / Extreme Weather Plan EACB					
Asset Examination Status EHC					
Asset Type	207	207	0	100.0%	1
ELR	207	207	0	100.0%	1
End Easting and Northing	207	140	67	67.6%	5
End Mileage					
Last Evaluation Date	207	201	6	97.1%	2
Last Examination Date	207	201	6	97.1%	2
Operational Status	207	207	0	100.0%	1
Owning Party					
Route	207	206	1	99.5%	1
Side	207	175	32	84.5%	4
Start Easting and Northing	207	137	70	66.2%	5
Start Mileage					
Track Name	207	175	32	84.5%	4

Table 19: Earthworks, Rock Cuttings Attribute Accuracy Scores and Gradings

Attributes	Results	Pass	Fail	Accuracy Score	Accuracy Grading
Asset ID	207	206	1	99.5%	1
Currently included in Adverse / Extreme Weather Plan EACB Asset Examination Status EHC					
Asset Type	208	208	0	100.0%	1
ELR	208	208	0	100.0%	1
End Easting and Northing	208	170	38	81.7%	4
End Mileage					
Last Evaluation Date	207	200	7	96.6%	2
Last Examination Date	207	200	7	96.6%	2
Operational Status	208	208	0	100.0%	1
Owning Party					
Route	208	207	1	99.5%	1
Side	208	168	40	80.8%	4
Start Easting and Northing	208	178	30	85.6%	4
Start Mileage					
Track Name	208	174	34	83.7%	4

Table 20: Earthworks, Soil Cuttings Attribute Accuracy Scores and Gradings

Attributes	Results	Pass	Fail	Accuracy Score	Accuracy Grading
Asset ID	207	201	6	97.1%	2
Currently included in Adverse / Extreme Weather Plan EACB Asset Examination Status EHC					
Asset Type	207	207	0	100.0%	1
ELR	207	206	1	99.5%	1
End Easting and Northing	207	135	72	65.2%	5
End Mileage					
Last Evaluation Date	207	201	6	97.1%	2
Last Examination Date	207	207	0	100.0%	1
Operational Status	207	207	0	100.0%	1
Owning Party					
Route	207	206	1	99.5%	1
Side	207	171	36	82.6%	4
Start Easting and Northing	207	136	71	65.7%	5
Start Mileage					
Track Name	207	173	34	83.6%	4

Table 21: Structures and Earthwork Sub-Asset Type Accuracy Scores and Gradings

Asset Type	Sub-Asset Type	Results	Pass	Fail	Accuracy Score	Accuracy Grading
Structures	Overline Bridges	2484	2377	107	95.7%	2
	Underline Bridges	2691	2545	146	94.6%	3
Earthworks	Embankment	2277	2063	214	90.6%	3
	Rock Cutting	2285	2127	158	93.1%	3
	Soil Cutting	2277	2050	227	90.0%	3

3.3.5.2.3 Combined Accuracy and Completeness Grading

The numeric accuracy and completeness grading for an asset group sample was based on the following:

- Completeness score, S_C; and
- Accuracy score, S_A.

As the scoring bands for grading purposes are identical for accuracy and completeness (as shown at Table 14 above) the completeness and accuracy gradings at the sub-asset type level were used to generate the combined grading at this level. The grading assigned was taken from the principle set out in the ADCGAM whereby the combined accuracy and completeness grading awarded is the highest number (i.e. the lowest score) of the two:

'The Numeric score is based on three criteria: Accuracy, Precision and Completeness. To receive a particular score all three criteria must be satisfied for that score.'

Similarly, to combine gradings awarded at sub-asset type level to the asset type level, the grading awarded is the highest of the contributing gradings at the sub-asset type level.

Following this principle, the results of the combined accuracy and completeness gradings to create sub-asset level gradings; and combining sub-asset gradings to generate asset level gradings are shown at Table 22.

Table 22: Asset Type and Sub-Asset Type Gradings

Asset Type Grading		Sub-Asset Type Grading			Accuracy	Completeness
Structures	3	Overline Bridges	2	Score	95.7%	100.0%
				Grading	2	1
		Underline Bridges	3	Score	94.6%	100.0%
				Grading	3	1
Earthworks	3	Embankments	3	Score	90.6%	100.0%
				Grading	3	1
		Rock Cuttings	3	Score	93.1%	99.5%
				Grading	3	1
		Soil Cuttings	3	Score	90.0%	99.0%
				Grading	3	1

3.3.5.2.4 Materiality of Errors

Where the tests do not identify a tolerance on the results, then an absolute comparison was used between the value in the Assessment Dataset and the comparable value. An exact match being required to achieve a pass and no engineering judgement made about the variation, as this is a data assessment not an engineering assessment.

There may therefore be areas of this assessment which the ORR and NR consider less significant than others, when their engineering judgement on the materiality of variations is considered. Considerations of materiality could affect the gradings of attributes and consequentially the sub-asset type and asset type gradings, when aggregated at those levels

For example, in the comparison of BCMI scores (asset level) of underline bridges, between the values in the CARRs database and the BCMI database these scores vary by 1% in 16 of 207 cases. A variation of 1% may not be considered significant from a structures engineering perspective.

4 Conclusions

4.1 Introduction

Having applied the methodology to the two principle workstreams, Accuracy and Completeness, this Section of the report pulls these together to provide an overall assessment of the results which have been developed for the commission. In this regard it provides a commentary on the process which has been adopted and highlights the key findings of the study.

The final sub-section provides a tabulated assessment of the numeric aspect of Confidence Gradings which have been awarded based on the work undertaken.

The alpha aspect of confidence grading is not considered by this report, having been agreed during CP5 between the ORR and NR to be 'A' for the relevant asset types.

4.2 Dataset Assessment

The assessment exercise demonstrates that the results for accuracy and completeness vary, between each other, considerably. For accuracy, the results vary between the structures and earthworks asset types, for what appear to be differing reasons. Conclusions were therefore drawn separately for accuracy and completeness and within accuracy for each asset type.

4.2.1 Accuracy Dataset Assessment

The accuracy of the majority of attributes evaluated for both structures and earthworks are well within the parameters required by the Mandate. The numeric accuracy Confidence Gradings of both structures and earthworks are marred by issues, affecting a sub-set of the attributes under assessment, which reduce the overall result. It is considered that if these issues were addressed, systemically, then the required numeric accuracy Confidence Gradings would be achieved within the parameters of this assessment.

It is noted that work is currently underway within NR to systemically address these issues. For example, in relation to the earthworks issue NR are in the process of re-eventing the attributed start/end eastings/northings and mileages using the master "where" data (WKT). The work will be delivered prior to the start of the 2019/20 earthworks inspection season. There are two parts to this:

1. A one-off mass exercise before season start up on 23 October 2019.
2. Then as an automated procedure that works as an overnight batch to resynchronise any spatial data edited on a particular day

4.2.1.1 Structures Accuracy Dataset Assessment

Within NR, the asset management of structures is supported by a series of independent central databases, plus contractors' own databases where aspects of

asset management are outsourced. Within this set of databases, the same attribute may exist within more than one database, and/or change of data state within one database should trigger changes in the data state of others.

Under this assessment, data from four NR central databases and one contractor database was either evaluated or used to provide supporting data to the assessment.

The main issue identified during the structures accuracy dataset assessment, was that these multiple databases are on occasions misaligned, particularly in relation to cyclical examinations.

These misalignments apply to both of:

3. Attributes within databases having different values for the same examination cycle; and
4. Attributes within databases being from different examination cycles.

For the two sub-asset types evaluated under structures, overline and underline bridges, this issue appears more pronounced for underline bridges. This is considered to be because a far greater proportion of overline than underline bridges have outside party responsibility for most types of examination and therefore the NR attributes for these are, legitimately, blank.

4.2.1.2 Earthworks Accuracy Dataset Assessment

The principal issue with the earthworks attributes affecting the accuracy assessment, was with the start and end co-ordinate pairings and their relationship to the linear location references (start and end mileages). In a significant number of cases, the start co-ordinate pairings were associated with the end mileage and vice versa, i.e. the spatial and linear references were inverted against each other.

This referencing inversion may consequentially have an impact on other aspects of the linear referencing system, particularly the Side and Track Name attributes under assessment. It should be noted though that the linear referencing system for earthworks, in relation to these differs from other asset types. This may be another contributing factor, for example track as depicted in the National Electronic Sectional Appendix. To be definitive in this area would require a full root cause analysis, probably coupled with the correction of a sub-set of the affected data, which is outside the scope of this assessment.

4.2.2 Completeness Dataset Assessment

All sub-asset types were well in excess of the parameters required by the Mandate, for this assessment.

4.3 Numeric Confidence Grading

Table 23 shows the numeric confidence gradings achieved under this assessment. For this assessment the required parameters were a 95% confidence and 4% precision (allowing an accuracy grading of ‘2’ to be awarded if the sample

demonstrates suitable compliance). This requirement was used to drive the sample size, as described in section 3.3.1 above, the scores and gradings are therefore only accurate to this confidence and precision level.

Table 23: Numeric Confidence Gradings

Asset Type Grading		Sub-Asset Type Grading			Accuracy	Completeness
Structures	3	Overline Bridges	2	Score	95.7%	100.0%
				Grading	2	1
		Underline Bridges	3	Score	94.6%	100.0%
				Grading	3	1
Earthworks	3	Embankments	3	Score	90.6%	100.0%
				Grading	3	1
		Rock Cuttings	3	Score	93.1%	99.5%
				Grading	3	1
		Soil Cuttings	3	Score	90.0%	99.0%
				Grading	3	1

5 Recommendations

5.1 Introduction

Section 4 of this report provides a summary of the findings of the assessment of NR's structures and earthworks asset data quality. This section of the report provides a summary of the recommendations which have been developed to address the issues which have emerged from the study.

5.2 Recommendations

The recommendations which have emerged from the study are included in Table 24. An observation and suggestion for improving the nature of future independent assessments is also made, at Table 25, as a result of undertaking this assessment.

Table 24: Assessment Recommendations

Number	Recommendations to Network Rail	Benefits	Location in Text
2019ADQ01	NR should define and migrate to a single combined linear and spatial location referencing system. The definition should include the data requirement, the relationship between the linear and spatial facets, the accuracy and tolerance and the purpose and use of the linear and spatial facets.	1. Valid cross comparisons can be made between asset types, via location reference. 2. The data is prepared for migration to NR's ambition of a single central integrated asset management system (CSAMS). 3. Supports a 'horses for courses' approach in the field, including where applicable modern mobile technologies.	**4.2.1.2**
2019ADQ02	NR should produce and implement a consolidated set of asset data requirements, including their data quality parameters. Currently the source of these is diverse including guides and manuals, conventions and derivation from sources of other purposes, for example, engineering standards	1. Clarity and focus, 2. Maintenance and control as a discipline	Phase 1 duration and Phase 2 start-up

Number	Recommendations to Network Rail	Benefits	Location in Text
2019ADQ03	NR should strengthen their processes, procedures and controls for maintaining the alignment of multiple central databases with overlapping datasets and data delivery into them. They should consider automation, to identify misalignment on an ongoing basis.	1. NR can rely on a, logical, single version of the truth. 2. The data is prepared for migration to NR's ambition of a single central integrated asset management system (CSAMS).	**4.2.1.1**
2019ADQ04	NR should undertake an assurance programme of its own asset data quality. The ORR, or Reporter on their behalf, may then audit the results of the assurance programme.	1. Is pro-active and ongoing rather than retrospective. 2. Is adaptable to emerging needs. 3. More cost-effective use of the Reporter.	Derived from 2019ADQ03

Table 25: Assessment Observation/Suggestion

Number	Recommendations to Network Rail	Benefits	Location in Text
2019ADQObs01	The ORR and NR should consider the nature of future independent data quality assessments for the master source comparison aspects of this assessments, considering factors such as; clarity of data requirements, communication of requirement, training, controls, routine monitoring of compliance and improvement of the data management system.	1. Considers modern data capture methods, where there is no independent source of comparison. 2. Is pro-active and ongoing rather than retrospective. 3. Is adaptable to emerging needs, rather than driving an 'A2' behaviour.	Various, deviations from the Mandate

Appendix A

Mandate L3AR005

A1 Mandate L3AR005

Mandate for Independent Reporter

Title	CP5 Asset Data Quality Assurance 2017
Unique Mandate Reference Number	L3AR005
Date	3rd May 2018
ORR Lot Lead	Peter Moran
ORR Lead for this inquiry	Ashley Goddard
Network Rail Lot Lead	Jonathan Haskins
Network Rail lead for this inquiry	Gerald Forward

Background

The ORR set a regulated output on Network Rail to demonstrate confidence in the quality and governance over its asset data.

Within the CP5 Final Determination, the ORR specified that asset data quality should be at A2 for the datasets held by April 2017.

The target confidence grade of A2 is set by asset type and based on the standard Independent Reporter confidence grading structure for system reliability (the 'alpha') and data accuracy (the 'numeric'). The system reliability aspect was the subject of work between NR and ORR during 2017. This determined that the 'Asset Data Governance Management System' was in place and had been sufficiently implemented at Route level to meet this test.

In addition, internal measurement and reporting within Network Rail has demonstrated the progress made regarding the data accuracy levels against the agreed target. This has proven sufficient to confirm that the target of '2' has been achieved within Track, Signals and Operational Property. This also confirmed that a select few data points had failed to achieve this level for Telecoms and Electrification.

As a consequence of the work carried out during 2017, this review will focus only on the data accuracy element for those asset types that have not yet been deemed compliant with the 2 grading.

Purpose

The objective of the independent reporter's review is to determine the accuracy of the information held at March 2017 for Earthworks and Structures assets as set out within this mandate.

The reporter should highlight areas of concern or non-compliance to Network Rail to allow corrective action to be planned / initiated.

We expect an open and honest dialogue so that all parties can arrive at a consensus of the position regarding the data held for these assets.

Scope

The scope of this review is for the Independent Reporter to test and assure the data accuracy element of the confidence grading for Earthworks and Structures.

This will be based on a statistical evaluation of how well the Assessment Dataset represents the physical world, using a statistically significant sample. This assessment is required to be completed at the attribute level for each asset type under consideration.

The dimensions considered for the data accuracy score are both the accuracy[9] or precision[10] and completeness of the asset data, as defined below:

- Data Accuracy or Precision Assessment to evaluate the correctness of the data at the attributes level.
- Data Completeness Assessment to evaluate how well the database reflects reality of assets in the physical world. Completeness is calculated based on the 3 types of completeness errors:
    - No record (i.e. the asset exists in the real world but not in the database/ asset register)
    - Spurious record (i.e. the asset exists in the system but not in the real world)
    - Duplicate record (i.e. two system records relate to the same physical asset)

Methodology

The reporter should undertake the assessment of these dimensions on a sample of data. This sample should be representative of the asset base and consider factors that may materially affect data quality. To help inform these tests we would expect the review to include:

- Desktop review of the published processes for data collection, data analysis and reporting
- Assessment of the accuracy of the source data by comparison with other data sources
- Interviews with NR employees involved in the process from on-site data collection, data verification, data analysis to data reporting
- Review of relevant assurance activities for the source data

[9] the degree of closeness of a quantity to that quantity's true value
[10] the degree to which repeated measurements under unchanged conditions show the same results

The expectation is that the reporter will propose a sampling plan appropriate to provide a statistically significant assessment of data accuracy to grade '2'. Network Rail asset counts (population sizes) are provided in Appendix 1.

Table 1 - Confidence Grading Assessment Matrix

Accuracy grading system

Accuracy Band	Description
1*	Data used to calculate the measure is accurate to within 0.1%
1	Data used to calculate the measure is accurate to within 1%
2	Data used to calculate the measure is accurate to within 5%
3	Data used to calculate the measure is accurate to within 10%
4	Data used to calculate the measure is accurate to within 25%
5	Data used to calculate the measure is accurate to within 50%
6	Data used to calculate the measure is inaccurate by more than 50%
X	Data accuracy cannot be measured

Notes:

1. Accuracy is a measure of the closeness of the data used in the system to the true values.

2. Accuracy is defined at the 95% confidence level - i.e. the true value of 95% of the data points will be in the accuracy bands defined above.

Table 2: Asset attributes

This table describes the asset attributes by asset and sub asset type in scope of the assessment.

Asset Type	Sub Asset Type	Attributes
Structures	Overline Bridges	ID Start Mileage Primary ELR Owning Party Operational Status

		Primary Material CMI score (Asset Level) CMI score (PLBE) CMI Date Detailed Exam Date HCE examination date Number of Decks
	Underline Bridges	ID Start Mileage Primary ELR Owning Party Operational Status Primary Material CMI score (Asset level) CMI score (PLBE) CMI date Detailed Exam Date Underwater examination date Number of decks HCE examination date
Earthworks	Embankment	Asset ID Currently included in Adverse/Extreme Weather Plan EACB Asset Examination Status EHC Asset Type ELR End Easting End Mileage End Northing Last Evaluation Date Last Examination Date Operational Status

		Owning Party
		Route
		Side
		Start Easting
		Start Mileage
		Start Northing
		Track Name
	Soil Cutting	Asset ID
		Currently included in Adverse/Extreme Weather Plan
		EACB
		Asset Examination Status
		EHC
		Asset Type
		ELR
		End Easting
		End Mileage
		End Northing
		Last Evaluation Date
		Last Examination Date
		Operational Status
		Owning Party
		Route
		Side
		Start Easting
		Start Mileage
		Start Northing
		Track Name
	Rock Cutting	Asset ID
		Currently included in Adverse/Extreme Weather Plan
		EACB
		Asset Examination Status
		EHC
		Asset Type
		ELR
		End Easting
		End Mileage
		End Northing
		Last Evaluation Date
		Last Examination Date
		Operational Status
		Owning Party

	Route Side Start Easting Start Mileage Start Northing Track Name

For advice to the Independent Reporter, Network Rail has previously determined the most appropriate statistical methods for sampling its assets to be stratified and cluster sampling. For this assessment, the Independent Reporter is not limited to one of these methods but it should evidence the appropriateness of any selected approach.

The expectation is that an approach, confirmation of data sets and relevant accompanying details regarding the baseline assessment will cover all routes and central functions.

Network Rail recognises five methods to validating asset data, these consist of the following:

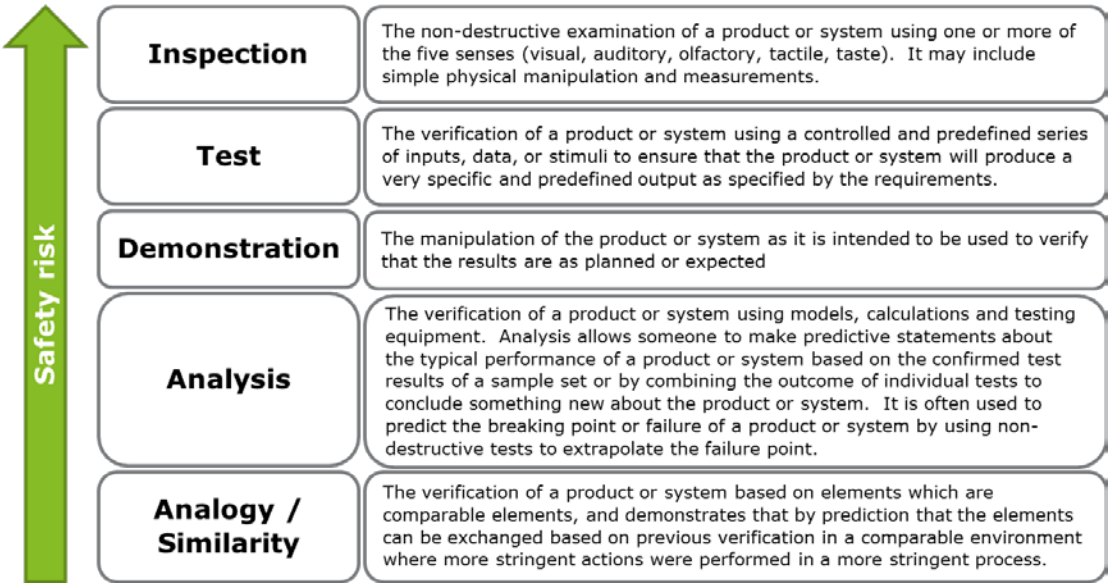

Figure 2 - Methods to validating asset data

There is an expectation that the Independent Reporter will work with Network Rail to present the findings to those interested parties.

The proposal should include your proposed approach to providing the services, including:

- Sampling methodology and approach
- Engagement with and required access to the business
- Approach to managing safety

- System access requirements
- Innovative methods

Please also provide indications of any third party relationships which may be used to deliver the requirements - providing details of the company/companies you will/may engage and how you will manage them throughout the implementation of this service.

Timescales and deliverables

- Agreement of statistical methodology: upon project inception
- Interim findings meetings: by 13th July 2018
- Full draft report issued by 27th July 2018
- Audit opinion issued 3rd August 2018
- Final report issued by 10th August 2018

Independent Reporter Proposal

The Reporter shall prepare a proposal for review by the ORR and Network Rail on the basis of this mandate. ORR and Network Rail will review the proposal with reference to the criteria for selection.

The final approved proposal will form part of the mandate and shall be attached to this document.

The proposal will detail methodology, tasks, programme, deliverables, resources and costs (including expenses).

The Reporter shall provide qualified personnel with direct experience in the respective disciplines to be approved by the ORR and Network Rail. The contractor is asked to submit details of the previous experience and qualifications of such personnel as part of their proposal.

Appendix 1 – Network Rail asset counts

Route	Structures		Earthworks		
	Overline bridges	Underline bridges	Embankments	Soil cutting	Rock cutting
Anglia	534	1,305	6,696	4,157	66
LNE&EM	1,479	3,374	27,492	15,715	6,645
LNW	2,442	4,206	18,095	16,403	1,866
Scotland	1,399	3,012	17,328	14,130	2,916
South East	685	2,139	7,226	5,094	1,390
Wales	754	1,757	8,358	5,696	1,273
Wessex	655	1,283	7,006	4,959	521
Western	977	1,868	10,084	6,472	1,616

Appendix 2 – Joint ORR and Network Rail Guidance to Reporters

1. The purpose of this document is to describe the trilateral relationship between ORR, Network Rail and each Reporter. It sets out in a practical context what both ORR and Network Rail expect from Reporters, and seeks to encourage best practice. This will help Reporters to deliver work in a way which meets these expectations and requirements. These requirements will be taken into account as part of the Reporter Framework (as provided to Reporters).

2. This guidance is owned and updated as necessary jointly by ORR and Network Rail. In the event of any discrepancy between this document and the Reporter contract, the latter will prevail. This guidance does not provide an exhaustive list of responsibilities and should Reporters wish to discuss these guidelines further they should contact the following for a trilateral discussion:

    - Andy Lewis for ORR; and
    - Jonathan Haskins for NR.

The trilateral relationship

3. Licence Condition 13 (LC13) of Network Rail network licence states:

    - "The role of the Reporter is to provide ORR with independent, professional opinions and advice relating to Network Rail's provision or contemplated provision of railway services, with a view to ORR relying on those opinions or advice in the discharge by ORR of its functions under, or in consequence of, the Act. Where appropriate, ORR shall give the licence holder an opportunity to make representations on those opinions or advice before relying on them."

4. Reporters should be familiar with the obligations as set out in LC13 and the terms of the contract.

5. For the avoidance of doubt, in delivering this role, ORR and Network Rail expect that Reporters will also add value to Network Rail in helping it to improve its performance and business as provider of railway services, wherever possible. However, it is recognised that this is not the primary purpose of the Reporter under the Licence and that this may not always be possible to deliver each mandate.

Role & duties of the reporters

6. Reporters must provide an independent view and remain impartial throughout the review.

    For example:

    - information should be shared equally and at the same time with both clients. Any correspondence or clarifications sought by Reporters should also be dealt with in the same way; and
    - communication between all three parties should be open e.g. both ORR and Network Rail should be invited to or made aware of meetings or discussions even if the meeting is more appropriate with only one client.

Identifying Reporter work

7. ORR will identify instances where there is a requirement to engage a Reporter. In practical terms, this is likely to arise from on-going discussions with Network Rail and in most cases (except urgent or exceptional cases) the potential for engagement of Reporters will have been identified in advance.

Mandates – Reporter Proposals

8. Clause 4 of the contract sets out the key requirements around provision of services. Requirements for reporter work normally arise from the day to day discussion of issues between ORR and Network Rail.

9. ORR will prepare a draft mandate for each piece of work and will in most cases agree this with Network Rail.

10. Mandates will be presented in a standard format for consistency and will clearly set out:

    - the purpose;
    - the scope;
    - why the review is necessary;
    - what it will achieve;
    - the expected outputs; and
    - timescales for providing reports.

11. Once agreed with Network Rail, ORR will email the mandate to the relevant Reporter(s), asking for comments and a proposal for the work, which should include costs and CVs for the proposed Reporter team. The Reporter has seven working days to respond with a proposal or such other timescale as determined by ORR. Every proposal must include:

    - costs;
    - resources;
    - CVs of the proposed mandate team – when providing proposals, Reporters should make the most efficient use of their resources including the most appropriate make-up of the review team;
    - methodology for delivering the aims of the mandate;
    - timescales;
    - framework of meetings, including a tripartite findings meeting before issue of the draft report;
    - expected deliverables and a concise explanation of how the aims of the mandate will be met; and

- for larger scale reporter studies, the project management approach and project plans should be made explicit

Where there are multiple Reporters on a Lot, the ORR and Network Rail will use the following criteria to determine which Reporter they will select to conduct the work.

Procedure for Call Off under the Framework Agreements

Where more than one Contractor has been selected for any particular lot, ORR and Network Rail will allocate mandates on the basis of the following criteria:

1. The expertise required is only available from one source. This may be due to ownership of exclusive design rights or patents.
2. Where the mandate constitutes follow up work, which is directly related to a recently completed study.
3. The Contractor which demonstrates the greatest expertise in the subject matter of the mandate or the approach required.
4. The Contractor's performance against the performance framework
5. An overall assessment of value for money based on cost and complexity of work.

If the ORR and Network Rail cannot determine the most appropriate Contractor for a mandate using the above criteria, ORR and Network Rail will conduct a mini-tender with the Contractors who have been awarded the relevant lot using the following criteria in order to determine the most economically advantageous proposal:

1. The Contractor demonstrates sufficient knowledge of subject matter and possesses the technical skills, resource and competencies required for the work.
2. Contractor Costs.
3. The Contractor demonstrates innovation and value for money in its proposal.
4. The Contractor's performance against the performance framework.

12. Prior to conducting such a mini-tender, ORR and Network Rail will inform Contractors of the relative weighting of the above criteria and of any additional sub-criteria applicable in the context of a particular mandate.
13. ORR and Network Rail will endeavour to discuss the proposals received and to confirm by e-mail within **five working days** that the proposal is acceptable (or otherwise). There may be circumstances where ORR and Network Rail need longer to respond.
14. ORR will then formally instruct the reporter to start work, and the reporter will arrange a start-up meeting with key representatives from both ORR and Network Rail.

Mandates – During Delivery

15. The following sets out some key points regarding conduct of any inquiry. Reporters must provide an independent view and remain impartial throughout the inquiry. They should expect to discuss their progress and findings trilaterally with ORR and Network Rail and for some challenge to be given – particularly in relation to the factual accuracy of the findings.

Costs and expenses

16. If additional funds are required to deliver a mandate beyond those agreed at the outset, a timely proposal and justification must be given to ORR and Network Rail (as soon as the issue arises). The Reporter should notify ORR and Network Rail who will discuss and respond in a reasonable timescale. Additional work (and cost) must not proceed without approval.

17. Any reasonably incurred expenses will be reimbursed by Network Rail. Only expenses that have been incurred in accordance with Network Rail's expenses policy will be paid. It should be specifically noted that reporters must use standard class travel and plan journeys in advance as much as possible. In addition no claims for lunch will be processed even if submitted. In the event that a Reporter is working on a 'call out' during the night which takes them into the morning, the Reporter will be eligible to claim up to £7.50 for breakfast. No other scenario qualifies for claiming breakfast. Hotel accommodation costs will only be paid up to the maximum rate limit (per person per night, including VAT) as set out in Network Rail's expenses policy.

18. All invoices should be sent to Matthew Blackwell at Network Rail prior to being sent to Network Rail Accounts Payable.

Amendment to mandates

19. For practical reasons it may be necessary for a mandate to be revised once work has commenced or awarded. For the avoidance of doubt this will not lead to the ORR and Network Rail seeking to re-run the award of the mandate unless ORR and Network Rail agree that the revision constitutes a material change to the original mandate.

Meetings

20. Unless otherwise directed, all key meetings must be trilateral and both parties should be made aware of any other meetings taking place.

21. The Reporter should take minutes of meetings, which should be provided to all parties within 7 working days.

Issues or concerns

22. Should a situation arise whereby either ORR or Network Rail is dissatisfied with the quality of a piece of work, we will explain clearly our reasons, gain approval from the other client and then, if we deem appropriate, may request the Reporter to re-do that part of work at no additional cost.

23. Should the Reporter encounter any issues with an inquiry (review) the Reporter should notify:

    - Andy Lewis for ORR
    - Jonathan Haskins for NR

Reports

The report document

24. **All** Reports must include an 'Executive Summary' which should be written clearly, concisely and highlight key findings and key recommendations.

25. The full reports should also be written concisely in plain English, and should provide a brief 'Introduction' outlining the aims of the mandate and how these have been met. They should provide further detail on what is mentioned in the Executive Summary and there should not be any material points raised in the main report which have not already been mentioned in the Executive Summary.

26. Where there is commercially sensitive information in the report, the Executive Summary will be published on ORR's website, with any necessary redactions, instead of the full report. Otherwise, usually the full report will be published unless any redactions are appropriate due to a Freedom of Information Act exemption.

Recommendations

27. A recommendation is a specific action that the Reporter considers, following its analysis, should be undertaken by either Network Rail, or any other party. While the majority of recommendations are likely to be for Network Rail, not all need to be.

28. Reporters should make all recommendations SMART (Specific, Measureable, Achievable, Realistic and Timebound). The Reporter should:

    - provide a clear description of the recommendation and the benefit that implementation will deliver;
    - outline the evidence which is required in order for the recommendation to be closed out; and
    - discuss and agree a target date for completion of the recommendation with ORR and Network Rail.

29. Recommendations should only be included in the report if they actually add value to either ORR or Network Rail or another industry party and the benefits are sufficient to justify implementation. It is acceptable for a report not to include recommendations, as long as key requirements of the mandate have been met (e.g. if an inquiry finds that Network Rail is fully compliant with its requirements). A smaller number of well-targeted and SMART recommendations which will deliver tangible improvements is preferable to a large number of general recommendations.

30. In order to add further value, the report may also include observations on areas for improvement which do not need to be captured in a formal Recommendation if they are not central to delivery of the mandate requirements.

31. Recommendations will be tracked by the Reporter which generated them.

Payment

32. Reporters must include the purchase order number, and unique mandate reference (UMR) number for work when invoicing Network Rail for payment.

33. The clients can query invoices and have the right to check timesheets (and expenses) and investigate work before payment is agreed.

Post-mandate review

34. The clients will provide feedback on the work carried out, having assessed performance using the Performance Framework on a per mandate basis. This will reflect any issues or concerns raised with the Reporter during delivery of the mandate.

35. The clients will also hold formal feedback sessions with each Reporter every six months to review progress.

Appendix B

Summary of Meetings

B1 Summary of Meetings

During the two phases of the commission the meetings in the sub-sections below were held.

Throughout both phases of the review a weekly telecon was held chaired by Arup with participation from ORR and Network Rail. These telecons provided the opportunity for Arup to share details of progress to date and highlight emerging issues. Brief notes of each of these telecons were shared shortly after the call

B1.1 Phase 1

Date	Attendance	Purpose	Meeting Type
14 November '18	ORR NR Arup	Phase 1 kick-off Tripartite meeting	Face-to-Face: London
20 November '18	NR Arup	Discussion on the data requirements statement supplied to Network Rail	Telecon
23 November '18	NR Arup	Follow up call regarding data requirements	Telecon
28 November '18	NR Arup	Discussion on the Network Rail feedback on the structures question clarification points and discussion on the earthworks questions	Telecon
3 December '18	NR Arup	Follow up call with asset data specialists	Telecon
5 December '18	ORR NR Arup	Tripartite meeting to discuss the emerging Phase 2 approach and Phase 1 close out	Face-to-Face: London
10 December '18	NR Arup	Follow up on data request	Telecon
18 December '18	NR Arup	Meeting with Simon Bishop (LNW) to discuss structures data	Face-to-Face: Manchester
19 December '18	ORR NR Arup	Final 2018 catch up on progress	Telecon
9 January '19	NR Arup	Meeting with Alex Davison (LNW) to discuss structures data	Face-to-Face: Manchester
22 January '19	NR Arup	Consideration of the practicalities of accessing these various sources of data	Face-to-Face: Milton Keynes

B1.2 Phase 2:

Date	Attendance	Purpose	Meeting Type
12 February ‘19	ORR NR Arup	First review of Arup Phase 2 proposal	Telecon
26 February ‘19	ORR Arup	Review of ORR comments on Arup’s Phase 2 proposal	Telecon
26 March ‘19	ORR NR Arup	Phase 2 kick off Tripartite meeting	Face-to-Face: London
3 April ‘19	NR Arup	Data transfer discussion	Telecon
12 April ‘19	NR Arup	Structures supporting data discussion	Telecon
15 April ‘19	NR Arup	Structures ownership discussion	Telecon
23 April ‘19	NR Arup	Data supply discussion	Telecon
3 May ‘19	ORR NR Arup	Confirmation of the attributes that could be included in the review based on current asset data appreciation	Face-to-Face: London
7 June ‘19	ORR NR Arup	Review of the outcome of the pilot in terms of results and lessons from the actual review process ahead of going into the full execution	Face-to-Face: London
11 June ‘19	NR Arup	Earthworks data clarification	Telecon
17 June ‘19	ORR NR Arup	Review progress or data acquisition and take decision on the move to full implementation	Telecon
10 July ‘19	NR Arup	The first of two workshops scheduled with Network Rail structures with access to the Network Rail systems gathering additional information / evidence	Face-to-Face: Milton Keynes
18 July ‘19	NR Arup	The second workshop scheduled with Network Rail earthworks with access to the Network Rail systems gathering additional information / evidence	Face-to-Face: Milton Keynes
19 July ‘19	NR Arup	Follow up workshop with Network Rail Structures to close out further issues	Face-to-Face: Milton Keynes
31 July ‘19	NR Arup	Second follow up workshop with Network Rail structures to close out final issues	Face-to-Face: Milton Keynes

Date	Attendance	Purpose	Meeting Type
6 August ‘19	NR Arup	Follow up workshop with Network Rail Earthworks to close out further issues	Telecon
21 August ‘19	ORR NR Arup	Presentation of full review findings	Face-to-Face: London
10 September ‘19	ORR NR Arup	Presentation of commission final report and report feedback	Face-to-Face: London

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Appendix C

Detail of Sample Generation

C1 Detail of Sample Generation

C1.1 Asset Sample – Overline Bridges

The following method was used to generate the Asset Sample for overline bridges.

- Input File[11]: Feb19 P12 Overline.xlsx
- Intermediate File: Feb19 P12 Overline - Full Set.xlsx
- Output File: Feb19 P12 Overline - Accuracy Sample.xlsx

The steps used were:

1. A copy of the Input File was taken to the intermediate file.
2. A column was added to the intermediate file (column N) titled Random Number (Dynamic) and each data row had its cell populated with the Excel =RAND() function. This resulted in each data row having a random number assigned to it.

   The version of Excel used utilised Mersenne Twister algorithm to generate random numbers.
3. The Excel RAND function is a dynamic function, which therefore re-calculates each time the workbook re-calculates. So a copy of the Random Number (Dynamic) column was taken to a second added column (column O) titled Random Number (Static) using Excel Copy and Paste Values. All subsequent processing was then based on this static view.
4. A check was undertaken on the uniqueness of the Random Number (Static) content, by adding a third column (column P) and populating the cell of each data row with the Excel formula =COUNTIF(O:O,O<current row>) with <current row> varying for each cell.

   The formula returned 1 in all cases, demonstrating all Random Number (Static) values to be unique. Processing this formula was quite onerous, as essentially an outer join, joining each cell in the column to itself and all other rows in the column which has performance implications, the column was therefore removed after the results were obtained.
5. The workbook was sorted on the Random Number (Static) column by cell value ascending.
6. The header row and the first four hundred data rows were selected and copied to the output file. Providing 207 candidates for accuracy assessment, plus reserve candidates in the event of issues.
7. Spot checks were undertaken of rows in the output file to the corresponding rows in the input file, via the asset IDs to check that the

[11] The files listed in this appendix are available on request.

processing had not disrupted the attributes within the rows. No issues were found.

C1.2 Asset Sample – Underline Bridges

The method and results were identical to overline bridges, at section C1.1 above. For the filenames replace ‘overline’ with ‘underline’ therein.

C1.3 Asset Sample – Embankments

The method to produce this sample was as at section C1.1 above, with the variations described below.

- Input File: Feb 19 Embankment Raw Data.xlsx
- Intermediate File: Feb 19 Embankment Raw Data - Full Set.xlsx
- Output File: Feb 19 Embankment Raw Data - Accuracy Sample.xlsx

The variations in the steps to those described in section on page 1C1.1 above were:

1. No change.
2. Column T was used.
3. Column U was used.
4. Column V was used and the formula referenced column U.
5. No change.
6. No change.
7. No change.

C1.4 Asset Sample – Rock Cuttings

The method to produce this sample was as at section C1.1 above, with the variations described below.

- Input File: Feb 19 Rock Cutting Raw Data.xlsx
- Intermediate File: Feb 19 Rock Cutting Raw Data - Full Set.xlsx
- Output File: Feb 19 Rock Cutting Raw Data - Accuracy Sample.xlsx

The variations in the steps to those described in section C1.1 above were:

1. No change.
2. Column T was used.
3. Column U was used.
4. Column V was used and the formula referenced column U.
5. No change.

6. No change.
7. No change.

C1.5 Asset Sample – Soil Cuttings

The method to produce this sample was as at section C1.1 above, with the variations described below.

- Input File: Feb 19 Soil Cutting Raw Data.xlsx
- Intermediate File: Feb 19 Soil Cutting Raw Data - Full Set.xlsx
- Output File: Feb 19 Soil Cutting Raw Data - Accuracy Sample.xlsx

The variations in the steps to those described in section C1.1 above were:

1. No change.
2. Column T was used.
3. Column U was used.
4. Column V was used and the formula referenced column U.
5. No change.
6. No change.
7. No change.

C1.6 Network Location Sample

The method to produce this sample was as described at section C1.1 above, with the variations described below.

Input File: NetworkLinks.dbf

Intermediate File: NetworkLinks.csv.xlsx

Output File: NetworkLinks - Completeness Sample.csv.xlsx

The variations in the steps to those described in section C1.1 above were:

1. The NetworkLinks.dbf file, a CSV file, was loaded into Excel as such and saved to the intermediate file as an Excel workbook, so that the Excel functions in subsequent steps could be applied.
2. Column K was used.
3. Column L was used.
4. Column M was used and the formula referenced column L.
5. No change.

6. The header row and the first one hundred and twenty data rows were included in the sample. This provides the ideal forty two cluster start locations (clusters of five apply) plus reserve candidates.
7. No change.

Appendix D

Core Dataset to Mandate Mapping

D1 Core Dataset to Mandate Mapping

D1.1 Core Datasets – Structures

The Core Datasets for structures were delivered as six files, covering both the underline and overline bridge sub-asset types for assessment. The data is from NR's February 2019 corporate and regulatory reporting data consolidation. Each file consisted of a header row attributing names to columns and a number of data rows, the data row volumes are described at Table 27 below.

Two files were specific to one of the two sub-asset types:

- Feb19 P12 Overline.xlsx for overline bridges; and
- Feb19 P12 Underline.xlsx for underline bridges.

Four files contained records for both sub-asset types, with an individual record applying to an overline bridge or an underline bridge:

- Feb19 P12 HCE.xlsx for Hidden Critical Element examination details;
- Feb19 P12 NumberOfDecks_Final.xlsx for number of spans information;
- Feb19 P12 PLBE_Final.xlsx for Principal Load Bearing Element examination details; and
- Feb19 P12 SCMI_AND_EXAM_DATE_Final.xlsx for detailed examination details.

The relationship between the attributes of these files and the attributes to be evaluated, under the Mandate, is described at Table 26 below.

Table 26: Mandate to Core Data Cross Reference for Structures

Mandate Reference			**Assessment Reference**	
Asset Type	Sub Asset Type	Attributes	Assessment File	Assessment Attribute
Structures	Overline Bridges	ID	Feb19 P12 Overline.xlsx	ELR + RAILWAY_ID (Columns B and D)
		Start Mileage	Feb19 P12 Overline.xlsx	START_MILEAGE (Column C)
		Primary ELR	Feb19 P12 Overline.xlsx	ELR (Column B)
		Owning Party	Feb19 P12 Overline.xlsx	OWNING_PARTY (Column J)
		Operational Status	Feb19 P12 Overline.xlsx	OPERATIONAL_STATUS (Column I)
		Primary Material	Feb19 P12 Overline.xlsx	PRIMARY_MATERIAL (Column K)
		CMI score (Asset Level)	Feb19 P12 SCMI_AND_EXAM_DATE_Final.xlsx	SCMI_AND_EXAM_DATE_2SCMISCMI (Column C)
		CMI score (PLBE)	Feb19 P12 PLBE_Final.xlsx	MaxOfBCMI_SCORE (Column M)
		CMI Date	Feb19 P12 SCMI_AND_EXAM_DATE_Final.xlsx	ExamDate (Column B)
		Detailed Exam Date	Feb19 P12 Overline.xlsx	LAST_EXAM_DATE (Column L)

Mandate Reference			Assessment Reference	
Asset Type	Sub Asset Type	Attributes	Assessment File	Assessment Attribute
		HCE examination date	Feb19 P12 HCE.xlsx	INSPECTION_DATE (Column K)
		Number of Decks	Feb19 P12 NumberOfDecks_Final.xlsx	MaxOfMAJORELEMENTNO (Column G)
	Underline Bridges	ID	Feb19 P12 Underline.xlsx	ELR + RAILWAY_ID (Columns B and D)
		Start Mileage	Feb19 P12 Underline.xlsx	START_MILEAGE (Column C)
		Primary ELR	Feb19 P12 Underline.xlsx	ELR (Column B)
		Owning Party	Feb19 P12 Underline.xlsx	OWNING_PARTY (Column J)
		Operational Status	Feb19 P12 Underline.xlsx	OPERATIONAL_STATUS (Column I)
		Primary Material	Feb19 P12 Underline.xlsx	PRIMARY_MATERIAL (Column K)
		CMI score (Asset level)	Feb19 P12 SCMI_AND_EXAM_DATE_Final.xlsx	SCMI_AND_EXAM_DATE_2SCMISCMI (Column C)
		CMI score (PLBE)	Feb19 P12 PLBE_Final.xlsx	MaxOfBCMI_SCORE (Column M)
		CMI date	Feb19 P12 SCMI_AND_EXAM_DATE_Final.xlsx	ExamDate (Column B)

Mandate Reference			Assessment Reference	
Asset Type	Sub Asset Type	Attributes	Assessment File	Assessment Attribute
		Detailed Exam Date	Feb19 P12 Underline.xlsx	LAST_EXAM_DATE (Column L)
		Underwater examination date	Feb19 P12 Underline.xlsx	LAST_UNDERWATER_EXAM_DATE (Column M)
		Number of decks	Feb19 P12 NumberOfDecks_Final.xlsx	MaxOfMAJORELEMENTNO (Column G)
		HCE examination date	Feb19 P12 HCE.xlsx	INSPECTION_DATE (Column K)

An initial, relatively superficial, non-intrusive set of checks were performed against the Core Data for structures. The aim of the tests was to ensure that the data was reasonably formed and of the volume anticipated, by reference to the discovery work under Phase 1, as set out in the Phase 2 Proposal section 5.3.

The Phase 1 discovery work was undertaken against Core Data for structures dating from April 2017, so approaching two years older than the assessment data. With this consideration, the volume results were reasonable and described at Table 27 below. The data types and ranges checks were all successful.

Table 27: Core Data Volumes for Structures

		Phase 1 Discovery File		**Phase 2 Assessment File**			
Asset	File Type	File Name	No. of Data Rows	File Name	No. of Data Rows	Difference	%age Difference
Structures	Overline Bridges	Structures Overline Bridges Raw Data 28 04 2017.xls	10,806	Feb19 P12 Overline.xlsx	10,830	24	0.22%
	Underline Bridges	Structures Underline Bridges Raw Data 28 04 2017.xls	19,943	Feb19 P12 Underline.xlsx	19,932	-11	-0.06%
	HCE Examination	Structures HCE Raw Data 28 04 2017.xlsx	1,799	Feb19 P12 HCE.xlsx	1,899	100	5.27%
	No. of Decks	Structures NumberOfDecks_ Raw Data 28 04 2017.xlsx	26,582	Feb19 P12 NumberOfDecks_Final.xlsx	26,457	-125	-0.47%
	PLBE CMI Scores	Structures PLBE_ Raw Data 28 04 2017.xlsx	26,582	Feb19 P12 PLBE_Final.xlsx	26,457	-125	-0.47%

		Phase 1 Discovery File		Phase 2 Assessment File			
Asset	File Type	File Name	No. of Data Rows	File Name	No. of Data Rows	Difference	%age Difference
	Bridge CMI and Detailed Examination Date	Structures SCMI_AND_EXAM_DATE_ Raw Data 28 04 2017.xlsx	26,582	Feb19 P12 SCMI_AND_EXAM_DATE_Final.xlsx	26,457	-125	-0.47%

D1.2 Core Datasets – Earthworks

The Core Datasets for earthworks were delivered as three files, one for each of three earthwork sub-asset types under assessment; embankments, rock cuttings and soil cuttings. The data was from NR's February 2019 corporate and regulatory reporting data consolidation. Each file consisted of a header row attributing names to columns and a number of data rows, the data row volumes are described at Table 29 below.

The three sub-asset types, by file, were:

- Feb 19 Embankment Raw Data.xlsx for embankments;
- Feb 19 Rock Cutting Raw Data.xlsx for rock cuttings; and
- Feb 19 Soil Cutting Raw Data.xlsx soil cuttings.

The relationship between the attributes of these files and the attributes to be evaluated, under the Mandate, is described at Table 28 below.

Table 28: Mandate to Core Data Cross Reference for Earthworks

Mandate Reference			**Assessment Reference**		
Asset Type	**Sub Asset Type**	**Attributes**	**Assessment File**	**Assessment Attribute**	**Notes**
Earthworks	Embankment	Asset ID	Feb 19 Embankment Raw Data.xlsx	ELR + StartMileage + EndMileage + Up_Down + Track Name (Columns F, P, H, N and S)	
		Currently included in Adverse / Extreme Weather Plan	Not assessed, as not maintained by NR pending the introduction of the NR CSAMS application, agreed at the meeting 3rd May 2019.		
		EACB	Not assessed, no independent source of verification identified as this is maintained by the in-field aspects of the NR earthworks (JBA) application, agreed at the meeting 3rd May 2019.		
		Asset Examination Status	Not assessed, no independent source of verification identified as this is maintained by the in-field aspects of the NR earthworks (JBA) application, agreed at the meeting 3rd May 2019.		
		EHC	Not assessed, no independent source of verification identified as this is maintained by the in-field aspects of the NR earthworks (JBA) application, agreed at the meeting 3rd May 2019.		
		Asset Type	Feb 19 Embankment Raw Data.xlsx	Asset_Type (Column E)	
		ELR	Feb 19 Embankment Raw Data.xlsx	ELR (Column F)	

Mandate Reference			Assessment Reference		
Asset Type	**Sub Asset Type**	**Attributes**	**Assessment File**	**Assessment Attribute**	**Notes**
		End Easting	Feb 19 Embankment Raw Data.xlsx	EndEasting (Column G)	
		End Mileage	Not tested for accuracy, earthworks are divided into five chain, track relative, lengths. Each length constitutes an asset record, there are therefore no visible, earthwork relative, real world markers. Mileages were used as part of the completeness assessment. The relationship between end easting and northing and end mileage was tested.		
		End Northing	Feb 19 Embankment Raw Data.xlsx	EndNorthing (Column I)	
		Last Evaluation Date	Direct look-up of NR earthworks (JBA) application	Asset level Previous tab.	
		Last Examination Date	Feb 19 Embankment Raw Data.xlsx	EE_EnteredDate (Column J)	Additional information on mapping supplied by NR 08/03/2019
		Operational Status	Feb 19 Embankment Raw Data.xlsx	DisusedLine (Column K)	Additional information on mapping supplied by NR 08/03/2019
		Owning Party	Not tested for accuracy, currently all assets in the data set are assumed to be owned by NR. There is work underway, to acquire data about third party earthworks which pose a risk to the railways which		

Mandate Reference			Assessment Reference		
Asset Type	**Sub Asset Type**	**Attributes**	**Assessment File**	**Assessment Attribute**	**Notes**
			is being marshalled outwith the current data set, for inclusion in the CSAMS system but this is not yet maintained.		
		Route	Feb 19 Embankment Raw Data.xlsx	OpRoute (Column M)	
		Side	Feb 19 Embankment Raw Data.xlsx	Up_Down (Column N)	
		Start Easting	Feb 19 Embankment Raw Data.xlsx	Easting (Column O)	
		Start Mileage	Not tested for accuracy, earthworks are divided into five chain, track relative, lengths. Each length constitutes an asset record, there are therefore no visible, earthwork relative, real world markers. Mileages were used as part of the completeness assessment. The relationship between start easting and northing and start mileage was tested.		
		Start Northing	Feb 19 Embankment Raw Data.xlsx	Northing (Column Q)	
		Track Name	Feb 19 Embankment Raw Data.xlsx	Track Name (Column S)	

Mandate Reference			**Assessment Reference**		
Asset Type	**Sub Asset Type**	**Attributes**	**Assessment File**	**Assessment Attribute**	**Notes**
	Rock Cutting	Asset ID	Feb 19 Rock Cutting Raw Data.xlsx	ELR + StartMileage + EndMileage (Columns F, P and H)	
		Currently included in Adverse / Extreme Weather Plan	Not assessed, as not maintained by NR pending the introduction of the NR CSAMS application, agreed at the meeting 3rd May 2019.		
		EACB	Not assessed, no independent source of verification identified as this is maintained by the in-field aspects of the NR earthworks (JBA) application, agreed at the meeting 3rd May 2019.		
		Asset Examination Status	Not assessed, no independent source of verification identified as this is maintained by the in-field aspects of the NR earthworks (JBA) application, agreed at the meeting 3rd May 2019.		
		EHC	Not assessed, no independent source of verification identified as this is maintained by the in-field aspects of the NR earthworks (JBA) application, agreed at the meeting 3rd May 2019.		
		Asset Type	Feb 19 Rock Cutting Raw Data.xlsx	Asset_Type (Column E)	
		ELR	Feb 19 Rock Cutting Raw Data.xlsx	ELR (Column F)	

Mandate Reference			Assessment Reference		
Asset Type	**Sub Asset Type**	**Attributes**	**Assessment File**	**Assessment Attribute**	**Notes**
		End Easting	Feb 19 Rock Cutting Raw Data.xlsx	EndEasting (Column G)	
		End Mileage	Not tested for accuracy, earthworks are divided into five chain, track relative, lengths. Each length constitutes an asset record, there are therefore no visible, earthwork relative, real world markers. Mileages were used as part of the completeness assessment. The relationship between end easting and northing and end mileage was tested.		
		End Northing	Feb 19 Rock Cutting Raw Data.xlsx	EndNorthing (Column I)	
		Last Evaluation Date	Direct look-up of NR earthworks (JBA) application	Asset level Previous tab.	
		Last Examination Date	Feb 19 Rock Cutting Raw Data.xlsx	EE_EnteredDate (Column J)	Additional information on mapping supplied by NR 08/03/2019
		Operational Status	Feb 19 Rock Cutting Raw Data.xlsx	DisusedLine (Column K)	Additional information on mapping supplied by NR 08/03/2019
		Owning Party	Not tested for accuracy, currently all assets in the data set are assumed to be owned by NR. There is work underway, to acquire data about third party earthworks which pose a risk to the railways which		

Mandate Reference			Assessment Reference		
Asset Type	**Sub Asset Type**	**Attributes**	**Assessment File**	**Assessment Attribute**	**Notes**
			is being marshalled outwith the current data set, for inclusion in the CSAMS system but this is not yet maintained.		
		Route	Feb 19 Rock Cutting Raw Data.xlsx	OpRoute (Column M)	
		Side	Feb 19 Rock Cutting Raw Data.xlsx	Up_Down (Column N)	
		Start Easting	Feb 19 Rock Cutting Raw Data.xlsx	Easting (Column O)	
		Start Mileage	Not tested for accuracy, earthworks are divided into five chain, track relative, lengths. Each length constitutes an asset record, there are therefore no visible, earthwork relative, real world markers. Mileages were used as part of the completeness assessment. The relationship between start easting and northing and start mileage was tested.		
		Start Northing	Feb 19 Rock Cutting Raw Data.xlsx	Northing (Column Q)	
		Track Name	Feb 19 Rock Cutting Raw Data.xlsx	Track Name (Column S)	

Mandate Reference			**Assessment Reference**		
Asset Type	**Sub Asset Type**	**Attributes**	**Assessment File**	**Assessment Attribute**	**Notes**
	Soil Cutting	Asset ID	Feb 19 Soil Cutting Raw Data.xlsx	ELR + StartMileage + EndMileage (Columns F, P and H)	
		Currently included in Adverse / Extreme Weather Plan	Not assessed, as not maintained by NR pending the introduction of the NR CSAMS application, agreed at the meeting 3rd May 2019.		
		EACB	Not assessed, no independent source of verification identified as this is maintained by the in-field aspects of the NR earthworks (JBA) application, agreed at the meeting 3rd May 2019.		
		Asset Examination Status	Not assessed, no independent source of verification identified as this is maintained by the in-field aspects of the NR earthworks (JBA) application, agreed at the meeting 3rd May 2019.		
		EHC	Not assessed, no independent source of verification identified as this is maintained by the in-field aspects of the NR earthworks (JBA) application, agreed at the meeting 3rd May 2019.		
		Asset Type	Feb 19 Soil Cutting Raw Data.xlsx	Asset_Type (Column E)	
		ELR	Feb 19 Soil Cutting Raw Data.xlsx	ELR (Column F)	

Mandate Reference			Assessment Reference		
Asset Type	**Sub Asset Type**	**Attributes**	**Assessment File**	**Assessment Attribute**	**Notes**
		End Easting	Feb 19 Soil Cutting Raw Data.xlsx	EndEasting (Column G)	
		End Mileage	Not tested for accuracy, earthworks are divided into five chain, track relative, lengths. Each length constitutes an asset record, there are therefore no visible, earthwork relative, real world markers. Mileages were used as part of the completeness assessment. The relationship between end easting and northing and end mileage was tested.		
		End Northing	Feb 19 Soil Cutting Raw Data.xlsx	EndNorthing (Column I)	
		Last Evaluation Date	Direct look-up of NR earthworks (JBA) application	Asset level Previous tab.	
		Last Examination Date	Feb 19 Soil Cutting Raw Data.xlsx	EE_EnteredDate (Column J)	Additional information on mapping supplied by NR 08/03/2019
		Operational Status	Feb 19 Soil Cutting Raw Data.xlsx	DisusedLine (Column K)	Additional information on mapping supplied by NR 08/03/2019
		Owning Party	Not tested for accuracy, currently all assets in the data set are assumed to be owned by NR. There is work underway, to acquire data about third party earthworks which pose a risk to the railways which		

Mandate Reference			Assessment Reference		
Asset Type	**Sub Asset Type**	**Attributes**	**Assessment File**	**Assessment Attribute**	**Notes**
			is being marshalled outwith the current data set, for inclusion in the CSAMS system but this is not yet maintained.		
		Route	Feb 19 Soil Cutting Raw Data.xlsx	OpRoute (Column M)	
		Side	Feb 19 Soil Cutting Raw Data.xlsx	Up_Down (Column N)	
		Start Easting	Feb 19 Soil Cutting Raw Data.xlsx	Easting (Column O)	
		Start Mileage	Not tested for accuracy, earthworks are divided into five chain, track relative, lengths. Each length constitutes an asset record, there are therefore no visible, earthwork relative, real world markers. Mileages were used as part of the completeness assessment. The relationship between start easting and northing and start mileage was tested.		
		Start Northing	Feb 19 Soil Cutting Raw Data.xlsx	Northing (Column Q)	
		Track Name	Feb 19 Soil Cutting Raw Data.xlsx	Track Name (Column S)	

An initial, relatively superficial, non-intrusive set of checks were performed against the Core Data for earthworks. The aim of the tests was to ensure that the data is reasonably formed and of the volume anticipated, by reference to the discovery work under Phase 1, as set out in the Phase 2 Proposal section 5.3.

The Phase 1 discovery work was undertaken against Core Data for structures dating from November 2018, so approximately four months older than the assessment data. With this consideration, the volume results were reasonable and described at Table 29 below. The data types and ranges checks were successful, for the attributes supplied.

Issue remain with two attributes, as reported during Phase 1:

1. No attributes were supplied for the Currently included in Adverse / Extreme Weather Plan element of the Mandate; and
2. For the Last Evaluation Date attribute the content is for a foreign key to another database table, rather than the attrite values of that table.

Table 29: Core Data Volumes for Earthworks

		Phase 1 Discovery File		**Phase 2 Assessment File**			
Asset	**File Type**	**File Name**	**No. of Data Rows**	**File Name**	**No. of Data Rows**	**Difference**	**%age Difference**
Earthworks	Embankments	Embankments Raw Data 2.xlsx	102,589	Feb 19 Embankment Raw Data.xlsx	102,682	93	0.09%
	Rock Cuttings	Rock Cutting Raw Data 2.xlsx	16,433	Feb 19 Rock Cutting Raw Data.xlsx	16,476	43	0.26%
	Soil Cuttings	Soil Cutting Raw Data 2.xlsx	73,117	Feb 19 Soil Cutting Raw Data.xlsx	73,176	59	0.08%

Appendix E

Supporting Datasets – National and Sample Specific

E1 Supporting Datasets – National and Sample Specific

E1.1 National Datasets

E1.1.1 National Datasets – Aerial Imagery and LiDAR

The high resolution aerial imagery and matching processed LiDAR data was supplied by NR via HDD and copied onto internal servers for use in remote visual surveying assessment, described in 3.3.2.2 above.

Initially, 3,297 random ¼ km² Ordnance Survey Great Britain (OSGB) referenced data tiles were supplied to visually evaluate applicable attributes within the accuracy assessment. As well as this, separate ¼ km² OSGB referenced data tiles covering the entirety of the 103 ELR's were provided to be assessed during the completeness assessment.

During the full execution, due to the sparsity of rock cuttings the initial random sample of data provided was exhausted and a further 1,287 ¼ km² OSGB referenced data tiles of high resolution aerial imagery and LiDAR data were provided by NR, to ensure the completion of the assessment.

High-resolution aerial imagery provided the potential to review a national data set as a primary source for visually locating earthworks and structures, for conformation of relevant features and data completeness measurements.

LiDAR data provides an alternative data set showing height variation of the ground, allowing for the confirmation of the presence of earthworks and structures, as well allowing for the detection of earthworks and structures through visual barriers in the aerial imagery, such as vegetation coverage.

E1.1.2 National Datasets – Network Model

The NR network model is a spatially and logically connected link/node network, representing the track centre lines nationally. It is maintained on a monthly cycle for use within their business. The assessment was based on the January 2019 version.

The network model is made up of four attributed shapefiles (sixteen physical files) representing Links, Nodes, Reference Lines and Waymarks

Within the assessment this data was used to:

1. Generate random network locations, for the start points of completeness cluster sampling, under remote surveying; and
2. Provide a base reference for network locations via ELR and mileage.

E1.1.3 National Datasets – Oblique Imagery

Access to this data was provided via the supply by NR of logins to their Route Viewer application, used within their business and supply chain. It provided a national high resolution angled image set, rather than the downwards view from aerial imagery.

E1.2 Sample Specific Datasets

E1.2.1 Bridges Subject to Detailed Examination and Cycle Intervals

Source: CARRs Database

Extracted: May 2019

Format: Excel

Description:

A listing of all bridges which are subject to detailed examination by NR, with the interval in years between detailed examinations for each member.

This listing is joined to the core data via either the combination of ELR and Railway ID or the GUIDs. Initial spot checks demonstrated that these joins can be successfully made to random sample members where applicable, the main proving is through the data accuracy measurement pilot, see section 2.4.2.4 above of the methodology.

E1.2.2 Bridges Applicable to HCE Examinations and Dates

Source: HCE Database

Extracted: May 2019

Format: Excel

Description:

A listing of all bridges containing priority 1 HCEs and therefore subject to HCE examinations, together with the last HCE examination date as an independent source of that date to the core data.

This listing is joined to the core data via the combination of ELR and Railway ID. Initial spot checks demonstrated that these joins can be successfully made to random sample members where applicable, the main proving is through the data accuracy measurement pilot, see section 2.4.2.4 above of the methodology.

E1.2.3 Bridges Subject to Underwater Examination and Cycle Intervals

Source: Scour Database

Extracted: May 2019

Format: Excel

Description:

A listing of all bridges which are subject to underwater examination by NR, with the interval in years between underwater examinations for each member.

This listing is joined to the core data via either the combination of ELR and Railway ID or the GUIDs. Initial spot checks demonstrated that these joins can be successfully made to random sample members where applicable, the main proving is through the data accuracy measurement pilot, see section 2.4.2.4 above of the methodology.

E1.2.4 Latest Bridge Detailed Examination Reports

Source: CARRs Database

Extracted: April 2019

Format: Individual PDF files

Description:

A set of PDF files of the latest bridge examiners detailed examination report, per bridge, as supplied by the examiner to NR and approved by them. The scope of the set provided is those members of the overline and underline samples which have detailed examination reports.

The set of PDFs were not indexed, initial checks verified that the correct report can be found by searching within the set of files on the combination of ELR and Railway ID, within Windows Explorer.

E1.2.5 Latest Bridge Underwater Examination Reports

Source: CARRs Database

Extracted: April 2019

Format: Individual PDF files

Description:

A set of PDF files of the latest bridge underwater examiners underwater examination report, per bridge, as supplied by the examiner to NR and approved by them. The scope of the set provided is those members of the underline sample which have underwater examination reports.

The set of PDFs were not indexed, initial checks verified that the correct report can be found by searching within the set of files on the combination of ELR and Railway ID, within Windows Explorer.

E1.2.6 Bridge Principal Load Bearing Elements

Source: Derivation, BCMI Database and Detailed Examination Report

Extracted: Not applicable, calculated on test execution

Format: Not applicable

Description:

The algorithm for the extraction of PLBE scoring in the core data was provided so that the detailed test procedures contain instructions for repeating this calculation against the detailed examination report, per bridge. This allows independent verification of the values held in the BCMI database.

E1.2.7 Bridge Ownership Records

Source: Route correspondence systems

Extracted: Various 2019, supplied May 2019

Format: Various e.g. Word, Outlook, Excel

Description:

The records of agreement with other parties, e.g. highway authorities, about the ownership of bridges which are not owned by NR but are listed in the core datasets as impinging on the NR network. Records were provided for the initial 207 members of the overline and underline samples, it was agreed that any additional needs would be addressed during results refinement, see section 2.4.4.2 above of the methodology.

E1.2.8 Bridges Exempt from BCMI Calculations

Source: BCMI database

Extracted: June 2019

Format: Excel

Description:

A listing of bridges whose design parameters fall outside of the BCMI calculation characteristic and are therefore exempt, from this calculation. The dataset was extracted from a copy of the BCMI database using a query supplied by NR.

Note: This need was established as part of piloting the accuracy assessment, rather than in the original Phase 2 methodology. It was therefore proven through the pilot exercise.

E1.2.9 Bridges Managed as Footbridges

Source: CARRs database

Extracted: June 2019

Format: Excel

A listing of bridges which NR manage as footbridges, rather than overline bridges and are therefore legitimately not in their listings of underline bridges.

Note: This need was established as part of piloting the completeness assessment, rather than in the original Phase 2 methodology. It was therefore proven through the pilot exercise.

E1.2.10 Earthworks Latest Inspection Report

Source: Direct access to the NR earthworks (JBA) application

Extracted: Access provided May2019, used thereafter as needed

Format: On-line access through the application interface

Description:

Independent inspection reports for earthworks are not produced, rather they are generated from the JBA application. Access to this application was therefore provided, so that testers can look up the relevant attributes, together with their history and changed values over time, when executing the tests.

E1.2.11 Earthworks Latest Evaluation Report

Source: Direct access to the NR earthworks (JBA) application

Extracted: Access provided May2019, used thereafter as needed

Format: On-line access through the application interface

Description:

Independent evaluation reports for earthworks are not produced, rather they are generated from the JBA application. Access to this application was therefore provided, so that testers could look up the relevant attributes, together with their history and changed values over time, when executing the tests.

The key triggers, driven by data changes, for evaluation were assessed from the NR engineering standards and these triggers and their outcome then assessed through the tests.

E1.2.12 Earthworks Inspection Cycle

Source: Derivation, JBA database and NR engineering standards

Extracted: Not applicable, calculated on test execution

Format: Not applicable

Description:

The algorithm for the calculation of the inspection cycle for the five-chain inspection length containing an earthwork asset was provided. The detailed test procedures contain instructions for repeating this calculation, against the applicable parameters from the JBA application, per earthwork asset.

Appendix F

Detailed Test Procedures

Appendix G

Detailed Test Results

G1 Detailed Test Results

The detailed test results are provided in the accompanying Excel workbook L3AR005 Data Quality Assessment - Final Report Appendix G.xlsx. The tabs in this workbook relate to the test procedures at Appendix F, via the references of those test procedures