Hannah Stephenson

From: Steven Masia <SMASIA@ncc.nsw.gov.au>
Sent: Monday, 20 February 2017 4:46 PM
To: Kieran Black
Subject: RE: PP_2016_NEWCA_010_00 - AMEND NEWCASTLE LEP 2012 FOR LAND BOUNDED BY MOSBRI CRES & KITCHENER PDE THE HILL

Hi Kieran

Thanks for getting back to me on this one.

Regards

Steve

Steven Masia | Senior Urban Planner
Strategic Planning | Planning and Regulatory
Newcastle City Council
Phone: +61 2 4974 2817
Email: smasia@ncc.nsw.gov.au
Web: www.newcastle.nsw.gov.au
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---

From: Kieran Black [mailto:Kieran.Black@finance.nsw.gov.au]
Sent: Monday, 20 February 2017 2:12 PM
To: Steven Masia
Cc: Kayleigh Swallow
Subject: PP_2016_NEWCA_010_00 - AMEND NEWCASTLE LEP 2012 FOR LAND BOUNDED BY MOSBRI CRES & KITCHENER PDE THE HILL

Hi Steve,

Subsidence Advisory NSW have no issues with this proposal. We will impose conditions and engineering controls on any future development as appropriate, given the presence and nature of underlying mine workings.

Cheers

Kieran Black
Subsidence Risk Engineer

Subsidence Advisory NSW | An Agency of the Department of Finance, Services and Innovation
p (02) 4908 4362 |
e k.black@minesub.nsw.gov.au | www.subsidence.nsw.gov.au
Ground Floor, Government Offices, 117 Bull Street Newcastle West NSW 2302

NSW GOVERNMENT | Subsidence Advisory NSW

the sender.

Hannah Stephenson

From: Kayleigh Swallow
Sent: Monday, 20 February 2017 1:17 PM
To: Kieran Black
Subject: New Enquiry from 12/1/17 - FW: Public authority consultation - planning proposal to amend Newcastle LEP 2012 for land bounded by Mosbri Crescent & Kitchener Parade The Hill
Attachments: Letter to - MSB dated 12 Jan 2017 - consultation for Mosbri Cres planning proposal.pdf

Hi Kieran

Steve from Newcastle City Council called.

Re: email sent on 12/1/17 sent to mail@minesub.nsw.gov.au in relation to a planning proposal to change building heights. NCC are also proposing to change the zone from low density to medium density.

NCC are seeking our advice in relation to acceptance of the planning proposal, in particular to change building heights.

The area consists of the NBN site and surrounding properties – 11-17 Mosbri Crescent, The Hill and Kitchener Parade.

I have requested Steve to resend the email as no current file has been opened. After some investigation I have been able to find the FN which is FN70-02925N0.

Please see email below and attachments. You will see from the attached letter there is a link which takes you to the attachments. Select “Rezoning of land bounded by Mosbri Crescent and Kitchener Parade, The Hill” (second title in list). Steve indicated that the document to bring your attention to is “Planning Proposal – Att A to Council report”.

Would you like me to open a new file at this stage?

Steve’s contact details are:

4974 2817

Email: smasia@ncc.nsw.gov.au

Thanks

Tanya Mason
Administration Officer

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e kayleigh.swallow@finance.nsw.gov.au | www.subsidence.nsw.gov.au
Ground Floor, Government Offices, 117 Bull Street Newcastle West NSW 2302

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From: Steven Masia [mailto:SMASIA@ncc.nsw.gov.au]
Sent: Monday, 20 February 2017 12:16 PM
To: Kayleigh Swallow
Subject: FW: Public authority consultation - planning proposal to amend Newcastle LEP 2012 for land bounded by Mosbri Crescent & Kitchener Parade The Hill

Steven Masia | Senior Urban Planner
Strategic Planning | Planning and Regulatory
Newcastle City Council
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Web: www.newcastle.nsw.gov.au
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From: Steven Masia
Sent: Thursday, 12 January 2017 4:33 PM
To: 'mail@minesub.nsw.gov.au'
Subject: Public authority consultation - planning proposal to amend Newcastle LEP 2012 for land bounded by Mosbri Crescent & Kitchener Parade The Hill

Dear Sir / Madam

Please find attached request for public authority consultation.

Regards

Steven Masia | Senior Urban Planner
Strategic Planning | Planning and Regulatory
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Email: smasia@ncc.nsw.gov.au
Web: www.newcastle.nsw.gov.au
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Planning and Regulatory

The City of Newcastle
PO Box 489, Newcastle
NSW 2300 Australia
Phone: 4974 2000
Fax: 4974 2222
Email: mail@ncc.nsw.gov.au
www.newcastle.nsw.gov.au

12 January 2017

mail@minesub.nsw.gov.au

The District Manager
Newcastle District Office
Mine Subsidence Board
PO Box 488G
NEWCASTLE NSW 2300

Dear Sir / Madam

PUBLIC AUTHORITY CONSULTATION PLANNING PROPOSAL PP_2016_NEWCA_010_00 - AMEND NEWCASTLE LEP 2012 FOR LAND BOUNDED BY MOSBRI CRES & KITCHENER PDE THE HILL

Newcastle City Council is seeking your comments in relation to the above Planning Proposal, pursuant to section 56(2) of the *Environmental Planning and Assessment Act 1979*, Gateway determination dated 22 December 2016.

A copy of the Planning Proposal and Gateway determination is available on the Department of Planning and Environment's LEP Tracking webpage for your review:

(http://leptracking.planning.nsw.gov.au/PublicList.aspx?ProjectTitle=&AreaId=106&ProposalType=0+or+Amending)

It is requested that your comments are received by 3 February 2017 in order to allow the planning proposal to go on public exhibition. Please advise if you are unable to meet this timeframe. Council would appreciate a response stating your comments or that you have no objections regarding the planning proposal.

It is noted that the Gateway determination may contain a number of conditions to be addressed prior to public exhibition. The planning proposal has not been updated at this stage as Council will also consider the outcomes of the public authority consultation, prior to updating the planning proposal for the public exhibition. If you are interested in any of the gateway conditions please advise Council.

If you require any further information please contact me at smasia@ncc.nsw.gov.au or on 02 4974 2817.

Steven Masia
SENIOR URBAN PLANNER

Hannah Stephenson

From: Paul Gray
Sent: Wednesday, 21 February 2018 1:23 PM
To: Kieran Black
Cc: David Sedgman; Kayleigh Swallow
Subject: TENQ18-17056N1 Please call back - [redacted]
Attachments: FN70-02925N0 MINING.pdf

Hi Kieran, can you please call [redacted] to discuss this site? He's on a plane back from Canberra at 6. The property goes to auction early March, thanks Paul

---

From: Kayleigh Swallow
Sent: Wednesday, 21 February 2018 11:13
To: Paul Gray; David Sedgman
Subject: Please call back - [redacted]

Called regarding 11-17 Mosbri Cres, The Hill. Lot 1 DP 204077 – He has a Geotech report from Douglas Partners and wishes to discuss any issues with this site.

Thanks

Kayleigh Swallow
Administration Officer

Please note my working days are Weds, Thurs, Fri.

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Hannah Stephenson

From: [redacted]@northrop.com.au>
Sent: Wednesday, 23 May 2018 2:18 PM
To: Kieran Black
Subject: RE: NBN site

Thanks Kieran.

[redacted]
Northern NSW Regional Manager
Northrop Consulting Engineers Pty Ltd
T: [redacted]
M: [redacted]
Level 1, 215 Pacific Highway Charlestown NSW 2290
PO Box 180 Charlestown NSW 2290
www.northrop.com.au

From: Kieran Black <Kieran.Black@finance.nsw.gov.au>
Sent: Wednesday, 23 May 2018 1:40 PM
To: [redacted]@northrop.com.au>
Subject: NBN site

Hi [redacted] – as discussed

Nearby workings in dirty seam – 35 – 55 m

[redacted]

Kieran Black
Technical Manager

Subsidence Advisory NSW | An Agency of the Department of Finance, Services and Innovation
p (02) 4908 4391
e Kieran.Black@finance.nsw.gov.au | www.subsidenceadvisory.nsw.gov.au

Ground Floor, Government Offices, 117 Bull Street Newcastle West NSW 2302

Please consider the environment before printing this email

Hannah Stephenson

From: Kieran Black
Sent: Friday, 28 September 2018 11:45 AM
To: [redacted]'
Subject: FW: NBN Site - Nearby Shaft locations

Hi [redacted],

Hows it going ?

This is what we have

Hope it helps

[redacted]

From: [redacted] [mailto:[redacted]@coffey.com]
Sent: Thursday, 27 September 2018 4:46 PM
To: Kieran Black <Kieran.Black@finance.nsw.gov.au>
Subject: NBN Site - Nearby Shaft locations

Kieran

During the filling of NBN Site we hit voids instead of pillar on the first run and had to relocate the mine workings by 10m.

Anyways hoping SANSW could confirm the locations of the pits for the New winnings and the A, B, C, and F pits. Or let me know how confident SANSW is in their locations so when I rearrange the mine plans it all makes sense.

Regards

[redacted]
Senior Geotechnical Engineer

t: [redacted]
m: [redacted]

coffey
A TETRA TECH COMPANY

Crescent Newcastle Pty Ltd
Proposed Multi - Building Residential Development
11-17 Mosbri Crescent, Cooks Hill NSW 2300

754-NTLGE220504-AH.Rev3

Mine Subsidence Investigation Report

14 January 2019

Technology
is the product
of intelligence
not the
cause of it

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Proposed Multi - Building Residential Development 11-17 Mosbri Crescent, Cooks Hill, NSW 2300

Prepared for
Crescent Newcastle Pty Ltd

Prepared by
Coffey Services Australia Pty Ltd
19 Warabrook Boulevard
Warabrook
NSW 2304 Australia
t: +61 2 4016 2300
ABN 55 139 460 521

14 January 2019

754-NTLGE220504-AH.Rev3

Quality information

Revision history

Revision	Description	Date	Originator	Reviewer	Approver
Version 0	Report Draft	6/11/2018	Simon Baker	Jules Darras	Simon Baker
Revision 1	Report Final	28/11/2018	Simon Baker	Jules Darras	Simon Baker
Revision 2	Report Final	17/12/2018	Simon Baker	Jules Darras	Simon Baker
Revision 3	Report Final	14/01/2019	Simon Baker	Jules Darras	Simon Baker

Distribution

Report Status	No. of copies	Format	Distributed to	Date
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Revision 2	1	PDF	Richard Anderson, Mark Purdy	17/12/2018
Revision 3	1	PDF	Richard Anderson, Mark Purdy	14/01/2019

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1. Introduction

Crescent Newcastle Pty Ltd (Crescent) commissioned Coffey Services Australia Pty Ltd (Coffey) to carry out a mine subsidence investigation for the proposed multi building residential development located at 11-17 Mosbri Crescent, Cooks Hill, NSW.

This report addresses the scope of work outlined in our proposal referenced as 754-NTLGE220504.P01.Rev02, Section 2.2 Mine Subsidence Investigation, dated 27 August 2018. Preliminary contamination assessment and geotechnical investigations will be reported separately.

The currently proposed development will include:

- Construction of residential accommodation comprising 172 dwellings, being:
  - Eleven (11) two storey townhouse style dwellings fronting Mosbri Crescent, located above a basement car park containing 34 visitor spaces and 11 resident spaces;
  - Three (3) residential flat buildings (Building A, B, and C) containing 161 dwellings, ranging from one to three bedrooms; being
    - Building A including a nine (9) storey east wing and six (6) storey west wing;
    - Building B comprising seven (7) storeys and a roof top communal open space, with (9) town house style dwellings facing the internal courtyard;
    - Building C comprising five (5) levels;
- Interconnected car parking for Building A, B & C located on the ground floor and first level, contains 1 visitor spaces and 196 resident spaces;
- Pedestrian path, providing connection from Mosbri Crescent to Kitchener Parade; and
- Associated landscaping, communal open space, services and site infrastructure.

Site is sloping south westerly towards Mosbri Crescent Reserve and existing ground RLs within the footprint of the Building A, B and C varies between RL 36m AHD and RL 38.00m AHD. The combined basement levels will require excavation of approximately 8.5m to 9.5m below existing ground level (RL 28.10m AHD and RL 29.60m AHD) at the rear (eastern) side of the property although the proposed excavation is generally less than 4m.

Two storey townhouses are proposed along Mosbri Crescent with single basement level. Maximum excavation required for the proposed townhouses will be approximately 4.5m below ground level (basement RL 25.40m AHD to RL 27.40m AHD).

Vehicular access to the proposed development is via ramp from Mosbri Crescent connecting with proposed basements driveways, located next to apartment building located at 9 Mosbri Crescent, north western side of site.

Prior to this report Coffey was given following documents:

- Site Survey Plan prepared by Monteath & Powys Pty Ltd, titled as “Detail Survey Over Lot 1 DP204077, NBN Studios, Mosbri Crescent, The Hill”, referenced as 15/047 and dated 10/4/15, inclusive;
- Preliminary Architectural Drawings prepared by Marchese Partners International Pty Ltd, titled as “11-17 Mosbri Crescent, The Hill NSW 2300”, referenced as job 171114 and comprises of drawing from DA2.01 to DA2.11, dated as 10/10/2018, water marked as **work in progress**.

This report presents the results of the mine subsidence investigation carried out to assess the current conditions in the two mine levels encountered under the site. Results of the mine subsidence modelling will be provided in a separate report.

The site is known to be located over abandoned workings in both the Yard Seam and the Borehole Seam.

2. Scope of work undertaken

This mine subsidence assessment was based on the following:

- Review of previous job files in the area.
- Setting out borehole locations by survey based on review of mine workings plans
- Preparation of safety documentation, liaison with DYBD and organising an underground service locator to clear the proposed drilling areas
- Drilling four boreholes to the base of the Borehole Seam
- Downhole survey using downhole geophysics, camera, sonar and acoustic viewer
- Coal pillars stability assessment using rectangular pillar theories, incorporated in the Modified UNSW Power Law strength equation as presented in Galvin et al (1998). The Factor of Safety (FOS) of the pillars and the likelihood of subsidence occurring were estimated by this method.

3. Investigation Methodology

3.1. Borehole Drilling

The site investigation was conducted between 3 September 2018 to 21 September 2018, comprising drilling of four boreholes. The workings of the Borehole Seam are fairly well documented and as such, the boreholes were set out targeting either bords or pillars in the Borehole Seam.

Boreholes BH01 and BH03 were fully cored, targeting a bord and a pillar of the Borehole Seam respectively. BH01 and BH03 were drilled using a Comacchio 450 using HQ sized diamond bit. BH01 was drilled to a depth of 102.1m and BH03 was drilled to a depth 102.14m.

Boreholes BH02A and BH04 were drilled by washbore method with a polycrystalline diamond (PCD) targeting a pillar and a bord of the Borehole Seam respectively. BH02A was drilled to a depth of 102.0m and BH4 was drilled to 101.6m.

Borehole BH02 was abandoned after a conflict with underground infrastructure.

The borehole locations are shown on the site plan, attached.

Point load testing was undertaken in the lab on selected recovered core with the results summarised on the borehole logs. All fieldwork, including the logging of subsurface profile and collection of samples was carried out by a geotechnical engineer from Coffey. Borehole BH01 was cased to a depth of 45.3m due to loss of circulation at or above the Yard Seam.

Borehole BH02A was able to hold water through the Yard Seam without casing. There was no circulation loss to the base of the Borehole Seam workings indicating that no open joints were encountered.

Boreholes BH03 and BH04 were cased to depths of 45.5m and 44.6m respectively after encountering Yard Seam workings and were then able to hold water until encountering the Borehole Seam.

3.2. Downhole Observations

Following drilling the boreholes were sounded with:

- Geophysical survey to assess alignment, deviation, relative rock density (Refer to Appendix B)
- Acoustic televiewer to log rock structure, defects and open joints (Refer to Appendix B)
- Sonar to assess the dimension of encountered voids

- A camera to observe conditions within any encountered voids (Refer to Appendix C)

4. Laboratory testing

Point load tests were undertaken on select core samples in accordance with RMST223 in our Newcastle NATA accredited lab. The test results are indicated on the logs and are summarised in the Figure 1.

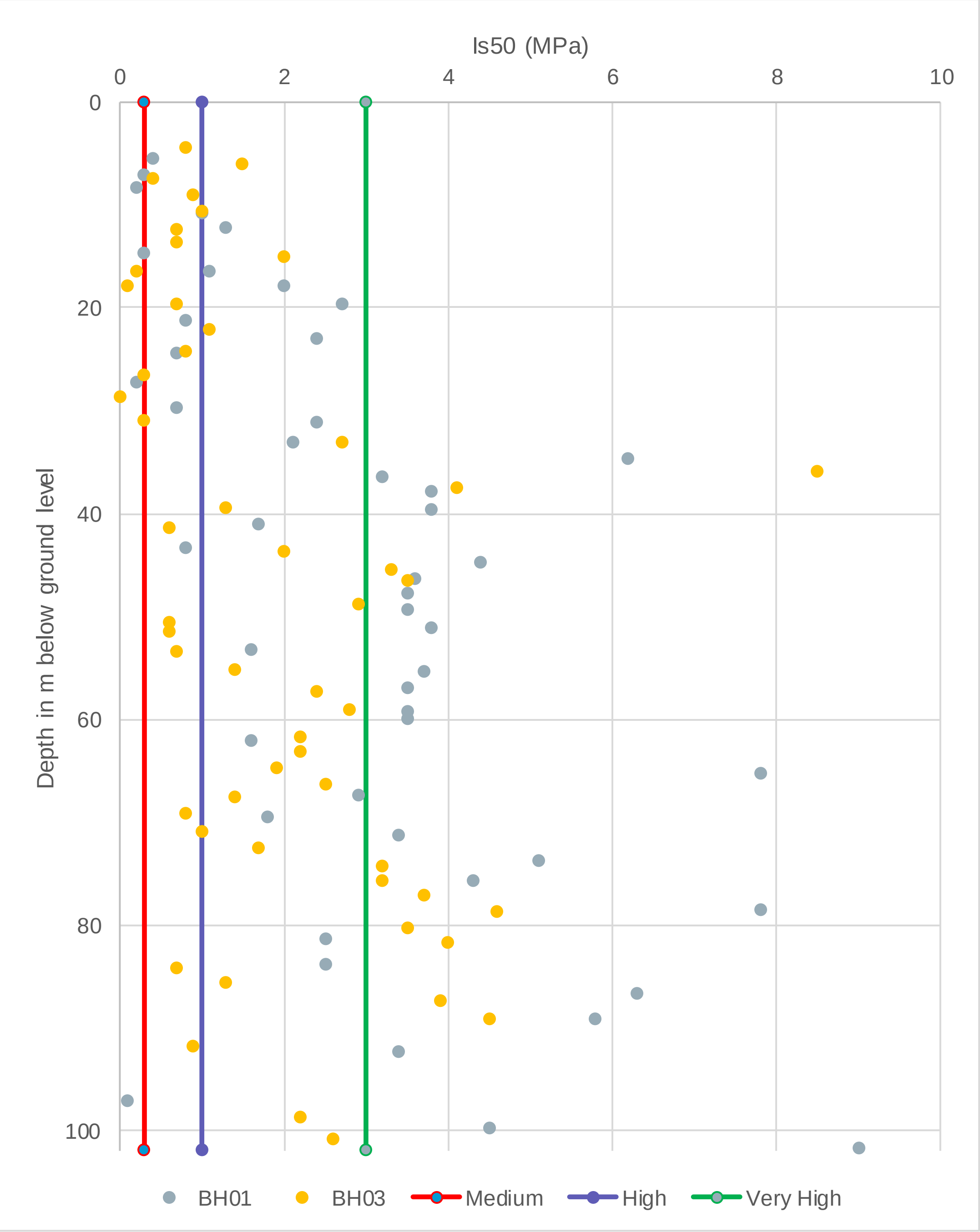

Figure 1: Summary of point load testing

From the testing the rock strength above the Yard Seam is generally low to medium strength, while below the Two Foot Seam the rock strength is generally high to very high.

5. Surface conditions

The site is an irregular shaped land with an approximate area of 1.2ha and consists of properties 11-17 Mosbri Crescent, Cooks Hill.

At the time of the investigation, a two / three storey commercial building was present within the site (NBN building), covering one third of the site area with a single basement level carpark. A couple of sheds, cooling tower and satellite dish were present within the rear portion of the property. A two level carpark was present towards the north and few parking bays at the back of the exiting NBN building. The remaining site area being covered in associated pavements, grassed area and several mature trees scattered along the site boundary. Vehicular access to site was via driveways from Mosbri Crescent.

The site is located within the Newcastle City Council area, adjacent to Mosbri Crescent carriageway, which is a minor road reserve within the local area. The site shares eastern boundary with Arcadia Park reserve located uphill. The site is bounded by the following properties, public roads and infrastructure:

- Kitchener Parade carriageway and road reserve to the north of the site
- Arcadia Park to the east of the site
- Two and three storey residential buildings and Mosbri Crescent to the north west and west of site boundary; and
- Single and double storey residential buildings to south and south west of the site

The site topography during the investigation slopes was generally gently to moderately sloping and has an angle of approximately 10° towards the south west to west.

6. Ground model

6.1. Regional geology

Based on the 1:100,000 scale Newcastle Coalfield Geology map, the site is underlain by rocks and soils derived from the late Permian aged Lambton Subgroup of the Newcastle Coal Measures comprising sandstone, siltstone, claystone, coal and tuff. This corresponds to site observations with high plasticity clay soils underlain by sandstone.

6.2. Subsurface conditions

At the locations of the boreholes, the site is overlayed by fill material to a depths of between 0.25m and 2.8m. Fill is underlain by residual soils grading into extremely weathered material comprising clay materials to a depth of 4.7m. It is noted the boreholes were carried out in accessible areas only which comprise the current carpark or paved areas. Further drilling will be required at later stage to confirm the preliminary ground model.

The borehole location plan is provided in Drawing 1. All borehole logs from the site investigation are provided in Appendix A with downhole geophysics provided in Appendix B.

The interpreted geotechnical units encountered at the site are shown in Table 1.

Table 1: Summary of ground model stratigraphy

Stratum	Depth to base of unit below ground level (m)				Comments
	BH01	BH02A	BH03	BH04	
Fill	0.4	0.25	0.45	2.8	Bitumen overlying sandy gravel followed by sandy clay. (Sandy clay and uncontrolled fill encountered in BH04)
Residual soil/extremely weathered material	4.2	NE	3.4	4.6	Clay to sandy clay medium plasticity
Bar Beach Formation	25.05	26.05	17.2	16.8	Interbedded and interlaminated sandstone and siltstone. Typically low to medium strength
Dudley Seam Upper?	26.55	27.7	18.5	18.1	Coal
Dudley Split	27.8	28.6	27.35	27.3	Interbedded and interlaminated sandstone and siltstone. Typically medium strength. Significantly thicker on the southern side of the site.
Dudley Seam (AKA Dirty Seam)	29.68	30.3	29.4	29	Coal not mined under the site. Nearby mining from C Pit
Bogey Hole Formation	42.9	43.8	41.65	41.7	Interbedded and interlaminated sandstone and siltstone Typically very high strength. Note lower 1.5m has collapsed into the mine workings
Yard Seam	43.7	44.9	43.15	42.8	Mined by AACo from the C Pit
Tighes Hill Formation	54.4	55.5	52.75	52.6	Interbedded and interlaminated sandstone and siltstone Typically high to very high strength
Two Foot Seam	55.0	56.1	53.2	53.4	Not mined
Tighes Hill Formation Continued	93.2	94.8	92.6	92.1	Interbedded and interlaminated sandstone and siltstone Typically high to very high strength
Borehole Seam	99.3	100.7	98.7	98.7	Mined by AACo from the Sea/ New Winnings Pit
Waratah Sandstone	>102.1	>102	102.14	101.6	Fine to coarse grained sandstone, very high strength
Notes: > Limit of investigation NE Not encountered					

Boreholes BH01, BH03 and BH04 encountered workings within the Yard Seam at depths of 41.55m to 43.5m, 41.6m to 43.15m and 41.7m to 42.8m respectively.

Groundwater inflows were not encountered within soil profile during the site investigation, however water inflow was observed during downhole camera work. The stationary water levels after encountering the mine workings was approximately 3m AHD.

6.3. Downhole Observations

Following drilling and as a part of the mine subsidence investigation, on 4 September 2018, a CCTV camera was used to observe conditions in the borehole BH01. Some water was observed flowing into the boreholes from 12m BGL (approximately 19m AHD) although the source could not be positively identified. Similar water was observed in BH03 on the 13 September 2018 from approximately 20m BGL 13m AHD. No such water was observed in BH04 on the 14 September 2018.

Sonar was used within the Yard Seam of BH01 and BH03 as well as the Borehole Seam for boreholes BH01 and BH04. Sonar data was used to confirm dimension of voids and data is presented on drawings, Drawing 2, Drawing 3, Drawing 7 to Drawing 10.

Acoustic televiewer was used in all boreholes except the lower portion of BH03. The information indicates that the overburden rock is nearly horizontally bedded with some open fractures. Data is provided in Appendix B. The data suggests that the overburden and interborder is not disturbed enough to have previously undergone significant subsidence.

Downhole camera was typically used to verify the presence of large voids at mine level. Screen shots are provided in Appendix C.

6.3.1. Overburden / interburden

A summary of the joints and washout defects observed in the televiewer is provided in Figure 2.

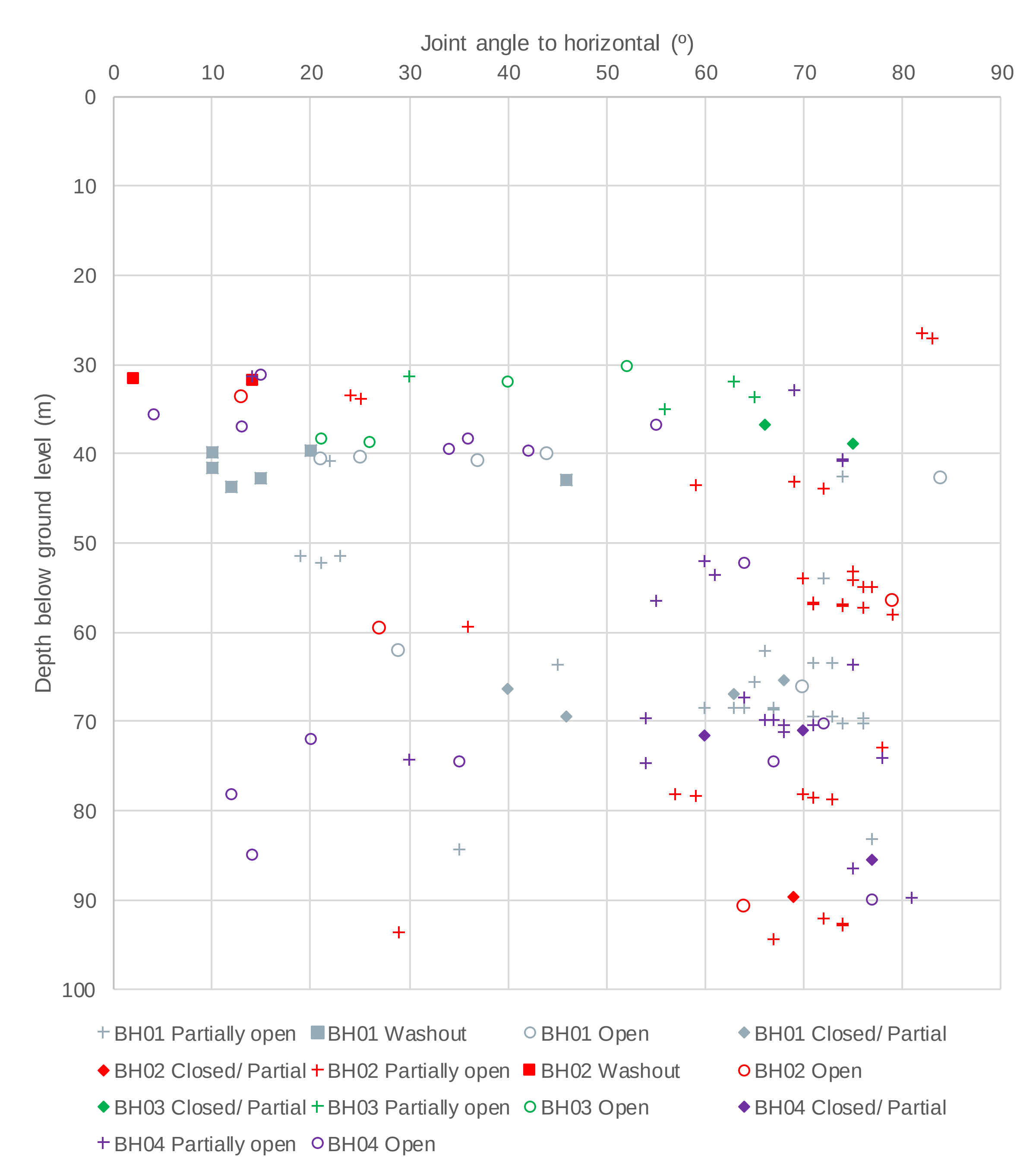

Figure 2: Summary of defects from televiewer

Based on the above there is an increased density of defects above the Yard Seam which corresponds to the delamination and roof cave in in this area.

Within the lower portion, the defects are mostly closed with an increased density of open joints in BH04.

6.3.2. Yard Seam

The open voids encountered within the Yard Seam and Borehole Seam were scanned by a down hole sonar and inspected with CCTV camera. Although attempted, voids within the yard seam were too small to get clear sonar images.

The CCTV encountered the following:

- BH01 Clear void at mine level with smaller voids visible within the spanning overburden
- BH03 generally rubble within mine level
- BH04 very poor visibility with small voids

6.3.3. Borehole Seam

The sonar scans and CCTV footage encountered the following:

- BH01
  - 4.5m wide bord near the floor with the near pillar being only 0.7m away from the borehole
  - 4.2m wide at 0.2m from the top of void
  - The length of bord observed was 17m
  - A void height of approximately 0.5m with rubble on the floor
- BH04
  - 5.8m wide bord near the floor 22m in length with an interruption at 4.1m
  - 5.5m wide by 21m long at 0.5m above the floor
  - 4.8m wide near the roof of the void
  - Top of voids was hard to make out with the discoloured water while large blocks of siltstone were visible on the floor

7. Factual information on workings

7.1. Yard Seam

7.1.1. History

The Yard Seam was originally mined by the government using convict labour in the eastern parts of Newcastle. In the 1820's, due to inefficiencies of using labour not experienced in coal mining, the British Government decided to offload the burden of coal to private hands, the largest in the area being AACo which had previously been investing in wool.

In December 1831, AACo's A pit was officially opened with the first wagons of coal being released down the gravity powered railway that led to the harbour at the time. This Pit was approximately 260m north west of the site. Later in 1837, a second pit was installed to the Yard Seam (B Pit 330m west of the site) with a third C Pit in 1841. The workings under the site most likely being from the C Pit located 120m south of the site.

Due to the age of the workings, mapping is very limited. Outlines are shown on Sheet 4 of RT566 (Drawing 2). A record tracing RT654 (Exhibit Y Royal Commission of Earth Subsidence at Newcastle) is available for the project although it only has an outline of the area worked as well.

Operations ceased from the A pit in 1846 with work continuing from the C Pit, which closed in the 1850.

Coffey has now been involved in several projects which have investigated the condition of the Yard Seam mine workings. These include the Tax Office building, the Crown Development and the Acculon Development. Our findings from these projects are discussed below.

7.1.2. Working dimensions

Based on the previous investigations, the mine workings (bords) are typically about 5m in width with pillars about 1.5m up to 2m in width (generally around 1.7m wide) with a mined height of about 0.9m to 1.2m. The newer Yard Seam workings in the F Pit, located 770m south west of the site (RT566 Sheet 7) were larger due to being completed within a different era.

The following information was encountered around the Yard Seam within the subject site.

- BH01:
  - 41.65 – 0.11m tool drop followed by
  - 0.25m core loss (siltstone) and 0.1m of siltstone returned
  - 0.3m of core loss (small void only on CCTV)
  - 0.45m of siltstone (still in roof with bedding cored at horizontal)
  - 0.65m of no core with a 0.5m tool drop. Width of bord on sonar was less than 2m
  - 0.1m of coal at the base of the workings possibly intact.
- BH02A
  - Solid coal from 43.75m to 44.9 with a possible 0.2m thick silty layer
- BH03
  - 0.1m tool drop 41.62m
  - 0.1m siltstone
  - 0.33 tool drop
  - 0.35m of core loss
  - 0.7m of rubble including weathered siltstone and coal
- BH04
  - 0.2m tool drop at 38.15m
  - 3.45m siltstone/ sandstone
  - 0.6m coal
  - 0.2m silty layer
  - 0.11m tool drop at 42.5m
  - 0.2m coal

Although sonar imaging was attempted at the site, the voids were too small due to roof fall in with signals being bounced around. Voids encountered were generally less than 0.3m in height. Even the large void in BH01 could not get an image of the bord walls.

7.1.3. Previous grouting works

Previous grouting operations have been carried out in the Yard Seam in areas near the site. This was generally limited to the larger structures including the Telstra Building (400m north west; grouting records unavailable), Tax Office Building (420m north west), the Court House Building (490m north west) and the Acculon (460m north). Some of these sites are located outside the recorded mine workings boundaries. As such, the extent of the workings has been demonstrated to be outside the limits of workings shown on RT566.

7.2. Borehole Seam

7.2.1. History

The Borehole Seam was discovered in 1848. Mining was originally carried out by the AACo in the Hamilton area from the 'D Pit' shaft which was sunk at Denison Street and became operational in 1852 and later converted to an air shaft in 1877 for the No. 2 Pit. A nearby 'E Pit' was sunk in 1854 on Everton Street, 382m south west of D Pit and was primarily used for ventilation.

In 1861, the Australian Agricultural Company sank its No. 2 (169ft / 51.5 m deep) shaft near the intersection of Beaumont and Kemp Street, 1.3km south-west of the site. Later the 'Hamilton Pit' was sunk in 1872 near Lawson Street and Thomas St. These shafts were later combined for the mine generally known as the No. 2 Pit /Hamilton Pit workings.

In 1888, the AACo sunk its New Winning Pit in the Cooks Hill Area. According to Danvers Power (1912), the seam was worked by the bord and pillar method with pillar extraction in some areas. The nearest secondary workings are located over 350m to the south-west of the subject site with the main area of secondary workings being 500m south west of the site.

The workings of these two pits were separated by barrier coal which was originally 5 chains in width (RT566 Sheet 4), with this barrier later mined out (RT566 Sheet 8).

Danvers Power (1912) provides a description of the workings within the New Winnings Pit which indicates that headings were driven parallel and 70 yards (64m) apart, bords were 6 yards wide (5.4m) and 33 yards long (30m) and pillars were 12 yards wide (11m). This is a general representation of what was nominally aimed for in the pit, though pillars are generally slightly smaller under the site with the scaled pillar widths from RT566 generally being between 9.8m and 11.5m with an average of 10.6m. Similarly the scaled bord widths from the RT are 5.4m to 6.3m with an average of 5.8m.

The method of mining in bords is described by Danvers Powers (1912) to be as follows:

1. Middle Coal taken 7'7" (2.3m) with the Morgan band left in the mine;
2. Bottom Coal lifted 4'4" (1.3m) with the Jerry band being put to one side;
3. Top Coal dropped 4'1" (1.2m) with the aid of drums or ladders to stand on.

It is noted that the top coal stood up (did not collapse) better than the roof rock and so delamination and caving of the roof is expected, (this has been observed within numerous boreholes drilled in the area).

A passage from the 1908 Royal Commission below provides further information on the mined section. The sketch referred to is shown below as Figure 3.

> "The top lift (A) on the sketch is of an exceptionally tender nature and has little cohesive strength. The coal immediately above (B) is also of a very friable character. Following upon the third operation (dropping the top coal) the splint coal above, and frequently the shale roof, falls in the bords, and together with the dirt bands fill up more or less the space from which the coal has been excavated often to within about 3 feet of the top of the seam, thus, to some extent automatically supporting the pillars. The roof over the seam proper consists of splint coal and bands 4 feet, and overlying shale and sandstone."

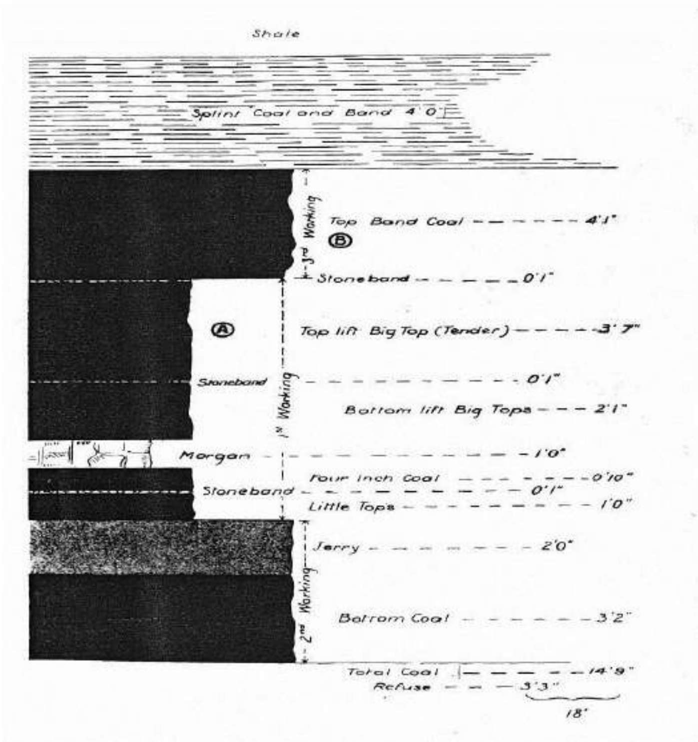

Figure 3: Borehole Seam section from 1908 Royal Commission

The above section is considered to be representative of the Borehole Seam in the area.

The mine workings of the No. 2 and Hamilton pits were abandoned in 1901 (RT566), while the New Wining Pit workings were abandoned in 1916.

7.2.2. Worked and current pillar heights

During mining, the poor quality splint coal was left in the roof of the mine workings as it had little commercial value. After the completion of mining, the upper split coal as well as some of the overlying laminated rock has fallen into the mine voids, as observed in several boreholes (by Coffey and others).

Modern borehole logs are available for several sites near the subject site including:

- The Court House Building, Bulk Fly Ash Grout
- The Acculon Building, Coffey report N08844/01-AD April 2004
- The GPT Development, Douglas Partners report 39826.14.R.001Rev1 July 2018
- 108 Church Street, Coffey report 754-NTLGE211941-AD May 2018

A summary of the findings from the current investigation combined with average Borehole Seam data from nearby projects is provided in Table 2.

Table 2: Summary of Borehole Seam data

Development	Location relative to site	Lower bound void (m)	Upper bound void (m)	Average Void (m)	Lower bound pillar height [2] (m)	Upper bound pillar height [2] (m)	Average Pillar height (m)	Full Seam thickness (m) (only)
BH01	Subject site			0.5			3.6	
BH02A								5.9
BH03								6.1
BH04				1.65			6.6	
Church [1]	330m north	-	-	-	-	-	-	6.0
Court House	500m north west	0.2	6.7	2.9	0.2	9.3	6.2	NA
Acculon	420m north	0.7	1.15	0.93	8.0	8.4	8.2	6.95
East End	400m north east	0.5	1.00	0.74	6.08	7.84	6.74	NA
New Winning Winding Shaft	570m south west							(22 feet) 6.7

Notes:

(1): evidence of crushing within coal pillar

(2): combined void plus rubble

NA: Accurate seam thickness not available

It is noted the bottom 2.5m of coal (Morgan Stone and below) in BH01 was still in place below the rubble.

The original pillar height at the New Winning Pit is shown to be 17' 0.5" (5.19m), which is slightly less than the working section from the Royal Commission of 18' (5.49m) given above.

7.2.3. Bord widths

After encountering voids at mine level, a sonar was used to scan the mine workings. The sonar scans encountered to following:

- BH01
  - 4.5m wide bord near the floor with the near pillar being only 0.7m away from the borehole
  - 4.2m wide at 0.2m from the top of void.
  - The length of bord observed was 17m
- BH04
  - 5.8m wide bord near the floor 22m in length with an interruption at 4.1m.
  - 5.5m wide by 21m long at 0.5m above the floor.
  - 4.8m wide near the roof of the void

7.2.4. Roof of workings

The immediate roof of the workings is comprised of a combination of silty coal overlain by siltstone and shale. Experience obtained from drilling numerous boreholes in the Borehole Seam workings in the Newcastle area shows that although prone to spalling and cave-in, the compressive strength of the immediate roof of the workings remains much greater than that of the underlying clean coal. Borehole BH01 had an axial I_{s50} strength of 3.4MPa while BH03 while BH03 had an axial I_{s50} strength of 0.9MPa (approximate UCS of 15MPa to 50MPa). Additionally, boreholes which have intersected mining bords show this material to 'arch' increasing the width of the pillar in this area. Therefore, punching failure of the workings into the roof is considered to be a non-credible case for these workings.

7.2.5. Borehole Seam floor conditions

The Waratah Sandstone forms the floor of the Borehole Seam.

A good knowledge base regarding the characteristics of the Waratah Sandstone beneath Newcastle is now available from numerous recent boreholes, carried out by Coffey in the area and records of old boreholes and mining conditions. Based on this, the Waratah Sandstone is considered:

- Free from tuffaceous clays, weaker rock beds or fractured zones
- At least 5 m thick
- Not prone to significant softening
- Not known to cause floor heave or pillar bearing capacity problems
- Very high to extremely high strength sandstone encountered in BH03

For the Waratah Sandstone, BH01 had an axial I_{s50} strength of 4.5MPa while BH03 while BH03 had an axial I_{s50} strength of 2.2MPa (approximate UCS of 80MPa and 40MPa). Therefore, punching failure of the workings into the floor is considered to be a non-credible case for these workings.

7.2.6. Discussion on the 1906 to 1908 subsidence events

As reported in the 1908 Royal Commission and summarised in a report by To, E.M. (1998), large scale subsidence events have occurred in the Borehole Seam workings beneath Newcastle. The consequences of these 'creeps' was cracks of up to 75mm width and surface depressions up to 825mm deep resulting in damage to buildings and infrastructure.

The crushing originated in an area of smaller square shaped pillars (with dimensions of 8m to 9m by 8m to 13m scaled off RT566) with subsequent crushing events potentially caused by the additional abutment loading associated with vertical stress redistribution away from the failed pillars. The locations of the three crush zones is shown on RT566 Sheet 4. The second crush zone is shown to be located between Church Street and Tyrell Street extending down to McCormack Street. The third zone is bounded by Perkin Street to the west and the limit of mining in the east.

Over more regularly shaped pillars near Tyrrell and Church streets, the subsidence measured was generally 600mm to 775mm. Another finding of the Commission was that the workings located in the shallower seams (i.e. the Dudley and Yard seams) may have contributed to the subsidence magnitude. The subsidence recorded in areas where the shallow seams were not worked was approximately half of the subsidence recorded for areas where shallow workings were present. That is approximately 300mm to 390mm.

No lives were lost and no buildings had to be demolished as a result of the 1906 – 1908 subsidence events. These events provide a valuable indication of the maximum subsidence or 'worst case' that could be expected from a large subsidence event. The failure was slow and access to some parts of the mine was possible for inspections during the creeps. Further expansion of the creeps halted without intervention. That is, the creeps eventually stopped on their own accord without human efforts to confine them. This subsidence event occurred while the mine workings were dewatered. Since then, the mine was abandoned with the water level within the mine allowed to rise, significantly reducing the stress on the pillars and thereby reducing the likelihood of further pillar failure. In this sense, the Borehole Seam workings underlying Newcastle have undergone a large scale proof load test. Although the pillars are gradually weakening as the roof falls occur.

It is noted the subject site falls outside the drawn limits of subsidence.

7.2.7. Confidence in the mine working record tracing

Borehole verification work from more than twenty boreholes drilled into bords within the New Winning Pit mine workings have verified that record tracing RT566 Sheet 8 is a close representation of the mine workings. Slight discrepancies exist between Sheet 4 and Sheet 8 however some of this may be due to scaling issues, plan damage (folding) and issues arising from stitching the separate images that make up the mine plans.

It is noted that a 10m shift in the mine workings was applied at the site after encountering a void at mine level within the first borehole BH01 where a pillar was expected. Remaining boreholes were then able to target mine workings as expected. This appears to be partly due to mis-alignment of the workings in the area of East End development 400m north east of the site which had been originally projected to the site.

7.2.8. Previous grouting works

Previous grouting workings have been carried out in the Borehole Seam. This was generally limited to the larger structures including:

- The Court House Building (500m north west)
- NeW Space (610m west north west)
- Icon Central (800m west).
- East End development 420m north of the site.

8. Discussion

8.1. State of mine workings

8.1.1. Yard Seam

It was not possible to verify the dimensions of mine workings within the Yard Seam due to the small void heights at mine level. The seam thickness was 1.2m thick at BH02A. This borehole also held water during drilling, indicating the overburden and Yard Seam was relatively free of fracture defects suggesting that pillars at mine level have not undergone crushing

However, with the size of void encountered at mine level being significantly filled with apparent roof collapse rubble, the potential for future pillar instability has been reduced.

8.1.2. Borehole Seam

Although the seam thickness encountered within BH02A and BH03 was approximately 600mm thinner that at the New Winning Shaft, the coal recovered in the cored borehole BH03 appears to be relatively solid with the only weak zone (core loss) being near the top of the coal pillar just below the 'Splint Coal'. In this zone, the geophysical density plots did not record a very low density that would suggest crushed coal in either borehole BH02A or BH03. As such it does not appear that the pillars have crushed in this area.

As the surrounding area to the north, east and south east is known to have crushed (i.e. Creep 1 and Creep 2 from 1906 and 1907, refer to Drawing 4) the workings within the Borehole Seam have a marginal factor of safety and may crush in the future.

8.2. Pillar stability assessment

8.2.1. Pillar factor of safety methodology

In order to quantify pillar stability, a factor of safety (FOS) is used. The factor of safety of an individual pillar is the ratio of pillar strength to pillar load. There are many published methods in practice around the world to estimate pillar strength. All are simplifications and, thus have limitations. In Australia, the UNSW Pillar Design method (Galvin et al 1998) is commonly used. This approach is based on semi-empirical relationships, derived from a database of failed and un-failed pillars. It is only valid where roof and floor conditions are good and where full pillar yield does not exist. In general, as discussed above based on core drilling of the seam this appears to be the case in this area.

An angle of draw defines a zone around a mined area or ‘panel’ that would be affected, should pillar failure occur. Due to the mainly fine grained and low strength nature of the overburden, an angle of draw of approximately 26.5° (2V:1H) has been adopted in this report.

The strength of the pillars with a width to height ratio ≤5 (S_p in MPa) can be estimated using Equation 1.

$$S_p = \frac{8.6(Q.w)^{0.51}}{h^{0.84}} \qquad (1)$$

Where: w = width of pillar (m), h = height of pillar (m).

Where the width to height ratio is >5, the equation is modified to Equation 2.

$$S_p = \frac{27.63(Q)^{0.51}}{w^{0.22}h^{0.11}}\left\{0.29\left[\left(\frac{w}{5h}\right)^{2.5} - 1\right] + 1\right\} \qquad (2)$$

Where: Q = shape factor:

- For width less than 6: $Q = \frac{2L}{L+w}$ (3)
- For width greater than 6: $Q = \left(\frac{2L}{L+w}\right)^{\frac{R-3}{3}}$ (4)

Where R = width/height

The assessed load applied to the coal pillars is obtained by the weight of all the overburden layers within the tributary area, expressed as a vertical pressure on the top of the pillar. The tributary area is typically taken the midway along bords and cut throughs surrounding a pillar, as shown in Figure 4.

Where: ‘TW’ is the tributary width and ‘TL’ is the tributary length.

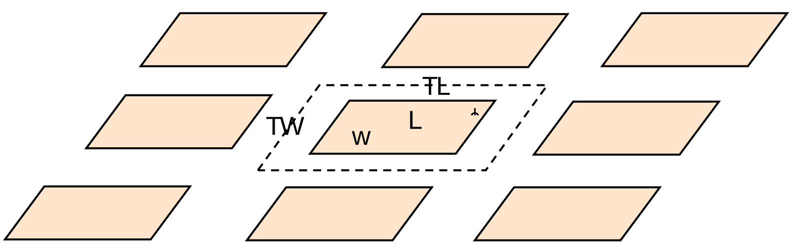

Figure 4: Tributary model

8.2.2. Pillar stability calculations

Yard Seam

For these calculations we have adopted three heights:

1. Lower bound pillar height based on inferred mined height of bords approximately 0.9m
2. The upper bound pillar height based on the maximum height (assuming all coal strength parameters) after roof collapse based on borehole data at the Acculon Site (approximately 1.6m)
3. Yard Seam thickness of 1.2m based on BH02A

For the pillar plan dimensions, we have adopted three widths:

1. 1.6m wide by 16m long
2. 1.9m wide by 16m long
3. 2.7m wide by 40m long (taken as the average pillar width of Yard Seam mine workings on RT566 Sheet 7 (unlikely to be applicable)

For the overburden load, we have adopted four states:

1. 'Dry state' equivalent to during mining under the site (i.e. 41m of cover)
2. 'Dry state' with abutment allowing for crush front under the site (i.e. 41m of cover)
3. 'Dry state' east of the site under the hill assuming 60m of cover
4. 'Dry state' east of the site under the hill assuming 60m of cover

It the above cases, the bord width has been set at 5.4m which is approximately 6 yards.

Borehole Seam

For these calculations we have adopted four heights:

1. The smaller height of pillar (i.e. above Morgan Stone) encountered in BH01 of 3.6m
2. The height of better quality coal (i.e. including Morgan and Jerry or height of full seam minus the top split coal) estimated at 4.7m encountered in BH03
3. The full coal pillar height of 6.1m encountered in BH03
4. The maximum pillar height (assuming all coal strength parameters) after roof collapse based on borehole data of BH04 being 6.6m

For the pillar plan dimensions we have adopted two widths:

1. Actually drawn plan dimensions
2. Less 1m to the drawn plan widths to model potential robbing of the pillars

For the overburden stress we have adopted eight states:

1. 'Dry state' equivalent to during mining under the site
2. A current 'Flooded State' allowing for buoyancy effect of pore pressures after flooding of the workings. Although the water table within the workings is at approximately 3m AHD, we have assumed that the water table may be lowered to approximately 50% (RL-28m) under the site
3. 'Dry state' with abutment loading under the site
4. 'Flooded State' with abutment loading under the site
5. 5 to 8: repeat of 1 to 4 with additional 20m of cover as present within the 'Creep 1 area'

These variations provide 'what if' scenarios so that an assessment can be made on how stable the workings are, even if the pillars aren't as expected.

The results of the analysis are presented in Tables 3 to 5 for the Yard Seam and Borehole Seam under the site and under The Hill (east of the site) respectively. In our opinion, the case of an equivalent 6.1m height of flooded workings is most likely for the Borehole Seam workings and the other cases provide a sensitivity assessment on the base case. These cases are shown in bold.

Results

Table 3: Summary of pillar stability calculations for Yard Seam

Pillar	**Width (m)**	**Length (m)**	**Tributary width (m)**	**Tributary length (m)**	**Abutment loading**	**Factor of safety**					
Location						Under site			East of site		
Pillar height (m)						0.9	1.2	1.6	0.9	1.2	1.6
Pillar 1	1.6	16	7.0	19	No Abutment	2.2	1.7	1.4	1.5	1.2	0.9
					With Abutment	1.6	1.2	1.0	1.0	0.8	0.6
Pillar 2	1.9	16	7.3	19	No Abutment	2.7	2.1	1.7	1.9	1.5	1.2
					With Abutment	1.9	1.5	1.2	1.2	1.0	0.8
Pillar 3	2.7	40	8.1	43	No Abutment	4.5	3.6	2.8	3.2	2.5	2.0
					With Abutment	3.8	3.0	2.4	2.5	2.0	1.6

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Table 4: Summary of pillar stability calculations for Borehole Seam under the site

Pillar	Width (m)	Length (m)	Scaled tributary width (m)	Tributary length (m)	Abutment loading	Factor of safety							
Height (m)						3.6		4.7		6.1		6.6	
Dry/ Flooded						Dry	Flooded	Dry	Flooded	Dry	Flooded	Dry	Flooded
Pillar 1	8.8	27.9	14.2	31.95	No Abutment	2.0	2.4	1.6	2.0	**1.3**	**1.6**	1.2	1.5
					With Abutment	1.3	1.6	1.0	1.3	**0.9**	**1.1**	0.8	1.0
	7.8				No Abutment	1.7	2.0	1.3	1.6	**1.1**	**1.3**	-	-
					With Abutment	1.1	1.3	0.9	1.1	**0.7**	**0.9**	-	-
Pillar 2	10.0	29.4	15.5	33.25	No Abutment	2.2	2.7	1.8	2.2	**1.5**	**1.8**	1.4	1.7
					With Abutment	1.5	1.8	1.2	1.5	**1.0**	**1.2**	0.9	1.1
	9.0				No Abutment	1.9	2.3	1.5	1.9	**1.3**	**1.5**	-	-
					With Abutment	1.2	1.5	1.0	1.2	**0.8**	**1.0**	-	-
Pillar 3	10.5	28.3	15.9	32.9	No Abutment	2.3	2.8	1.8	2.3	**1.5**	**1.8**	1.4	1.7
					With Abutment	1.5	1.8	1.2	1.5	**1.0**	**1.2**	0.9	1.1
	9.5				No Abutment	2.0	2.4	1.6	1.9	**1.3**	**1.6**	-	-
					With Abutment	1.3	1.6	1.0	1.3	**0.9**	**1.0**	-	-
Pillar 4	12.3	28.2	17.6	31.95	No Abutment	2.7	3.4	2.2	2.7	**1.8**	**2.2**	1.7	2.0
					With Abutment	1.8	2.2	1.4	1.7	**1.2**	**1.4**	1.1	1.3
	11.3				No Abutment	2.4	2.9	1.9	2.3	**1.6**	**1.9**	-	-
					With Abutment	1.5	1.9	1.2	1.5	**1.0**	**1.3**	-	-
Pillar 5	11.7	30.4	17.4	34.7	No Abutment	2.5	3.1	2.0	2.5	**1.6**	**2.0**	1.5	1.9
					With Abutment	1.7	2.1	1.3	1.7	**1.1**	**1.4**	1.0	1.3
	10.7				No Abutment	2.2	2.7	1.8	2.2	**1.4**	**1.8**	-	-
					With Abutment	1.4	1.8	1.2	1.4	**1.0**	**1.2**	-	-
Pillar 6	18.2	62.9	22.8	67.45	No Abutment	4.6	5.6	3.4	4.2	**2.6**	**3.2**	2.5	3.0
					With Abutment	3.6	4.4	2.7	3.3	**2.1**	**2.5**	1.9	2.4

Pillar	Width (m)	Length (m)	Scaled tributary width (m)	Tributary length (m)	Abutment loading	Factor of safety							
Height (m)						**3.6**		**4.7**		6.1		**6.6**	
Dry/ Flooded						**Dry**	**Flooded**	**Dry**	**Flooded**	Dry	Flooded	**Dry**	**Flooded**
	17.2				No Abutment	4.2	5.1	3.1	3.8	**2.4**	**2.9**	-	-
					With Abutment	3.3	4.0	2.4	3.0	**1.9**	**2.3**	-	-

Table 5: Summary of pillar stability calculations for Borehole Seam east of the site under the hill

Pillar	Width (m)	Length (m)	Scaled tributary width (m)	Tributary length (m)	Abutment loading	Factor of safety							
Height (m)						**3.6**		**4.7**		6.1		**6.6**	
Dry/ Flooded						**Dry**	**Flooded**	**Dry**	**Flooded**	Dry	Flooded	**Dry**	**Flooded**
Pillar 1	8.8	27.9	14.2	31.95	No Abutment	1.6	2.0	1.3	1.6	**1.1**	**1.3**	1.0	1.2
					With Abutment	1.0	1.2	0.8	1.0	**0.7**	**0.8**	0.6	0.8
	7.8				No Abutment	1.4	1.7	1.1	1.4	**0.9**	**1.1**	-	-
					With Abutment	0.8	1.0	0.7	0.8	**0.6**	**0.7**	-	-
Pillar 2	10.0	29.4	15.5	33.25	No Abutment	1.8	2.3	1.5	1.8	**1.2**	**1.5**	1.1	1.4
					With Abutment	1.0	1.2	0.8	1.0	**0.6**	**0.8**	0.6	0.7
	9.0				No Abutment	1.6	1.9	1.3	1.6	**1.0**	**1.3**	-	-
					With Abutment	0.8	1.0	0.7	0.8	**0.6**	**0.7**	-	-
Pillar 3	10.5	28.3	15.9	32.9	No Abutment	1.9	2.3	1.5	1.9	**1.2**	**1.5**	1.2	1.4
					With Abutment	1.0	1.2	0.8	1.0	**0.7**	**0.8**	0.6	0.8
	9.5				No Abutment	1.6	2.0	1.3	1.6	**1.1**	**1.3**	-	-
					With Abutment	0.9	1.1	0.7	0.9	**0.6**	**0.7**	-	-
Pillar 4	12.3	28.2	17.6	31.95	No Abutment	2.3	2.8	1.8	2.2	**1.5**	**1.8**	1.4	1.7
					With Abutment	1.2	1.5	1.0	1.2	**0.8**	**1.0**	0.7	0.9
	11.3				No Abutment	2.0	2.4	1.6	1.9	**1.3**	**1.6**	-	-
					With Abutment	1.1	1.3	0.9	1.1	**0.7**	**0.9**	-	-

Pillar	Width (m)	Length (m)	Scaled tributary width (m)	Tributary length (m)	Abutment loading	Factor of safety							
Height (m)						3.6		4.7		6.1		6.6	
Dry/ Flooded						Dry	Flooded	Dry	Flooded	Dry	Flooded	Dry	Flooded
Pillar 5	11.7	30.4	17.4	34.7	No Abutment	2.1	2.6	1.7	2.1	**1.4**	**1.7**	1.3	1.6
					With Abutment	1.1	1.4	0.9	1.1	**0.7**	**0.9**	0.7	0.9
	10.7				No Abutment	1.8	2.2	1.5	1.8	**1.2**	**1.5**	-	-
					With Abutment	1.0	1.2	0.8	1.0	**0.6**	**0.8**	-	-
Pillar 6	18.2	62.9	22.8	67.45	No Abutment	3.8	4.7	2.8	3.5	**2.1**	**2.6**	2.0	2.5
					With Abutment	2.1	2.6	1.6	2.0	**1.2**	**1.5**	1.2	1.4
	17.2				No Abutment	3.4	4.2	2.5	3.1	**2.0**	**2.4**	-	-
					With Abutment	1.9	2.4	1.4	1.8	**1.1**	**1.4**	-	-

Based on the above the coal pillars would be expected to have a marginal factor of safety against failure when allowing for the abutment load. The historical pillar run in the area appears to have stopped at large coal pillars like Pillar 4 and Pillar 6 or at the lower mined height evident in BH01.

8.3. Likelihood of pillar failure

The UNSW pillar design methodology includes a relationship between factor of safety and probability of failure. This is based on a statistical analysis of the data set of failed and un-failed cases.

It should be noted that to be included in the data set, the area mined would have to:

- Be regular and large enough for tributary load to be a good approximation of the pillar load
- Have involved the crushing of many adjacent pillars of similar widths and heights
- Have a sufficient time pass after completion of mining
- Have the failure confirmed to be due to pillar crushing rather than punching failure of the floor or roof of the workings
- Have all pillar dimensions known

Table 6 provides a summary of factor of safety versus probability and likelihood of failure.

Table 6: Pillar factor of safety and probability (after Galvin 1998)

Factor of safety	Likelihood of failure	probability of failure
0.87	8 in 10	0.8
1.00	5 in 10	0.5
1.22	1 in 10	0.1
1.30	5 in 100	0.05
1.38	2 in 100	0.02
1.44	1 in 100	0.01
1.63	1 in 1000	0.001
1.79	1 in 10000	0.0001
1.95	1 in 100000	0.00001
2.11	1 in 1000000	0.000001

Based on the above it is considered that failure of the mine workings within the Borehole Seam is considered likely to possible.

8.4. Estimated subsidence

8.4.1. Yard Seam

As borehole data indicates that the workings have not previously collapsed, it is likely that stresses induced by crushing in the Borehole Seam workings can result in future crushing in the Yard Seam. This is currently limited to a degree by the pillar support and the residual size of voids as a result of roof collapse that has already occurred.

For this assessment the following has been adopted:

- The two void heights of 0.3 and 0.5m (rounded)
- Pillar width of 1.6m

- Bord width of 5.4m
- A pillar bulking factor of 1.3

To estimate the amount of crush the following formula has been adopted.

$$Crush = \frac{[(H_v \times W_{(B+P)}) - W_P \times H_{Crush} \times BF_P]}{W_{(B+P)}}$$

Where

- H_v = height of void remaining
- $W_{(B+P)}$ = width of bord and pillar
- W_P = width of pillar
- H_{Crush} = Height of pillar being mobilised by the crush
- BF_P = bulking factor of pillar crushing

Using this information, it is estimated that the convergence (crush) of the seam may be between 0.2m and 0.3m.

Using the depths to workings of 42m, the subsidence parameters estimated for the site with reference to Holla (1987) are provided in Table 7.

Table 7: Subsidence parameters for Yard Seam assuming no grouting

Parameter	Lower bound	Upper bound
Maximum subsidence, Smax (mm)	200	300
Maximum tensile strain, +Emax (mm/m)	2	3
Maximum compressive strain, -Emax (mm/m)	3	4.5
Maximum tilt, Gmax (mm/m)	8	13
Tensile curvature radius (convex) (km)	5	3.5
Compression curvature radius (concave) (km)	3.3	2.2

8.4.2. Borehole Seam

Void heights of 0.5m (BH01) and 1.65m (BH04) were encountered at the site. Working on the assumption that the pillars have not previously been subject to convergence (crush), and based on calculations similar to those used on the Yard Seam, the amount of crush that can occur at seam level in the future is estimated at between 150mm and 300mm.

Using the depths to workings of 93m, the subsidence parameters estimated for the site with reference to Holla (1987) are provided in Table 7.

Table 8: Subsidence parameters for Borehole Seam assuming no grouting

Parameter	Lower bound	Upper bound
Maximum subsidence, Smax (mm)	130	250
Maximum tensile strain, +Emax (mm/m)	0.7	1.5
Maximum compressive strain, -Emax (mm/m)	1	2
Maximum tilt, Gmax (mm/m)	3	6
Tensile curvature radius (convex) (km)	14	7.5
Compression curvature radius (concave) (km)	10	5

The above estimations do not include the mine subsidence numerical modelling that is currently underway.

9. Preliminary recommendations

9.1. Yard Seam

Evidence of Yard Seam workings were encountered during this investigation. Due to the unmapped nature of the workings within the Yard Seam it is recommended a drilling and grouting exercise be completed prior to construction although after demolition of the existing buildings.

Boreholes may be spaced based on a regular grid pattern at 10m intervals (north to south) attempting to encounter at least every second bord. East to west these may be increased to 20m. Boreholes that encounter a pillar should be redrilled at a distance of 3m.

At the completion of drilling, a high mobility grout should be pumped into all boreholes. This grout should have a flow cone (in accordance with ASTM C 939 or similar) value of 20 seconds to 30 seconds, resulting in a slurry with the consistency of a ‘thin milkshake’ or ‘creamy soup’.

This is currently estimated to require in the order of 71 boreholes to the Yard Seam and a volume of grout in the order of 1,400m^3 to 2,000m^3 (20m^3 to 30m^3 per borehole). Due to the spacing of the boreholes the grouting may be considered a bulk grouting solution.

After grouting, the potential for subsidence from the Yard Seam can be considered to be ameliorated, and the subsidence parameters within the Yard Seam in Section 8.4.1 will be no longer relevant.

9.2. Borehole Seam

Numerical modelling and detailed settlement analysis for the Borehole Seam is currently being completed separately.

Preliminary it may be assumed that the site will require eight coal pillars around the outside of the site to support abutment loading from reaching the coal pillars under the site. Each coal pillar to be stabilised will likely require four grouting boreholes (two in each bord). At the two eastern corners a third consecutive bord should be grouted to protect from abutment loading.

Inside the site. a further two pillars will need additional support, each with two grouting boreholes, one on each side of the pillar to be supported.

This results in 40 grouting boreholes to the Borehole Seam. This borehole pattern is shown on Drawing 12.

From the boreholes in this investigation, the void heights are between 0.5m and 1.65m with between 3m and 5m of rubble infill. This means the grout take will be highly variable between boreholes between 100m^3 and 600m^3 for each location. Preliminarily suggest allowance for 400m^3 per borehole.

The boundary locations will be outside the site to push the collapse front away from the site and in turn reduce subsidence parameters for the site. As these borehole will be completed on angles, the works may be completed with the buildings in place should it be preferential to commence early works.

10. Closing remarks

Further advice on the uses and limitations of this report is presented in the attached document, ‘Important Information about your Coffey Report’.

Signature:	
Full name:	Simon Baker
Title:	Senior Geotechnical Engineer
Date:	14 January 2019

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Important information about your **Coffey** Report

As a client of Coffey you should know that site subsurface conditions cause more construction problems than any other factor. These notes have been prepared by Coffey to help you interpret and understand the limitations of your report.

Your report is based on project specific criteria

Your report has been developed on the basis of your unique project specific requirements as understood by Coffey and applies only to the site investigated. Project criteria typically include the general nature of the project; its size and configuration; the location of any structures on the site; other site improvements; the presence of underground utilities; and the additional risk imposed by scope-of-service limitations imposed by the client. Your report should not be used if there are any changes to the project without first asking Coffey to assess how factors that changed subsequent to the date of the report affect the report's recommendations. Coffey cannot accept responsibility for problems that may occur due to changed factors if they are not consulted.

Subsurface conditions can change

Subsurface conditions are created by natural processes and the activity of man. For example, water levels can vary with time, fill may be placed on a site and pollutants may migrate with time. Because a report is based on conditions which existed at the time of subsurface exploration, decisions should not be based on a report whose adequacy may have been affected by time. Consult Coffey to be advised how time may have impacted on the project.

Interpretation of factual data

Site assessment identifies actual subsurface conditions only at those points where samples are taken and when they are taken. Data derived from literature and external data source review, sampling and subsequent laboratory testing are interpreted by geologists, engineers or scientists to provide an opinion about overall site conditions, their likely impact on the proposed development and recommended actions. Actual conditions may differ from those inferred to exist, because no professional, no matter how qualified, can reveal what is hidden by earth, rock and time. The actual interface between materials may be far more gradual or abrupt than assumed based on the facts obtained. Nothing can be done to change the actual site conditions which exist, but steps can be taken to reduce the impact of unexpected conditions. For this reason, owners should retain the services of Coffey through the development stage, to identify variances, conduct additional tests if required, and recommend solutions to problems encountered on site.

Your report will only give preliminary recommendations

Your report is based on the assumption that the site conditions as revealed through selective point sampling are indicative of actual conditions throughout an area. This assumption cannot be substantiated until project implementation has commenced and therefore your report recommendations can only be regarded as preliminary. Only Coffey, who prepared the report, is fully familiar with the background information needed to assess whether or not the report's recommendations are valid and whether or not changes should be considered as the project develops. If another party undertakes the implementation of the recommendations of this report there is a risk that the report will be misinterpreted and Coffey cannot be held responsible for such misinterpretation.

Your report is prepared for specific purposes and persons

To avoid misuse of the information contained in your report it is recommended that you confer with Coffey before passing your report on to another party who may not be familiar with the background and the purpose of the report. Your report should not be applied to any project other than that originally specified at the time the report was issued.

Interpretation by other design professionals

Costly problems can occur when other design professionals develop their plans based on misinterpretations of a report. To help avoid misinterpretations, retain Coffey to work with other project design professionals who are affected by the report. Have Coffey explain the report implications to design professionals affected by them and then review plans and specifications produced to see how they incorporate the report findings.

Data should not be separated from the report*

The report as a whole presents the findings of the site assessment and the report should not be copied in part or altered in any way. Logs, figures, drawings, etc. are customarily included in our reports and are developed by scientists, engineers or geologists based on their interpretation of field logs (assembled by field personnel) and laboratory evaluation of field samples. These logs etc. should not under any circumstances be redrawn for inclusion in other documents or separated from the report in any way.

Geoenvironmental concerns are not at issue

Your report is not likely to relate any findings, conclusions, or recommendations about the potential for hazardous materials existing at the site unless specifically required to do so by the client. Specialist equipment, techniques, and personnel are used to perform a geoenvironmental assessment. Contamination can create major health, safety and environmental risks. If you have no information about the potential for your site to be contaminated or create an environmental hazard, you are advised to contact Coffey for information relating to geoenvironmental issues.

Rely on Coffey for additional assistance

Coffey is familiar with a variety of techniques and approaches that can be used to help reduce risks for all parties to a project, from design to construction. It is common that not all approaches will be necessarily dealt with in your site assessment report due to concepts proposed at that time. As the project progresses through design towards construction, speak with Coffey to develop alternative approaches to problems that may be of genuine benefit both in time and cost.

Responsibility

Reporting relies on interpretation of factual information based on judgement and opinion and has a level of uncertainty attached to it, which is far less exact than the design disciplines. This has often resulted in claims being lodged against consultants, which are unfounded. To help prevent this problem, a number of clauses have been developed for use in contracts, reports and other documents. Responsibility clauses do not transfer appropriate liabilities from Coffey to other parties but are included to identify where Coffey's responsibilities begin and end. Their use is intended to help all parties involved to recognise their individual responsibilities. Read all documents from Coffey closely and do not hesitate to ask any questions you may have.

* For further information on this aspect reference should be made to "Guidelines for the Provision of Geotechnical information in Construction Contracts" published by the Institution of Engineers Australia, National headquarters, Canberra, 1987.

Drawings

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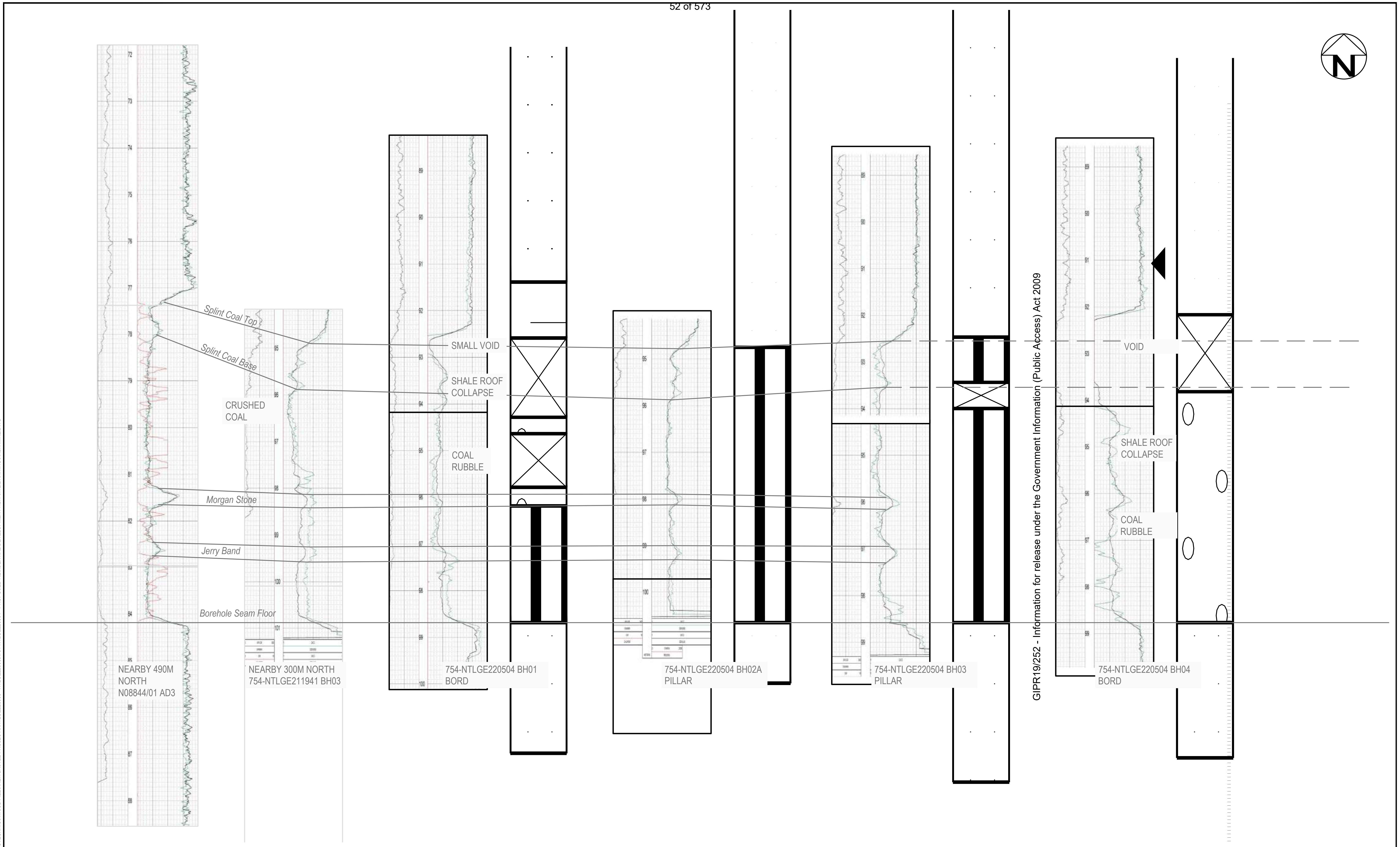

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revision

no.	description	drawn	approved	date
A	ORIGINAL ISSUE			

drawn	SJB
approved	JD
date	17/12/2018
scale	NTS
original size	A3

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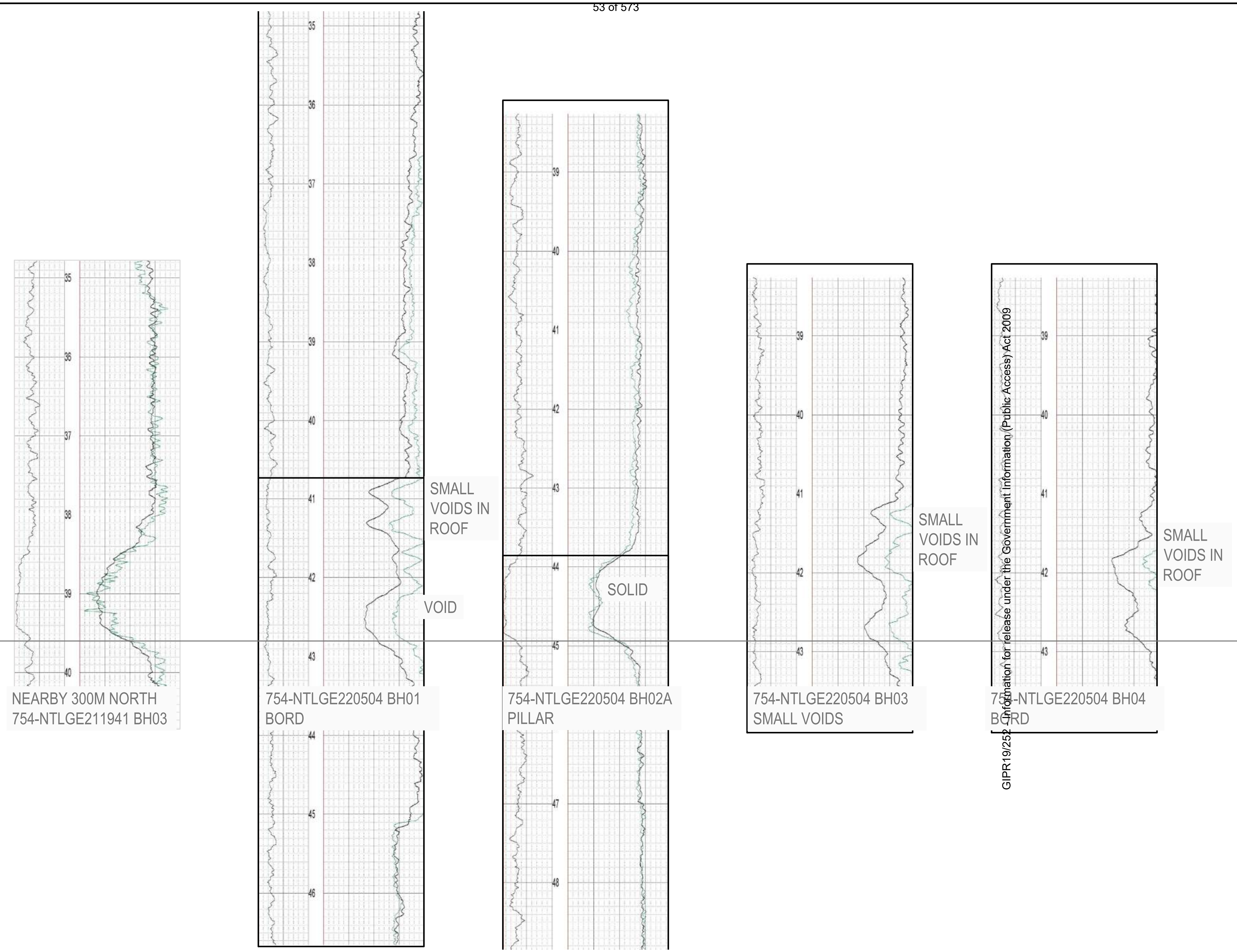
client:	CRESCENT NEWCASTLE PTY LTD
project:	PROPOSED RESIDENTIAL DEVELOPMENT NBN SITE - 11-17 MOSBRI CRESCENT THE HILL MINE SUBSIDENCE ASSESSMENT
title:	BOREHOLE SEAM SECTIONS
project no: 754-NTLGE220504	drawing no: DRAWING 5 — rev: A



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revision

no.	description	drawn	approved	date
A	ORIGINAL ISSUE			

drawn	SJB
approved	JD
date	17/12/2018
scale	NTS
original size	A3

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client: CRESCENT NEWCASTLE PTY LTD

project: PROPOSED RESIDENTIAL DEVELOPMENT
NBN SITE - 11-17 MOSBRI CRESCENT THE HILL
MINE SUBSIDENCE ASSESSMENT

title: YARD SEAM SECTIONS

project no: 754-NTLGE220504 drawing no: DRAWING 6 rev: A

Appendix A – Borehole logs

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Engineering Log - Borehole

Borehole ID.	**BH01**
sheet:	1 of 14
project no.	**754-NTLGE220504**
client:	**Crescent Newcastle Pty Ltd**
principal:	
project:	**Proposed Multi Building Residential Development**
location:	**11 - 13 Mosbri Crescent, Cooks Hill, NSW**
date started:	**03 Sep 2018**
date completed:	**07 Sep 2018**
logged by:	**MJ**
checked by:	**RB**

position: E: 385,619.90; N: 6,355,684.10 (MGA94) | surface elevation: 31.39 m (AHD) | angle from horizontal: 90°
drill model: Comacchio 450P, Track mounted | drilling fluid: non / water | hole diameter : 96 mm

drilling information / **material substance**

method & support	penetration 1 2 3	water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description (SOIL TYPE: plasticity or particle characteristic, colour, secondary and minor components)	moisture condition	consistency / relative density	hand penetrometer (kPa) 100 200 300 400	structure and additional observations
AD					0.0		CL-CI	**FILL: BITUMEN**: black, 50mm thick, fine to coarse gravel.	M			**FILL- WEARING COURSE**
			E	31			CH	**FILL: Sandy CLAY**: low to medium plasticity, grey, with fine grained sand.	<Wp			**FILL**
			E		1.0			**CLAY**: high plasticity, grey and pale grey, with orange lamination.	>Wp			**RESIDUAL SOIL**
			D + E	30			CL-CI	**CLAY**: low to medium plasticity, pale brown and grey, orange laminations, with fine sand, trace of fine gravel.	<Wp			
			E		2.0			2.0 m: becoming more pale grey and pale brown				
			E	29								
			E		3.0							
			B	28								
			E		4.0							
				27			SP	**SANDSTONE**: fine grained, orange, extremely weathered, very low to low strength.	M			**HIGHLY WEATHERED MATERIAL**
								Borehole BH01 continued as cored hole				
					5.0							
				26								
					6.0							
				25								
					7.0							
				24								

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method
AD auger drilling*
AS auger screwing*
HA hand auger
W washbore
RR rock roller/tricone

* bit shown by suffix
e.g. AD/T
B blank bit
T TC bit
V V bit

support
M mud
C casing
N nil

penetration
1 2 3 — no resistance ranging to refusal

water
10-Oct-12 water level on date shown
water inflow
water outflow

samples & field tests
B bulk disturbed sample
D disturbed sample
E environmental sample
SS split spoon sample
U## undisturbed sample ##mm diameter
HP hand penetrometer (kPa)
N standard penetration test (SPT)
N* SPT - sample recovered
Nc SPT with solid cone
VS vane shear; peak/remouded (kPa)
R refusal
HB hammer bouncing

classification symbol & soil description
based on Unified Classification System

moisture
D dry
M moist
W wet
Wp plastic limit
Wl liquid limit

consistency / relative density
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

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Engineering Log - Cored Borehole

client:	*Crescent Newcastle Pty Ltd*	Borehole ID.	***BH01***
principal:		sheet:	2 of 14
project:	*Proposed Multi Building Residential Development*	project no.	***754-NTLGE220504***
location:	*11 - 13 Mosbri Crescent, Cooks Hill, NSW*	date started:	***03 Sep 2018***
		date completed:	***07 Sep 2018***
		logged by:	***MJ***
		checked by:	***RB***

position: E: 385,619.90; N: 6,355,684.10 (MGA94) surface elevation: 31.39 m (AHD) angle from horizontal: 90°

drill model: Comacchio 450P, Track mounted drilling fluid: non / water hole diameter : 96 mm vane id.:

method & support	water	RL (m)	depth (m)	graphic log	material description (ROCK TYPE: grain characterisics, colour, structure, minor components)	weathering & alteration	estimated strength & Is50	samples, field tests & Is(50) (MPa)	core run & RQD	defect spacing (mm)	additional observations and defect descriptions (type, inclination, planarity, roughness, coating, thickness, other) — particular	general
		31										
			1.0									
		30										
			2.0									
		29										
			3.0									
		28										
			4.0									
		27			started coring at 4.55m							
HQ					**SANDSTONE**: fine to medium grained, brown/orange and grey, with sitlstone bands and black carbonaceous laminations.	DW						Defects are: PT, 0 - 10°, PL, RO, CN, unless otherwise described
			5.0								PT, 0 - 5°, PL, RO, CN	
		26						a=0.40 d=0.20			JT, 30°, PL, RO, CN	
			6.0									
		25							82%		JT, 75 - 90°, CU, RO, SN	
			7.0					a=0.30 d=0.40			PT, 0°, PL, VR, SN	
		24									PT, 20°, PL, RO, SN	

method & support
AS auger screwing
AD auger drilling
CB claw or blade bit
W washbore
NMLC NMLC core (51.9 mm)
NQ wireline core (47.6mm)
HQ wireline core (63.5mm)
PQ wireline core (85.0mm)
SPT standard penetration test
RR rock roller/tricone

water
10/10/12, water level on date shown
water inflow
complete drilling fluid loss
partial drilling fluid loss
25uL water pressure test result (lugeons) for depth interval shown

graphic log / core recovery
core recovered (graphic symbols indicate material)
no core recovered

core run & RQD
barrel withdrawn
RQD = Rock Quality Designation (%)

weathering & alteration*
RS residual soil
XW extremely weathered
HW highly weathered
DW distinctly weathered
MW moderately weathered
SW slightly weathered
FR fresh
*W replaced with A for alteration

strength
VL very low
L low
M medium
H high
VH very high
EH extremely high

defect type
PT parting
JT joint
SZ shear zone
SS shear surface
CO contact
CS crushed seam
SM seam

planarity
PL planar
CU curved
UN undulating
ST stepped
IR Irregular

roughness
SL slickensided
POL polished
SO smooth
RO rough
VR very rough

coating
CN clean
SN stain
VN veneer
CO coating

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Engineering Log - Cored Borehole

Borehole ID.	**BH01**
sheet:	3 of 14
project no.	**754-NTLGE220504**
date started:	**03 Sep 2018**
date completed:	**07 Sep 2018**
logged by:	**MJ**
checked by:	**RB**

client: ***Crescent Newcastle Pty Ltd***

principal:

project: ***Proposed Multi Building Residential Development***

location: ***11 - 13 Mosbri Crescent, Cooks Hill, NSW***

position: E: 385,619.90; N: 6,355,684.10 (MGA94) | surface elevation: 31.39 m (AHD) | angle from horizontal: 90°

drill model: Comacchio 450P, Track mounted | drilling fluid: non / water | hole diameter : 96 mm | vane id.:

drilling information | **material substance** | **rock mass defects**

method & support: HQ

RL (m)	depth (m)	material description (ROCK TYPE: grain characteristics, colour, structure, minor components)	weathering & alteration	samples, field tests & Is(50) (MPa) (a = axial; d = diametral)	core run & RQD	additional observations and defect descriptions (type, inclination, planarity, roughness, coating, thickness, other)
23		**SANDSTONE**: fine to medium grained, brown/orange and grey, with sitlstone bands and black carbonaceous laminations. *(continued)* 8.00 m: becoming grey 8.55 m: 250mm of carbonaceous laminations	MW - HW	a=0.20 d=0.40	82%	PT, 5°, PL, RO, SN
22	9.0					
21	10.0				71%	JT, 50°, PL, RO, SN JT, 50°, PL, RO, SN
		NO CORE: 0.18 m				
		SANDSTONE: fine to medium grained, brown and grey, with sitlstone bands and black carbonaceous laminations.	HW	a=1.00 d=1.00		JT, 70°, PL, RO, SN JT, 40°, PL, RO, SN JT, 30°, PL, RO, SN
20	11.0		XW		0%	PT, 0°, PL, RO, SN
			HW			
19	12.0		SW - FR	a=1.30 d=0.80		CS, IR, RO, SN JT, 70°, PL, RO, SN
		SILTSTONE: grey to dark grey, with sandstone bands and black carbonaceous laminations.				
18	13.0				82%	JT, 35°, PL, RO, SN
		NO CORE: 0.15 m				
17	14.0	**SANDSTONE**: fine grained, grey, with sitlstone bands and black carbonaceous laminations. 14.57 m: 70mm sandstone band	SW - FR	a=0.30 d=0.20		SM, 0°, PL, RO, CO
16	15.0	15.00 m: 150mm sandstone band 15.30 m: 150mm sandstone band with carbonaceous laminations			97%	

Defects are: PT, 0 - 10°, PL, RO, CN, unless otherwise described

method & support
AS auger screwing
AD auger drilling
CB claw or blade bit
W washbore
NMLC NMLC core (51.9 mm)
NQ wireline core (47.6mm)
HQ wireline core (63.5mm)
PQ wireline core (85.0mm)
SPT standard penetration test
RR rock roller/tricone

water
10/10/12, water level on date shown
water inflow
complete drilling fluid loss
partial drilling fluid loss
25uL water pressure test result (lugeons) for depth interval shown

graphic log / core recovery
core recovered (graphic symbols indicate material)
no core recovered

core run & RQD
barrel withdrawn
RQD = Rock Quality Designation (%)

weathering & alteration*
RS residual soil
XW extremely weathered
HW highly weathered
DW distinctly weathered
MW moderately weathered
SW slightly weathered
FR fresh
*W replaced with A for alteration

strength
VL very low
L low
M medium
H high
VH very high
EH extremely high

defect type
PT parting
JT joint
SZ shear zone
SS shear surface
CO contact
CS crushed seam
SM seam

planarity
PL planar
CU curved
UN undulating
ST stepped
IR Irregular

roughness
SL slickensided
POL polished
SO smooth
RO rough
VR very rough

coating
CN clean
SN stain
VN veneer
CO coating

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Engineering Log - Cored Borehole

Borehole ID.	**BH01**
sheet:	4 of 14
project no.	**754-NTLGE220504**
date started:	**03 Sep 2018**
date completed:	**07 Sep 2018**
logged by:	**MJ**
checked by:	**RB**

client: ***Crescent Newcastle Pty Ltd***

principal:

project: ***Proposed Multi Building Residential Development***

location: ***11 - 13 Mosbri Crescent, Cooks Hill, NSW***

position: E: 385,619.90; N: 6,355,684.10 (MGA94) surface elevation: 31.39 m (AHD) angle from horizontal: 90°

drill model: Comacchio 450P, Track mounted drilling fluid: non / water hole diameter : 96 mm vane id.:

drilling information | **material substance** | **rock mass defects**

Columns: method & support; water; RL (m); depth (m); graphic log; material description (ROCK TYPE: grain characterisics, colour, structure, minor components); weathering & alteration; estimated strength & Is50 (X = axial; O = diametral; VL L M H VH EH); samples, field tests & Is(50) (MPa) (a = axial; d = diametral); core run & RQD; defect spacing (mm) (30 100 300 1000 3000); additional observations and defect descriptions (type, inclination, planarity, roughness, coating, thickness, other) – particular / general

Method & support: HQ

RL (m): 15, 14, 13, 12, 11, 10, 9, 8

Depth (m): 17.0, 18.0, 19.0, 20.0, 21.0, 22.0, 23.0

Depth	Material description	Weathering	Samples / field tests	Core run & RQD	Defects (particular)
	SANDSTONE: fine to medium grained, grey, with sitlstone bands and black carbonaceous laminations.	SW - FR	a=1.10 d=0.20		
16.85 m	16.85 m: 110mm dark grey-brown siltstone band			97%	
					PT, 5°, PL, RO, SN
17.85 m	17.85 m: 350mm dark grey-brown siltstone band		a=2.00 d=0.70		
18.40 m	18.40 m: 160mm carbonaceous laminations				
18.65 m	18.65 m: 70mm siltstone band				
		XW			
		HW			
		SW - FR		89%	PT, 5°, PL, RO, SN PT, 5°, PL, RO, SN JT, 40°, PL, RO, SN JT, 45°, CU, RO, CN JT, 70°, PL, RO, SN
			a=2.70 d=0.80		
20.0	**SILTSTONE**: dark grey to grey, brown to pale brown laminations, with sandstone laminations.				PT, 0°, PL, RO, SN
					JT, 70°, PL, RO, SN
					JT, 70°, PL, RO, SN
					JT, 70°, PL, SO, SN
			a=0.80 d=0.60		
					JT, 70°, PL, SO, SN JT, 75°, CU, SO, CN
				88%	PT, 0°, PL, SO, CN
			a=2.40 d=0.50		

General: Defects are: PT, 0 - 10°, PL, RO, CN, unless otherwise described

method & support
AS auger screwing
AD auger drilling
CB claw or blade bit
W washbore
NMLC NMLC core (51.9 mm)
NQ wireline core (47.6mm)
HQ wireline core (63.5mm)
PQ wireline core (85.0mm)
SPT standard penetration test
RR rock roller/tricone

water
10/10/12, water level on date shown
water inflow
complete drilling fluid loss
partial drilling fluid loss
25uL water pressure test result (lugeons) for depth interval shown

graphic log / core recovery
core recovered (graphic symbols indicate material)
no core recovered

core run & RQD
barrel withdrawn
RQD = Rock Quality Designation (%)

weathering & alteration*
RS residual soil
XW extremely weathered
HW highly weathered
DW distinctly weathered
MW moderately weathered
SW slightly weathered
FR fresh
*W replaced with A for alteration

strength
VL very low
L low
M medium
H high
VH very high
EH extremely high

defect type
PT parting
JT joint
SZ shear zone
SS shear surface
CO contact
CS crushed seam
SM seam

planarity
PL planar
CU curved
UN undulating
ST stepped
IR Irregular

roughness
SL slickensided
POL polished
SO smooth
RO rough
VR very rough

coating
CN clean
SN stain
VN veneer
CO coating

coffey
A TETRA TECH COMPANY

Engineering Log - Cored Borehole

Borehole ID. **BH01**
sheet: 5 of 14
project no. **754-NTLGE220504**

client: **Crescent Newcastle Pty Ltd**
principal:
project: **Proposed Multi Building Residential Development**
location: **11 - 13 Mosbri Crescent, Cooks Hill, NSW**

date started: **03 Sep 2018**
date completed: **07 Sep 2018**
logged by: **MJ**
checked by: **RB**

position: E: 385,619.90; N: 6,355,684.10 (MGA94) | surface elevation: 31.39 m (AHD) | angle from horizontal: 90°
drill model: Comacchio 450P, Track mounted | drilling fluid: non / water | hole diameter : 96 mm | vane id.:

drilling information / material substance / rock mass defects

method & support: HQ
water: 14/09/18 (at approx. 29.0 m)

RL (m)	depth (m)	material description	weathering & alteration	samples, field tests & Is(50) (MPa)	core run & RQD	additional observations and defect descriptions
7		**SILTSTONE**: dark grey to grey, brown to pale brown laminations, with sandstone laminations. *(continued)*	SW - FR	a=0.70 d=0.60		JT, 75°, CU, SO, CN; PT, 5°, PL, RO, SN
	25.0	**COAL**: black, shiny, cleated.	MW / HW		38%	CS, 0°, PL, RO, CN; JT, 80°, ST, RO, CN; JT, 80°, IR, RO, CN
6, 5	26.0					
		NO CORE: 0.24 m				
4	27.0	**SILTSTONE**: grey-dark grey.	MW - SW	a=0.20 d=0.10		
3	28.0	**COAL**: black, shiny cleated, with slitstone bands and laminations. 28.40 m: 130mm siltstone band; 28.62 m: 80mm siltstone band; 29.28 m: 20mm siltstone laminations; 29.32 m: 150mm siltstone band; 29.50 m: 170mm siltstone laminations	HW		77%	CS; JT, 90°, PL, RO, CN; JT, 70°, CU, RO, CN; PT, 5°, PL, SL, CO; PT, 5°, PL, SL, CO; PT, 5°, PL, SL, CO; JT, 80°, PL, RO, CN; JT, 70°, PL, RO, CN; PT, PL, SL, CO; PT, 5°, PL, SL, CO; PT, 5°, PL, SL, CO; PT, 5°, PL, SL, CO
2	29.0					
1	30.0	**SILTSTONE**: grey to dark grey, with sandstone bands and black carbonaceous laminations.	MW	a=0.70 d=0.30		PT, 5°, CU, RO, SN
0	31.0	31.36 m: 650mm sandstone band with carbonaceous laminations		a=2.40 d=0.30	74%	PT, 10°, PL, RO, CO; PT, 10°, PL, RO, CO; PT, 10°, PL, RO, CO; PT, 10°, PL, RO, CO; PT, 5°, PL, RO, SN; PT, 5°, PL, RO, SN; JT, 45°, PL, SO, SN; PT, 0°, PL, RO, CO; PT, 0°, PL, RO, CO; PT, 0°, PL, RO, CO

general: Defects are: PT, 0 -10°, PL, RO, CN, unless otherwise described

method & support
AS auger screwing
AD auger drilling
CB claw or blade bit
W washbore
NMLC NMLC core (51.9 mm)
NQ wireline core (47.6mm)
HQ wireline core (63.5mm)
PQ wireline core (85.0mm)
SPT standard penetration test
RR rock roller/tricone

water
10/10/12, water level on date shown
water inflow
complete drilling fluid loss
partial drilling fluid loss
25uL water pressure test result (lugeons) for depth interval shown

graphic log / core recovery
core recovered (graphic symbols indicate material)
no core recovered

core run & RQD
barrel withdrawn
RQD = Rock Quality Designation (%)

weathering & alteration*
RS residual soil
XW extremely weathered
HW highly weathered
DW distinctly weathered
MW moderately weathered
SW slightly weathered
FR fresh
*W replaced with A for alteration

strength
VL very low
L low
M medium
H high
VH very high
EH extremely high

defect type
PT parting
JT joint
SZ shear zone
SS shear surface
CO contact
CS crushed seam
SM seam

planarity
PL planar
CU curved
UN undulating
ST stepped
IR Irregular

roughness
SL slickensided
POL polished
SO smooth
RO rough
VR very rough

coating
CN clean
SN stain
VN veneer
CO coating

coffey
A TETRA TECH COMPANY

Engineering Log - Cored Borehole

client:	*Crescent Newcastle Pty Ltd*	Borehole ID.	***BH01***
principal:		sheet:	6 of 14
project:	*Proposed Multi Building Residential Development*	project no.	***754-NTLGE220504***
location:	*11 - 13 Mosbri Crescent, Cooks Hill, NSW*	date started:	***03 Sep 2018***
		date completed:	***07 Sep 2018***
		logged by:	***MJ***
		checked by:	***RB***

position: E: 385,619.90; N: 6,355,684.10 (MGA94) surface elevation: 31.39 m (AHD) angle from horizontal: 90°
drill model: Comacchio 450P, Track mounted drilling fluid: non / water hole diameter : 96 mm vane id.:

drilling information | **material substance** | **rock mass defects**

method & support	water	RL (m)	depth (m)	graphic log	material description (ROCK TYPE: grain characteristics, colour, structure, minor components)	weathering & alteration	samples, field tests & Is(50) (MPa)	core run & RQD	additional observations and defect descriptions (type, inclination, planarity, roughness, coating, thickness, other)
HQ		-1			**SILTSTONE**: grey to dark grey, with sandstone bands and black carbonaceous laminations. *(continued)*	MW		74%	PT, 0°, PL, RO, CO; PT, 10°, PL, RO, CO; PT, 0°, PL, RO, CO; JT, 80°, CU, RO, CN; JT, 80°, PL, RO, CO; PT, 5°, PL, RO, CO; PT, 0°, PL, SO, CN
			33.0				a=2.10 d=0.50		
		-2			**SANDSTONE**: fine to medium grained, with sitlstone bands and black carbonaceous laminations.	MW - SW			PT, 10°, CU, SO, CN; PT, 10°, CU, SL, CN; SZ, RO, SN
			34.0		34.00 m: 60mm siltstone band				PT, 5°, PL, RO, SN
		-3						75%	PT, 5°, PL, SO, CN; PT, 5°, PL, RO, CN; PT, 0°, PL, SO, CN; PT, 0°, IR, VR, SN; PT, 5°, PL, RO, SN
							a=6.20 d=5.70		
			35.0						
		-4							PT, 5°, PL, RO, SN
					35.75 m: 130mm siltstone band				
			36.0						
		-5					a=3.20 d=2.50		PT, 0°, PL, VR, SN; PT, 5°, CU, RO, SN; PT, 0°, PL, SO, CN
			37.0		37.06 m: 100mm siltstone band				PT, 0°, PL, SO, CN; PT, 5°, PL, SO, SN; PT, 5°, PL, SO, SN
		-6			37.25 m: 280mm carbonaceous laminations			90%	PT, 0°, PL, SO, CN; PT, 20°, PL, RO, CN; JT, 80 - 90°, UN, RO, SN
			38.0				a=3.80 d=3.80		PT, 5°, PL, RO, SN
		-7			38.48 m: 250mm carbonaceous laminations				PT, 5°, CU, RO, SN; PT, 10°, PL, VR, SN; PT, 5°, CU, RO, SN
			39.0		39.10 m: 460mm siltstone and carbonaceous laminations				PT, 5°, PL, RO, SN; PT, 5°, PL, RO, SN; PT, 5°, PL, RO, SN; PT, 5°, PL, RO, SN
		-8					a=3.80 d=2.60	60%	PT, 5°, PL, RO, SN; PT, 5°, PL, RO, SN; CS, PL, RO, SN; JT, 40°, PL, RO, SN

general: Defects are: PT, 0 -10°, PL, RO, CN, unless otherwise described

method & support
AS auger screwing
AD auger drilling
CB claw or blade bit
W washbore
NMLC NMLC core (51.9 mm)
NQ wireline core (47.6mm)
HQ wireline core (63.5mm)
PQ wireline core (85.0mm)
SPT standard penetration test
RR rock roller/tricone

water
10/10/12, water level on date shown
water inflow
complete drilling fluid loss
partial drilling fluid loss
25uL water pressure test result (lugeons) for depth interval shown

graphic log / core recovery
core recovered (graphic symbols indicate material)
no core recovered

core run & RQD
barrel withdrawn
RQD = Rock Quality Designation (%)

weathering & alteration*
RS residual soil
XW extremely weathered
HW highly weathered
DW distinctly weathered
MW moderately weathered
SW slightly weathered
FR fresh
*W replaced with A for alteration

strength
VL very low
L low
M medium
H high
VH very high
EH extremely high

defect type
PT parting
JT joint
SZ shear zone
SS shear surface
CO contact
CS crushed seam
SM seam

planarity
PL planar
CU curved
UN undulating
ST stepped
IR Irregular

roughness
SL slickensided
POL polished
SO smooth
RO rough
VR very rough

coating
CN clean
SN stain
VN veneer
CO coating

coffey
A TETRA TECH COMPANY

Engineering Log - Cored Borehole

Borehole ID. **BH01**
sheet: 7 of 14
project no. **754-NTLGE220504**

client: **Crescent Newcastle Pty Ltd**
principal:
project: **Proposed Multi Building Residential Development**
location: **11 - 13 Mosbri Crescent, Cooks Hill, NSW**

date started: **03 Sep 2018**
date completed: **07 Sep 2018**
logged by: **MJ**
checked by: **RB**

position: E: 385,619.90; N: 6,355,684.10 (MGA94) surface elevation: 31.39 m (AHD) angle from horizontal: 90°
drill model: Comacchio 450P, Track mounted drilling fluid: non / water hole diameter : 96 mm vane id.:

RL (m)	depth (m)	material description	weathering & alteration	samples, field tests & Is(50) (MPa)	core run & RQD	additional observations and defect descriptions
-9		**SANDSTONE**: fine to medium grained, with sitlstone bands and black carbonaceous laminations. *(continued)*	MW - SW		60%	PT, 0°, PL, RO, SN; PT, 5°, PL, RO, SN; PT, 0°, PL, RO, VN; PT, 5°, CU, RO, SN; PT, 5°, PL, RO, SN
-10	41.0	41.00 m: 40mm siltstone band		a=1.70 d=0.40		PT, 5°, PL, RO, SN; PT, 0°, ST, RO, SN
		NO CORE: 0.11 m **TOOL DROP**: small void on CCTV.			14%	
	42.0	**NO CORE:** 0.25 m siltstone on density plots.				
		SILTSTONE: grey to dark grey.	MW - SW			
-11		**NO CORE:** 0.30 m **TOOL DROP**: small void on CCTV.				JT, 85°, PL, RO, SN
		SILTSTONE: grey to dark grey.	MW	a=0.80 d=0.60	15%	PT, 0°, PL, RO, CN; PT, 0°, PL, RO, CN
		NO CORE: 0.15 m siltstone on density plots.				
-12	43.0	**NO CORE:** 0.50 m **TOOL DROP**: void on CCTV.				JT, 80°, PL, RO, SN; PT, 0°, PL, RO, SN; PT, 0°, PL, RO, SN; PT, 5°, PL, RO, SN
		NO CORE: 0.10 m coal on density plots, fallin/rubble.	HW			
		COAL: black, shiny, cleated, floor of mine.	MW			PT, 5°, PL, RO, CO; PT, 5°, PL, RO, CO; PT, 5°, PL, RO, CO
	44.0	**SILTSTONE**: dark grey, with black carbonaceous laminations.	SW - FR		58%	
-13		**SANDSTONE**: fine to medium grained, grey to dark grey, with sitlstone bands and black carbonaceous laminations.		a=4.40 d=1.30		PT, 0°, PL, SO, CN
	45.0	**NO CORE:** 0.08 m	HW			
-14		**SANDSTONE**: fine to medium grained, grey to dark grey, with sitlstone bands and black carbonaceous laminations.	XW; SW - FR			PT, 0°, PL, SO, CN
-15	46.0	46.30 m: 100mm carbonaceous laminations		a=3.60 d=2.20	92%	
-16	47.0	47.60 m: 200mm carbonaceous laminations		a=3.50	100%	PT, 0°, PL, SO, CN

method & support: HQ. water: 100% loss (to approx. 47.0 m), 50% loss below.

Defects are: PT, 0 - 10°, PL, RO, CN, unless otherwise described

method & support
AS auger screwing
AD auger drilling
CB claw or blade bit
W washbore
NMLC NMLC core (51.9 mm)
NQ wireline core (47.6mm)
HQ wireline core (63.5mm)
PQ wireline core (85.0mm)
SPT standard penetration test
RR rock roller/tricone

water
10/10/12, water level on date shown
water inflow
complete drilling fluid loss
partial drilling fluid loss
25uL water pressure test result (lugeons) for depth interval shown

graphic log / core recovery
core recovered (graphic symbols indicate material)
no core recovered
core run & RQD
barrel withdrawn
RQD = Rock Quality Designation (%)

weathering & alteration*
RS residual soil
XW extremely weathered
HW highly weathered
DW distinctly weathered
MW moderately weathered
SW slightly weathered
FR fresh
*W replaced with A for alteration
strength
VL very low
L low
M medium
H high
VH very high
EH extremely high

defect type
PT parting
JT joint
SZ shear zone
SS shear surface
CO contact
CS crushed seam
SM seam

planarity
PL planar
CU curved
UN undulating
ST stepped
IR Irregular

roughness
SL slickensided
POL polished
SO smooth
RO rough
VR very rough

coating
CN clean
SN stain
VN veneer
CO coating

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coffey
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Engineering Log - Cored Borehole

Borehole ID.	**BH01**
sheet:	8 of 14
project no.	**754-NTLGE220504**
date started:	**03 Sep 2018**
date completed:	**07 Sep 2018**
logged by:	**MJ**
checked by:	**RB**

client: ***Crescent Newcastle Pty Ltd***

principal:

project: ***Proposed Multi Building Residential Development***

location: ***11 - 13 Mosbri Crescent, Cooks Hill, NSW***

position: E: 385,619.90; N: 6,355,684.10 (MGA94) surface elevation: 31.39 m (AHD) angle from horizontal: 90°

drill model: Comacchio 450P, Track mounted drilling fluid: non / water hole diameter : 96 mm vane id.:

method & support	water	RL (m)	depth (m)	material description (ROCK TYPE: grain characterisics, colour, structure, minor components)	weathering & alteration	samples, field tests & Is(50) (MPa)	core run & RQD	additional observations and defect descriptions (type, inclination, planarity, roughness, coating, thickness, other)
HQ	50% loss	-17		**SANDSTONE**: fine to medium grained, grey to dark grey, with sitlstone bands and black carbonaceous laminations. *(continued)*	SW - FR	d=2.90		
			49.0	49.06 m: 60mm carbonaceous laminations				
		-18				a=3.50 d=3.30	100%	PT, 10°, PL, RO, SN
			50.0					
		-19		50.55 m: 400mm carbonaceous laminations				PT, 5°, PL, RO, SN
			51.0			a=3.80 d=2.60		
		-20						
				51.75 m: 100mm carbonaceous laminations				
			52.0	52.20 m: 600mm carbonaceous laminations				
		-21					100%	
			53.0					PT, 10°, PL, RO, SN
		-22				a=1.60 d=0.10		
			54.0					
		-23		**COAL**: black, shiny cleated.	HW			CS, 0°, PL, CN
								JT, 85°, PL, RO, CN
			55.0	**SANDSTONE**: fine to medium grained, grey to dark grey, with sitlstone bands and black carbonaceous laminations.	SW - FR		97%	
		-24				a=3.70 d=0.10		

Defects are: PT, 0 - 10°, PL, RO, CN, unless otherwise described

method & support
AS auger screwing
AD auger drilling
CB claw or blade bit
W washbore
NMLC NMLC core (51.9 mm)
NQ wireline core (47.6mm)
HQ wireline core (63.5mm)
PQ wireline core (85.0mm)
SPT standard penetration test
RR rock roller/tricone

water
10/10/12, water level on date shown
water inflow
complete drilling fluid loss
partial drilling fluid loss
25uL water pressure test result (lugeons) for depth interval shown

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core run & RQD
barrel withdrawn
RQD = Rock Quality Designation (%)

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HW highly weathered
DW distinctly weathered
MW moderately weathered
SW slightly weathered
FR fresh
*W replaced with A for alteration

strength
VL very low
L low
M medium
H high
VH very high
EH extremely high

defect type
PT parting
JT joint
SZ shear zone
SS shear surface
CO contact
CS crushed seam
SM seam

planarity
PL planar
CU curved
UN undulating
ST stepped
IR Irregular

roughness
SL slickensided
POL polished
SO smooth
RO rough
VR very rough

coating
CN clean
SN stain
VN veneer
CO coating

coffey
A TETRA TECH COMPANY

Engineering Log - Cored Borehole

Borehole ID.	**BH01**
sheet:	9 of 14
project no.	**754-NTLGE220504**
date started:	**03 Sep 2018**
date completed:	**07 Sep 2018**
logged by:	**MJ**
checked by:	**RB**

client: ***Crescent Newcastle Pty Ltd***

principal:

project: ***Proposed Multi Building Residential Development***

location: ***11 - 13 Mosbri Crescent, Cooks Hill, NSW***

position: E: 385,619.90; N: 6,355,684.10 (MGA94) surface elevation: 31.39 m (AHD) angle from horizontal: 90°

drill model: Comacchio 450P, Track mounted drilling fluid: non / water hole diameter : 96 mm vane id.:

method & support	water	RL (m)	depth (m)	material description (ROCK TYPE: grain characterisics, colour, structure, minor components)	weathering & alteration	samples, field tests & Is(50) (MPa) (a = axial; d = diametral)	core run & RQD	additional observations and defect descriptions (type, inclination, planarity, roughness, coating, thickness, other) – particular	general
HQ	50% loss	-25		**SANDSTONE**: fine to medium grained, grey to dark grey, with sitlstone bands and black carbonaceous laminations. *(continued)*	SW - FR		97%	PT, 10°, PL, RO, SN	Defects are: PT, 0 - 10°, PL, RO, CN, unless otherwise described
				56.62 m: 60mm coal seam					
		-26	57.0			a=3.50 d=1.00			
		-27	58.0	57.98 m: 920mm siltstone, dark grey to black band			95%	PT, 0°, PL, RO, CO PT, 0°, PL, RO, CO	
				58.60 m: 50mm carbonaceous laminations					
		-28	59.0	59.38 m: 80mm coarse sandstone band		a=3.50 d=0.60		PT, 10°, PL, RO, SN	
		-29	60.0	60.20 m: 600mm carbonaceous laminations		a=3.50 d=0.20		PT, PL, RO, SN	
		-30	61.0	61.40 m: 170mm carbonaceous laminations			94%	PT, PL, RO, SN	
		-31	62.0			a=1.60 d=0.30		JT, 80°, PL, SO, CN PT, PL, RO, SN CS, 0°, PL, CN	
		-32	63.0	62.75 m: 150mm coal, black, shiny cleated band			94%	PT, 0°, PL, RO, SN	

method & support
AS auger screwing
AD auger drilling
CB claw or blade bit
W washbore
NMLC NMLC core (51.9 mm)
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core run & RQD
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strength
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defect type
PT parting
JT joint
SZ shear zone
SS shear surface
CO contact
CS crushed seam
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planarity
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CU curved
UN undulating
ST stepped
IR Irregular

roughness
SL slickensided
POL polished
SO smooth
RO rough
VR very rough

coating
CN clean
SN stain
VN veneer
CO coating

coffey
A TETRA TECH COMPANY

Engineering Log - Cored Borehole

client:	*Crescent Newcastle Pty Ltd*	Borehole ID.	**BH01**
principal:		sheet:	10 of 14
project:	*Proposed Multi Building Residential Development*	project no.	**754-NTLGE220504**
location:	*11 - 13 Mosbri Crescent, Cooks Hill, NSW*	date started:	**03 Sep 2018**
		date completed:	**07 Sep 2018**
		logged by:	**MJ**
		checked by:	**RB**

position: E: 385,619.90; N: 6,355,684.10 (MGA94) | surface elevation: 31.39 m (AHD) | angle from horizontal: 90°

drill model: Comacchio 450P, Track mounted | drilling fluid: non / water | hole diameter : 96 mm | vane id.:

method & support	water	RL (m)	depth (m)	material description (ROCK TYPE: grain characteristics, colour, structure, minor components)	weathering & alteration	samples, field tests & Is(50) (MPa) (a = axial; d = diametral)	core run & RQD	additional observations and defect descriptions (type, inclination, planarity, roughness, coating, thickness, other)
HQ	50% loss	-33		**SANDSTONE**: fine to medium grained, grey to dark grey, with sitlstone bands and black carbonaceous laminations. *(continued)*	SW - FR			JT, 80°, PL, SO, CN
		-34	65.0			a=7.80 d=3.30	94%	
			66.0					PT, 0°, PL, SO, CN
		-35						JT, 80°, PL, RO, SN PT, 0°, PL, RO, SN
		-36	67.0			a=2.90 d=1.00	100%	
		-37	68.0					PT, 0°, PL, RO, SN
		-38	69.0	69.30 m: 180mm carbonaceous laminations		a=1.80 d=2.30		PT, 0°, PL, RO, SN
		-39	70.0				87%	JT, 80°, PL, RO, CN PT, 0°, PL, RO, SN PT, 0°, PL, RO, SN JT, 90°, CU, RO, SN
		-40	71.0	71.00 m: 1.2m medium to coarse sandstone band		a=3.40 d=3.70		

general: Defects are: PT, 0 - 10°, PL, RO, CN, unless otherwise described

method & support
AS auger screwing
AD auger drilling
CB claw or blade bit
W washbore
NMLC NMLC core (51.9 mm)
NQ wireline core (47.6mm)
HQ wireline core (63.5mm)
PQ wireline core (85.0mm)
SPT standard penetration test
RR rock roller/tricone

water
10/10/12, water level on date shown
water inflow
complete drilling fluid loss
partial drilling fluid loss
25uL water pressure test result (lugeons) for depth interval shown

graphic log / core recovery
core recovered (graphic symbols indicate material)
no core recovered

core run & RQD
barrel withdrawn
RQD = Rock Quality Designation (%)

weathering & alteration*
RS residual soil
XW extremely weathered
HW highly weathered
DW distinctly weathered
MW moderately weathered
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FR fresh
*W replaced with A for alteration

strength
VL very low
L low
M medium
H high
VH very high
EH extremely high

defect type
PT parting
JT joint
SZ shear zone
SS shear surface
CO contact
CS crushed seam
SM seam

planarity
PL planar
CU curved
UN undulating
ST stepped
IR Irregular

roughness
SL slickensided
POL polished
SO smooth
RO rough
VR very rough

coating
CN clean
SN stain
VN veneer
CO coating

coffey
A TETRA TECH COMPANY

Engineering Log - Cored Borehole

Borehole ID.	**BH01**
sheet:	11 of 14
project no.	**754-NTLGE220504**
client:	**Crescent Newcastle Pty Ltd**
principal:	
project:	**Proposed Multi Building Residential Development**
location:	**11 - 13 Mosbri Crescent, Cooks Hill, NSW**
date started:	**03 Sep 2018**
date completed:	**07 Sep 2018**
logged by:	**MJ**
checked by:	**RB**

position: E: 385,619.90; N: 6,355,684.10 (MGA94) | surface elevation: 31.39 m (AHD) | angle from horizontal: 90°
drill model: Comacchio 450P, Track mounted | drilling fluid: non / water | hole diameter : 96 mm | vane id.:

drilling information | **material substance** | **rock mass defects**

method & support	water	RL (m)	depth (m)	material description (ROCK TYPE: grain characterisics, colour, structure, minor components)	weathering & alteration	samples, field tests & Is(50) (MPa)	core run & RQD	additional observations and defect descriptions (type, inclination, planarity, roughness, coating, thickness, other)
HQ	50% loss	-41		**SANDSTONE**: fine to medium grained, grey to dark grey, with sitlstone bands and black carbonaceous laminations. *(continued)*	SW - FR		87%	PT, 0°, PL, RO, SN
		-42	73.0				100%	
		-43	74.0	74.36 m: 160mm siltstone band 74.52 m: 220mm medium to coarse grained sandstone 74.82 m: 50mm carbonaceous laminations		a=5.10 d=4.70		PT, 5°, PL, RO, SN
		-44	75.0	75.69 m: 250mm carbonaceous laminations		a=4.30 d=0.70		PT, 0°, PL, RO, CN
		-45	76.0	**SANDSTONE**: fine to medium grained, grey to dark grey and brown, with sitlstone bands and black carbonaceous laminations.			100%	
		-46	77.0	77.13 m: 50mm carbonaceous laminations				PT, 5°, PL, RO, SN
		-47	78.0	78.58 m: 20mm carbonaceous laminations		a=7.80 d=5.60	100%	
		-48	79.0	79.20 m: 1.08m carbonaceous laminations				PT, 5°, PL, RO, SN

general: Defects are: PT, 0 - 10°, PL, RO, CN, unless otherwise described

method & support
AS auger screwing
AD auger drilling
CB claw or blade bit
W washbore
NMLC NMLC core (51.9 mm)
NQ wireline core (47.6mm)
HQ wireline core (63.5mm)
PQ wireline core (85.0mm)
SPT standard penetration test
RR rock roller/tricone

water
10/10/12, water level on date shown
water inflow
complete drilling fluid loss
partial drilling fluid loss
25uL water pressure test result (lugeons) for depth interval shown

graphic log / core recovery
core recovered (graphic symbols indicate material)
no core recovered

core run & RQD
barrel withdrawn
RQD = Rock Quality Designation (%)

weathering & alteration*
RS residual soil
XW extremely weathered
HW highly weathered
DW distinctly weathered
MW moderately weathered
SW slightly weathered
FR fresh
*W replaced with A for alteration

strength
VL very low
L low
M medium
H high
VH very high
EH extremely high

defect type
PT parting
JT joint
SZ shear zone
SS shear surface
CO contact
CS crushed seam
SM seam

planarity
PL planar
CU curved
UN undulating
ST stepped
IR Irregular

roughness
SL slickensided
POL polished
SO smooth
RO rough
VR very rough

coating
CN clean
SN stain
VN veneer
CO coating

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Engineering Log - Cored Borehole

Borehole ID.	**BH01**
sheet:	12 of 14
project no.	**754-NTLGE220504**
client:	**Crescent Newcastle Pty Ltd**
principal:	
project:	**Proposed Multi Building Residential Development**
location:	**11 - 13 Mosbri Crescent, Cooks Hill, NSW**
date started:	**03 Sep 2018**
date completed:	**07 Sep 2018**
logged by:	**MJ**
checked by:	**RB**

position: E: 385,619.90; N: 6,355,684.10 (MGA94) surface elevation: 31.39 m (AHD) angle from horizontal: 90°
drill model: Comacchio 450P, Track mounted drilling fluid: non / water hole diameter : 96 mm vane id.:

method & support	water	RL (m)	depth (m)	material description	weathering & alteration	samples, field tests & Is(50) (MPa)	core run & RQD	additional observations and defect descriptions
HQ	50% loss	-49		**SANDSTONE**: fine to medium grained, grey to dark grey and brown, with sitlstone bands and black carbonaceous laminations. *(continued)*	SW - FR		100%	
			81.0	80.82 m: 80mm carbonaceous laminations 81.00 m: 430mm carbonaceous laminations				
		-50				a=2.50 d=1.40		
			82.0					
		-51					100%	
			83.0					
		-52						
			84.0			a=2.50 d=0.40		
		-53		84.20 m: 300mm carbonaceous laminations				PT, 0°, PL, RO, SN
			85.0					PT, 5°, PL, RO, SN
		-54		85.38 m: 70mm carbonaceous laminations			92%	
			86.0					PT, 0°, PL, RO, SN PT, 15°, PL, RO, CO, 10 mm
		-55		86.29 m: 20mm carbonaceous laminations 86.58 m: 100mm carbonaceous laminations 86.73 m: 50mm siltstone band		a=6.30 d=1.80		
			87.0	87.15 m: 100mm siltstone band				
		-56					100%	PT, 10°, PL, RO, SN

General: Defects are: PT, 0 - 10°, PL, RO, CN, unless otherwise described

method & support
AS auger screwing
AD auger drilling
CB claw or blade bit
W washbore
NMLC NMLC core (51.9 mm)
NQ wireline core (47.6mm)
HQ wireline core (63.5mm)
PQ wireline core (85.0mm)
SPT standard penetration test
RR rock roller/tricone

water
10/10/12, water level on date shown
water inflow
complete drilling fluid loss
partial drilling fluid loss
25uL water pressure test result (lugeons) for depth interval shown

graphic log / core recovery
core recovered (graphic symbols indicate material)
no core recovered

core run & RQD
barrel withdrawn
RQD = Rock Quality Designation (%)

weathering & alteration*
RS residual soil
XW extremely weathered
HW highly weathered
DW distinctly weathered
MW moderately weathered
SW slightly weathered
FR fresh
*W replaced with A for alteration

strength
VL very low
L low
M medium
H high
VH very high
EH extremely high

defect type
PT parting
JT joint
SZ shear zone
SS shear surface
CO contact
CS crushed seam
SM seam

planarity
PL planar
CU curved
UN undulating
ST stepped
IR Irregular

roughness
SL slickensided
POL polished
SO smooth
RO rough
VR very rough

coating
CN clean
SN stain
VN veneer
CO coating

CDF_0_9_06_LIBRARY.GLB rev:AS Log COF BOREHOLE: CORED 754-NTLGE220504.GPJ <<DrawingFile>> 29/10/2018 18:56

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Engineering Log - Cored Borehole

client:	**Crescent Newcastle Pty Ltd**	Borehole ID.	**BH01**
principal:		sheet:	13 of 14
project:	**Proposed Multi Building Residential Development**	project no.	**754-NTLGE220504**
location:	**11 - 13 Mosbri Crescent, Cooks Hill, NSW**	date started:	**03 Sep 2018**
		date completed:	**07 Sep 2018**
		logged by:	**MJ**
		checked by:	**RB**

position: E: 385,619.90; N: 6,355,684.10 (MGA94) surface elevation: 31.39 m (AHD) angle from horizontal: 90°
drill model: Comacchio 450P, Track mounted drilling fluid: non / water hole diameter : 96 mm vane id.:

method & support	water	RL (m)	depth (m)	material description (ROCK TYPE: grain characterisics, colour, structure, minor components)	weathering & alteration	samples, field tests & Is(50) (MPa) (a = axial; d = diametral)	core run & RQD	additional observations and defect descriptions (type, inclination, planarity, roughness, coating, thickness, other)
HQ	50% loss	-57		**SANDSTONE**: fine to medium grained, grey to dark grey and brown, with sitlstone bands and black carbonaceous laminations. *(continued)* 88.05 m: 0.5m carbonaceous laminations	SW - FR			
				88.64 m: 210mm siltstone band				PT, 10°, PL, RO, CN
			89.0	89.12 m: 300mm carbonaceous laminations		a=5.80 d=0.90	100%	
		-58						
			90.0					
		-59		90.40 m: 90mm carbonaceous laminations				PT, 20°, PL, RO, SN
			91.0					
		-60					97%	JT, 70°, PL, SO, CN
			92.0	**SILTSTONE**: dark grey, black with grey laminations, with carbonaceous laminations.				
		-61				a=3.40 d=0.40		
			93.0					PT, 0°, PL, RO, SN JT, 80°, PL, RO, CN
		-62		**NO CORE:** 0.55 m **TOOL DROP**: 0.5m void on CCTV.				
			94.0	**NO CORE:** 1.15 m 1.15m Coal in density plots			0%	
		-63						
			95.0	**CAVE-IN: COAL**: black, shiny, cleated.	MW		0%	CS, IR, SO, CO
		-64		**NO CORE:** 1.15 m Coal in density plots			17%	

Defects are: PT, 0 - 10°, PL, RO, CN, unless otherwise described

method & support
AS auger screwing
AD auger drilling
CB claw or blade bit
W washbore
NMLC NMLC core (51.9 mm)
NQ wireline core (47.6mm)
HQ wireline core (63.5mm)
PQ wireline core (85.0mm)
SPT standard penetration test
RR rock roller/tricone

water
10/10/12, water level on date shown
water inflow
complete drilling fluid loss
partial drilling fluid loss
25uL water pressure test result (lugeons) for depth interval shown

graphic log / core recovery
core recovered (graphic symbols indicate material)
no core recovered

core run & RQD
barrel withdrawn
RQD = Rock Quality Designation (%)

weathering & alteration*
RS residual soil
XW extremely weathered
HW highly weathered
DW distinctly weathered
MW moderately weathered
SW slightly weathered
FR fresh
*W replaced with A for alteration

strength
VL very low
L low
M medium
H high
VH very high
EH extremely high

defect type
PT parting
JT joint
SZ shear zone
SS shear surface
CO contact
CS crushed seam
SM seam

planarity
PL planar
CU curved
UN undulating
ST stepped
IR Irregular

roughness
SL slickensided
POL polished
SO smooth
RO rough
VR very rough

coating
CN clean
SN stain
VN veneer
CO coating

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Engineering Log - Cored Borehole

Borehole ID.	**BH01**
sheet:	14 of 14
project no.	**754-NTLGE220504**
date started:	**03 Sep 2018**
date completed:	**07 Sep 2018**
logged by:	**MJ**
checked by:	**RB**

client: **Crescent Newcastle Pty Ltd**

principal:

project: **Proposed Multi Building Residential Development**

location: **11 - 13 Mosbri Crescent, Cooks Hill, NSW**

position: E: 385,619.90; N: 6,355,684.10 (MGA94) | surface elevation: 31.39 m (AHD) | angle from horizontal: 90°

drill model: Comacchio 450P, Track mounted | drilling fluid: non / water | hole diameter : 96 mm | vane id.:

drilling information | **material substance** | **rock mass defects**

method & support	water	RL (m)	depth (m)	graphic log	material description (ROCK TYPE: grain characterisics, colour, structure, minor components)	weathering & alteration	estimated strength & Is50 (X = axial; O = diametral)	samples, field tests & Is(50) (MPa) (a = axial; d = diametral)	core run & RQD	defect spacing (mm)	additional observations and defect descriptions (type, inclination, planarity, roughness, coating, thickness, other)
HQ					**NO CORE:** 1.15 m *(continued)*						
		-65			**CAVE-IN: COAL**: black, shiny, cleated.	MW					CS, IR, RO, CN
			97.0		**COAL**: black, dull and shiney. 96.80 m: Floor of mine?				17%		
		-66			97.30 m: 300mm of dull coal			a=0.10 d=0.10			PT, 40°, PL, RO, CN JT, 60°, ST, RO, CN CS, IR, RO, CN
		-67	98.0						0%		CS, IR, RO, CN
		-68	99.0		99.27 m: 30mm siltstone, dark grey **SANDSTONE**: fine to coarse grained, grey.	FR					
			100.0					a=4.50 d=3.80			
		-69			100.05 m: 100mm coal band 100.52 m: 180mm medium to coarse grained sandstone				93%		PT, 0°, PL, RO, SN
		-70	101.0		101.26 m: 20mm medium to coarse grained sandstone 101.45 m: 25mm medium to coarse grained sandstone 101.78 m: 120mm conglomerate band			a=9.00 d=3.10			PT, 5°, UN, RO, SN
			102.0		Borehole BH01 terminated at 102.10 m Target depth						
		-71									
		-72	103.0								

Defects are: PT, 0 - 10°, PL, RO, CN, unless otherwise described

method & support
AS auger screwing
AD auger drilling
CB claw or blade bit
W washbore
NMLC NMLC core (51.9 mm)
NQ wireline core (47.6mm)
HQ wireline core (63.5mm)
PQ wireline core (85.0mm)
SPT standard penetration test
RR rock roller/tricone

water
10/10/12, water level on date shown
water inflow
complete drilling fluid loss
partial drilling fluid loss
25uL water pressure test result (lugeons) for depth interval shown

graphic log / core recovery
core recovered (graphic symbols indicate material)
no core recovered

core run & RQD
barrel withdrawn
RQD = Rock Quality Designation (%)

weathering & alteration*
RS residual soil
XW extremely weathered
HW highly weathered
DW distinctly weathered
MW moderately weathered
SW slightly weathered
FR fresh
*W replaced with A for alteration

strength
VL very low
L low
M medium
H high
VH very high
EH extremely high

defect type
PT parting
JT joint
SZ shear zone
SS shear surface
CO contact
CS crushed seam
SM seam

planarity
PL planar
CU curved
UN undulating
ST stepped
IR Irregular

roughness
SL slickensided
POL polished
SO smooth
RO rough
VR very rough

coating
CN clean
SN stain
VN veneer
CO coating

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Engineering Log - Borehole

Borehole ID.	**BH02**
sheet:	1 of 1
project no.	**754-NTLGE220504**
client:	**Crescent Newcastle Pty Ltd**
date started:	**10 Sep 2018**
principal:	
date completed:	**10 Sep 2018**
project:	**Proposed Multi Building Residential Development**
logged by:	**MJ**
location:	**11 - 13 Mosbri Crescent, Cooks Hill, NSW**
checked by:	**RB**

position: E: 385,624.50; N: 6,355,677.60 (MGA94) surface elevation: 30.94 m (AHD) angle from horizontal: 90°
drill model: Comacchio 450P, Track mounted drilling fluid: hole diameter : 100 mm

drilling information | **material substance**

method & support	penetration 1 2 3	water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description (SOIL TYPE: plasticity or particle characteristic, colour, secondary and minor components)	moisture condition	consistency / relative density	hand penetrometer (kPa) 100 200 300 400	structure and additional observations
AD/T		Not Observed	E					**FILL: BITUMEN**: Black, fine to coarse subangular gravel.				**FILL- WEARING COURSE**
												FILL- PAVEMENT
			E				CL	**FILL: Sandy GRAVEL**: fine to coarse grained, brown, with some cobbles 63mm to 80mm.	M	St		**FILL**
			E	30	1.0		CL	**FILL: Sandy CLAY**: low to medium plasticity, dark grey, grey and brown, fine to medium sand, some surounded sized gravel.	>Wp	VSt		
			SPT 3, 3, 8 N*=11					**FILL: CLAY**: medium plasticity, grey and pale grey, with orange.				
			E									
				29	2.0		SC	**CLAYEY SAND**: fine to coarse grained, pale brown and pale grey.	M			**RESIDUAL SOIL**
			SPT 6, 8, 9 N*=17				CL	**Sandy CLAY**: medium plasticity, grey, fine to medium grained sand.	~Wp	H		
				28	3.0		CL	**CLAY**: medium plasticity, orange mottled pale grey.				
									<Wp			**EXTREMELY WEATHERED MATERIAL**
			SPT 15/10mm HB N*=R	27	4.0			Borehole BH02 terminated at 4.01 m Safety reasons				
				26	5.0							
				25	6.0							
				24	7.0							
				23								

method
AD auger drilling*
AS auger screwing*
HA hand auger
W washbore
RR rock roller/tricone

* bit shown by suffix
e.g. AD/T
B blank bit
T TC bit
V V bit

support
M mud N nil
C casing

penetration
1 2 3 no resistance ranging to refusal

water
10-Oct-12 water level on date shown
water inflow
water outflow

samples & field tests
B bulk disturbed sample
D disturbed sample
E environmental sample
SS split spoon sample
U## undisturbed sample ##mm diameter
HP hand penetrometer (kPa)
N standard penetration test (SPT)
N* SPT - sample recovered
Nc SPT with solid cone
VS vane shear; peak/remouded (kPa)
R refusal
HB hammer bouncing

classification symbol & soil description
based on Unified Classification System

moisture
D dry
M moist
W wet
Wp plastic limit
Wl liquid limit

consistency / relative density
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

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Engineering Log - Borehole

Borehole ID.	**BH02A**
sheet:	1 of 13
project no.	**754-NTLGE220504**
date started:	**20 Sep 2018**
date completed:	**21 Sep 2018**
logged by:	**MJ**
checked by:	**RB**

client: **Crescent Newcastle Pty Ltd**

principal:

project: **Proposed Multi Building Residential Development**

location: **11 - 13 Mosbri Crescent, Cooks Hill, NSW**

position: E: 385,619.90; N: 6,355,693.60 (MGA94) surface elevation: 32.40 m (AHD) angle from horizontal: 90°

drill model: Comacchio 450P, Track mounted drilling fluid: non / water hole diameter : 96 mm

drilling information | **material substance**

method & support	penetration 1 2 3	water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description (SOIL TYPE: plasticity or particle characteristic, colour, secondary and minor components)	moisture condition	consistency / relative density	hand penetrometer (kPa) 100 200 300 400	structure and additional observations
AD			E					**FILL: BITUMEN PAVEMENT**: black, 50mm.				**FILL- WEARING COURSE**
			E	32				**FILL: Gravelly SAND**: fine to coarse grained, brown and pale grey, with angular to sub-angular gravel.	M			**FILL- PAVEMENT**
RR / N		Not Observed		31, 30, 29, 28, 27, 26, 25	1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0			**SANDSTONE**.				**HIGHLY WEATHERED BECOMING MODERATELY WEATHERED MATERIAL**

method
AD auger drilling*
AS auger screwing*
HA hand auger
W washbore
RR rock roller/tricone
* bit shown by suffix
e.g. AD/T
B blank bit
T TC bit
V V bit

support
M mud N nil
C casing

penetration
1 2 3 no resistance ranging to refusal

water
10-Oct-12 water level on date shown
water inflow
water outflow

samples & field tests
B bulk disturbed sample
D disturbed sample
E environmental sample
SS split spoon sample
U## undisturbed sample ##mm diameter
HP hand penetrometer (kPa)
N standard penetration test (SPT)
N* SPT - sample recovered
Nc SPT with solid cone
VS vane shear; peak/remouded (kPa)
R refusal
HB hammer bouncing

classification symbol & soil description
based on Unified Classification System

moisture
D dry
M moist
W wet
Wp plastic limit
Wl liquid limit

consistency / relative density
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

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Engineering Log - Borehole

Borehole ID.	**BH02A**
sheet:	2 of 13
project no.	**754-NTLGE220504**
date started:	**20 Sep 2018**
date completed:	**21 Sep 2018**
logged by:	**MJ**
checked by:	**RB**

client: ***Crescent Newcastle Pty Ltd***

principal:

project: ***Proposed Multi Building Residential Development***

location: ***11 - 13 Mosbri Crescent, Cooks Hill, NSW***

position: E: 385,619.90; N: 6,355,693.60 (MGA94) | surface elevation: 32.40 m (AHD) | angle from horizontal: 90°

drill model: Comacchio 450P, Track mounted | drilling fluid: non / water | hole diameter : 96 mm

drilling information						material substance						
method & support	penetration 1 2 3	water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description **SOIL TYPE**: plasticity or particle characteristic, colour, secondary and minor components	moisture condition	consistency / relative density	hand penetrometer (kPa) 100 200 300 400	structure and additional observations
RR N		Not Observed		24 23 22 21 20 19 18 17	9.0 10.0 11.0 12.0 13.0 14.0 15.0			**SANDSTONE**. *(continued)*				**MODERATELY WEATHERED TO SLIGHTLY WEATHERED**

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method
AD auger drilling*
AS auger screwing*
HA hand auger
W washbore
RR rock roller/tricone

* bit shown by suffix
e.g. AD/T
B blank bit
T TC bit
V V bit

support
M mud N nil
C casing

penetration
1 2 3 no resistance ranging to refusal

water
10-Oct-12 water level on date shown
water inflow
water outflow

samples & field tests
B bulk disturbed sample
D disturbed sample
E environmental sample
SS split spoon sample
U## undisturbed sample ##mm diameter
HP hand penetrometer (kPa)
N standard penetration test (SPT)
N* SPT - sample recovered
Nc SPT with solid cone
VS vane shear; peak/remouded (kPa)
R refusal
HB hammer bouncing

classification symbol & soil description
based on Unified Classification System

moisture
D dry
M moist
W wet
Wp plastic limit
Wl liquid limit

consistency / relative density
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

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Engineering Log - Borehole

Borehole ID.	**BH02A**
sheet:	3 of 13
project no.	**754-NTLGE220504**
client:	**Crescent Newcastle Pty Ltd**
principal:	
project:	**Proposed Multi Building Residential Development**
location:	**11 - 13 Mosbri Crescent, Cooks Hill, NSW**
date started:	**20 Sep 2018**
date completed:	**21 Sep 2018**
logged by:	**MJ**
checked by:	**RB**

position: E: 385,619.90; N: 6,355,693.60 (MGA94) surface elevation: 32.40 m (AHD) angle from horizontal: 90°

drill model: Comacchio 450P, Track mounted drilling fluid: non / water hole diameter : 96 mm

drilling information						material substance						
method & support	penetration 1 2 3	water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description SOIL TYPE: plasticity or particle characteristic, colour, secondary and minor components	moisture condition	consistency / relative density	hand penetrometer (kPa) 100 200 300 400	structure and additional observations
RR — N		Not Observed		16 15 14 13 12 11 10 9	17.0 18.0 19.0 20.0 21.0 22.0 23.0			**SANDSTONE**. *(continued)*				**MODERATELY WEATHERED TO SLIGHTLY WEATHERED**

method
AD auger drilling*
AS auger screwing*
HA hand auger
W washbore
RR rock roller/tricone
* bit shown by suffix
e.g. AD/T
B blank bit
T TC bit
V V bit

support
M mud N nil
C casing

penetration
1 2 3 no resistance ranging to refusal

water
10-Oct-12 water level on date shown
water inflow
water outflow

samples & field tests
B bulk disturbed sample
D disturbed sample
E environmental sample
SS split spoon sample
U## undisturbed sample ##mm diameter
HP hand penetrometer (kPa)
N standard penetration test (SPT)
N* SPT - sample recovered
Nc SPT with solid cone
VS vane shear; peak/remouded (kPa)
R refusal
HB hammer bouncing

classification symbol & soil description
based on Unified Classification System

moisture
D dry
M moist
W wet
Wp plastic limit
Wl liquid limit

consistency / relative density
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

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Engineering Log - Borehole

Borehole ID.	**BH02A**
sheet:	4 of 13
project no.	**754-NTLGE220504**
client:	**Crescent Newcastle Pty Ltd**
date started:	**20 Sep 2018**
principal:	
date completed:	**21 Sep 2018**
project:	**Proposed Multi Building Residential Development**
logged by:	**MJ**
location:	**11 - 13 Mosbri Crescent, Cooks Hill, NSW**
checked by:	**RB**

position: E: 385,619.90; N: 6,355,693.60 (MGA94) | surface elevation: 32.40 m (AHD) | angle from horizontal: 90°
drill model: Comacchio 450P, Track mounted | drilling fluid: non / water | hole diameter : 96 mm

drilling information | **material substance**

method & support	penetration	water	samples & field tests	RL (m)	depth (m)	material description (SOIL TYPE: plasticity or particle characteristic, colour, secondary and minor components)	moisture condition	consistency / relative density	hand penetrometer (kPa)	structure and additional observations
RR N		Not Observed		8		**SANDSTONE**. *(continued)*				**MODERATELY WEATHERED TO SLIGHTLY WEATHERED**
				7	25.0					
				6	26.0	**COAL**.				
				5	27.0					
				4	28.0	**SILTSTONE**.				
						COAL.				
				3	29.0	**SILTSTONE**.				**FRESH**
						COAL.				
				2	30.0	**SANDSTONE**.				
				1	31.0					

method
AD auger drilling*
AS auger screwing*
HA hand auger
W washbore
RR rock roller/tricone
* bit shown by suffix
e.g. AD/T
B blank bit
T TC bit
V V bit

support
M mud N nil
C casing

penetration
1 2 3 no resistance ranging to refusal

water
10-Oct-12 water level on date shown
water inflow
water outflow

samples & field tests
B bulk disturbed sample
D disturbed sample
E environmental sample
SS split spoon sample
U## undisturbed sample ##mm diameter
HP hand penetrometer (kPa)
N standard penetration test (SPT)
N* SPT - sample recovered
Nc SPT with solid cone
VS vane shear; peak/remouded (kPa)
R refusal
HB hammer bouncing

classification symbol & soil description
based on Unified Classification System

moisture
D dry
M moist
W wet
Wp plastic limit
Wl liquid limit

consistency / relative density
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

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Engineering Log - Borehole

Borehole ID. **BH02A**
sheet: 5 of 13
project no. **754-NTLGE220504**

client: ***Crescent Newcastle Pty Ltd***
principal:
project: ***Proposed Multi Building Residential Development***
location: ***11 - 13 Mosbri Crescent, Cooks Hill, NSW***

date started: ***20 Sep 2018***
date completed: ***21 Sep 2018***
logged by: ***MJ***
checked by: ***RB***

position: E: 385,619.90; N: 6,355,693.60 (MGA94) | surface elevation: 32.40 m (AHD) | angle from horizontal: 90°
drill model: Comacchio 450P, Track mounted | drilling fluid: non / water | hole diameter : 96 mm

method & support	penetration 1 2 3	water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description — SOIL TYPE: plasticity or particle characteristic, colour, secondary and minor components	moisture condition	consistency / relative density	hand penetrometer (kPa) 100 200 300 400	structure and additional observations
RR / N		Not Observed		0				**SANDSTONE**. *(continued)*				**FRESH**
				-1	33.0							
				-2	34.0							
				-3	35.0							
				-4	36.0							
				-5	37.0							
				-6	38.0							
				-7	39.0							

method
AD auger drilling*
AS auger screwing*
HA hand auger
W washbore
RR rock roller/tricone
* bit shown by suffix
e.g. AD/T
B blank bit
T TC bit
V V bit

support
M mud
N nil
C casing

penetration
1 2 3 — no resistance ranging to refusal

water
10-Oct-12 water level on date shown
water inflow
water outflow

samples & field tests
B bulk disturbed sample
D disturbed sample
E environmental sample
SS split spoon sample
U## undisturbed sample ##mm diameter
HP hand penetrometer (kPa)
N standard penetration test (SPT)
N* SPT - sample recovered
Nc SPT with solid cone
VS vane shear; peak/remouded (kPa)
R refusal
HB hammer bouncing

classification symbol & soil description
based on Unified Classification System

moisture
D dry
M moist
W wet
Wp plastic limit
Wl liquid limit

consistency / relative density
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

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Engineering Log - Borehole

Borehole ID.	**BH02A**
sheet:	6 of 13
project no.	**754-NTLGE220504**
date started:	**20 Sep 2018**
date completed:	**21 Sep 2018**
logged by:	**MJ**
checked by:	**RB**

client: **Crescent Newcastle Pty Ltd**

principal:

project: **Proposed Multi Building Residential Development**

location: **11 - 13 Mosbri Crescent, Cooks Hill, NSW**

position: E: 385,619.90; N: 6,355,693.60 (MGA94) | surface elevation: 32.40 m (AHD) | angle from horizontal: 90°

drill model: Comacchio 450P, Track mounted | drilling fluid: non / water | hole diameter : 96 mm

drilling information | **material substance**

method & support	penetration 1 2 3	water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description (SOIL TYPE: plasticity or particle characteristic, colour, secondary and minor components)	moisture condition	consistency / relative density	hand penetro-meter (kPa) 100 200 300 400	structure and additional observations
RR N		Not Observed		-8				**SANDSTONE**. *(continued)*				**FRESH**
				-9	41.0							
				-10	42.0							
				-11	43.0							
				-12	44.0			**COAL**: black.				
				-13	45.0			**SANDSTONE**: grey.				
				-14	46.0							
				-15	47.0							

method
AD auger drilling*
AS auger screwing*
HA hand auger
W washbore
RR rock roller/tricone

* bit shown by suffix
e.g. AD/T
B blank bit
T TC bit
V V bit

support
M mud N nil
C casing

penetration
1 2 3 no resistance ranging to refusal

water
10-Oct-12 water level on date shown
water inflow
water outflow

samples & field tests
B bulk disturbed sample
D disturbed sample
E environmental sample
SS split spoon sample
U## undisturbed sample ##mm diameter
HP hand penetrometer (kPa)
N standard penetration test (SPT)
N* SPT - sample recovered
Nc SPT with solid cone
VS vane shear; peak/remouded (kPa)
R refusal
HB hammer bouncing

classification symbol & soil description
based on Unified Classification System

moisture
D dry
M moist
W wet
Wp plastic limit
Wl liquid limit

consistency / relative density
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

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Engineering Log - Borehole

Borehole ID.	**BH02A**
sheet:	7 of 13
project no.	**754-NTLGE220504**
date started:	**20 Sep 2018**
date completed:	**21 Sep 2018**
logged by:	**MJ**
checked by:	**RB**

client: ***Crescent Newcastle Pty Ltd***

principal:

project: ***Proposed Multi Building Residential Development***

location: ***11 - 13 Mosbri Crescent, Cooks Hill, NSW***

position: E: 385,619.90; N: 6,355,693.60 (MGA94) surface elevation: 32.40 m (AHD) angle from horizontal: 90°

drill model: Comacchio 450P, Track mounted drilling fluid: non / water hole diameter : 96 mm

drilling information						material substance						
method & support	penetration 1 2 3	water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description **SOIL TYPE**: plasticity or particle characteristic, colour, secondary and minor components	moisture condition	consistency / relative density	hand penetro-meter (kPa) 100 200 300 400	structure and additional observations
RR — N		Not Observed		-16				**SANDSTONE**: grey. *(continued)*				**FRESH**
				-17	49.0							
				-18	50.0							
				-19	51.0							
				-20	52.0							
				-21	53.0							
				-22	54.0							
				-23	55.0							
								COAL: black.				

method
AD auger drilling*
AS auger screwing*
HA hand auger
W washbore
RR rock roller/tricone
* bit shown by suffix
e.g. AD/T
B blank bit
T TC bit
V V bit

support
M mud N nil
C casing

penetration
1 2 3 no resistance ranging to refusal

water
10-Oct-12 water level on date shown
water inflow
water outflow

samples & field tests
B bulk disturbed sample
D disturbed sample
E environmental sample
SS split spoon sample
U## undisturbed sample ##mm diameter
HP hand penetrometer (kPa)
N standard penetration test (SPT)
N* SPT - sample recovered
Nc SPT with solid cone
VS vane shear; peak/remouded (kPa)
R refusal
HB hammer bouncing

classification symbol & soil description
based on Unified Classification System

moisture
D dry
M moist
W wet
Wp plastic limit
Wl liquid limit

consistency / relative density
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

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Engineering Log - Borehole

Borehole ID.	**BH02A**
sheet:	8 of 13
project no.	**754-NTLGE220504**
date started:	**20 Sep 2018**
date completed:	**21 Sep 2018**
logged by:	**MJ**
checked by:	**RB**

client: ***Crescent Newcastle Pty Ltd***

principal:

project: ***Proposed Multi Building Residential Development***

location: ***11 - 13 Mosbri Crescent, Cooks Hill, NSW***

position: E: 385,619.90; N: 6,355,693.60 (MGA94) | surface elevation: 32.40 m (AHD) | angle from horizontal: 90°

drill model: Comacchio 450P, Track mounted | drilling fluid: non / water | hole diameter : 96 mm

method & support	penetration 1 2 3	water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description (SOIL TYPE: plasticity or particle characteristic, colour, secondary and minor components)	moisture condition	consistency / relative density	hand penetrometer (kPa) 100 200 300 400	structure and additional observations
RR N		Not Observed		-24				SANDSTONE.				FRESH
				-25	57.0							
				-26	58.0							
				-27	59.0							
				-28	60.0							
				-29	61.0							
				-30	62.0							
				-31	63.0							

method
AD auger drilling*
AS auger screwing*
HA hand auger
W washbore
RR rock roller/tricone
* bit shown by suffix
e.g. AD/T
B blank bit
T TC bit
V V bit

support
M mud N nil
C casing

penetration
1 2 3 no resistance ranging to refusal

water
10-Oct-12 water level on date shown
water inflow
water outflow

samples & field tests
B bulk disturbed sample
D disturbed sample
E environmental sample
SS split spoon sample
U## undisturbed sample ##mm diameter
HP hand penetrometer (kPa)
N standard penetration test (SPT)
N* SPT - sample recovered
Nc SPT with solid cone
VS vane shear; peak/remouded (kPa)
R refusal
HB hammer bouncing

classification symbol & soil description
based on Unified Classification System

moisture
D dry
M moist
W wet
Wp plastic limit
Wl liquid limit

consistency / relative density
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

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Engineering Log - Borehole

Borehole ID.	**BH02A**
sheet:	9 of 13
project no.	**754-NTLGE220504**
date started:	**20 Sep 2018**
date completed:	**21 Sep 2018**
logged by:	**MJ**
checked by:	**RB**

client: **Crescent Newcastle Pty Ltd**

principal:

project: **Proposed Multi Building Residential Development**

location: **11 - 13 Mosbri Crescent, Cooks Hill, NSW**

position: E: 385,619.90; N: 6,355,693.60 (MGA94) surface elevation: 32.40 m (AHD) angle from horizontal: 90°

drill model: Comacchio 450P, Track mounted drilling fluid: non / water hole diameter : 96 mm

drilling information						material substance						
method & support	penetration 1 2 3	water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description SOIL TYPE: plasticity or particle characteristic, colour, secondary and minor components	moisture condition	consistency / relative density	hand penetrometer (kPa) 100 200 300 400	structure and additional observations
RR / N		Not Observed		-32				**SANDSTONE**. *(continued)*				**FRESH**
				-33	65.0							
				-34	66.0							
				-35	67.0							
				-36	68.0							
				-37	69.0							
				-38	70.0							
				-39	71.0							

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method
AD auger drilling*
AS auger screwing*
HA hand auger
W washbore
RR rock roller/tricone
* bit shown by suffix
e.g. AD/T
B blank bit
T TC bit
V V bit

support
M mud N nil
C casing

penetration
1 2 3 no resistance ranging to refusal

water
10-Oct-12 water level on date shown
water inflow
water outflow

samples & field tests
B bulk disturbed sample
D disturbed sample
E environmental sample
SS split spoon sample
U## undisturbed sample ##mm diameter
HP hand penetrometer (kPa)
N standard penetration test (SPT)
N* SPT - sample recovered
Nc SPT with solid cone
VS vane shear; peak/remouded (kPa)
R refusal
HB hammer bouncing

classification symbol & soil description
based on Unified Classification System

moisture
D dry
M moist
W wet
Wp plastic limit
Wl liquid limit

consistency / relative density
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

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Engineering Log - Borehole

Borehole ID.	**BH02A**
sheet:	10 of 13
project no.	**754-NTLGE220504**
date started:	**20 Sep 2018**
date completed:	**21 Sep 2018**
logged by:	**MJ**
checked by:	**RB**

client: ***Crescent Newcastle Pty Ltd***

principal:

project: ***Proposed Multi Building Residential Development***

location: ***11 - 13 Mosbri Crescent, Cooks Hill, NSW***

position: E: 385,619.90; N: 6,355,693.60 (MGA94) surface elevation: 32.40 m (AHD) angle from horizontal: 90°

drill model: Comacchio 450P, Track mounted drilling fluid: non / water hole diameter : 96 mm

drilling information						material substance						
method & support	penetration 1 2 3	water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description **SOIL TYPE**: plasticity or particle characteristic, colour, secondary and minor components	moisture condition	consistency / relative density	hand penetro-meter (kPa) 100 200 300 400	structure and additional observations
RR N		Not Observed		-40				**SANDSTONE**. *(continued)*				**FRESH**
				-41	73.0							
				-42	74.0							
				-43	75.0							
				-44	76.0							
				-45	77.0							
				-46	78.0							
				-47	79.0							

method
- AD auger drilling*
- AS auger screwing*
- HA hand auger
- W washbore
- RR rock roller/tricone
- * bit shown by suffix
- e.g. AD/T
- B blank bit
- T TC bit
- V V bit

support
- M mud N nil
- C casing

penetration
1 2 3 no resistance ranging to refusal

water
- 10-Oct-12 water level on date shown
- water inflow
- water outflow

samples & field tests
- B bulk disturbed sample
- D disturbed sample
- E environmental sample
- SS split spoon sample
- U## undisturbed sample ##mm diameter
- HP hand penetrometer (kPa)
- N standard penetration test (SPT)
- N* SPT - sample recovered
- Nc SPT with solid cone
- VS vane shear; peak/remouded (kPa)
- R refusal
- HB hammer bouncing

classification symbol & soil description
based on Unified Classification System

moisture
- D dry
- M moist
- W wet
- Wp plastic limit
- Wl liquid limit

consistency / relative density
- VS very soft
- S soft
- F firm
- St stiff
- VSt very stiff
- H hard
- Fb friable
- VL very loose
- L loose
- MD medium dense
- D dense
- VD very dense

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Engineering Log - Borehole

Borehole ID.	**BH02A**
sheet:	11 of 13
project no.	**754-NTLGE220504**
date started:	**20 Sep 2018**
date completed:	**21 Sep 2018**
logged by:	**MJ**
checked by:	**RB**

client: ***Crescent Newcastle Pty Ltd***

principal:

project: ***Proposed Multi Building Residential Development***

location: ***11 - 13 Mosbri Crescent, Cooks Hill, NSW***

position: E: 385,619.90; N: 6,355,693.60 (MGA94) surface elevation: 32.40 m (AHD) angle from horizontal: 90°

drill model: Comacchio 450P, Track mounted drilling fluid: non / water hole diameter : 96 mm

drilling information						material substance						
method & support	penetration 1 2 3	water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description **SOIL TYPE**: plasticity or particle characteristic, colour, secondary and minor components	moisture condition	consistency / relative density	hand penetrometer (kPa) 100 200 300 400	structure and additional observations
RR — N		Not Observed		-48				**SANDSTONE**. *(continued)*				**FRESH**
					81.0							
				-49								
					82.0							
				-50								
					83.0							
				-51								
					84.0							
				-52								
					85.0							
				-53								
					86.0							
				-54								
					87.0							
				-55								

method
AD auger drilling*
AS auger screwing*
HA hand auger
W washbore
RR rock roller/tricone

* bit shown by suffix
e.g. AD/T
B blank bit
T TC bit
V V bit

support
M mud N nil
C casing

penetration
1 2 3 no resistance ranging to refusal

water
10-Oct-12 water level on date shown
water inflow
water outflow

samples & field tests
B bulk disturbed sample
D disturbed sample
E environmental sample
SS split spoon sample
U## undisturbed sample ##mm diameter
HP hand penetrometer (kPa)
N standard penetration test (SPT)
N* SPT - sample recovered
Nc SPT with solid cone
VS vane shear; peak/remouded (kPa)
R refusal
HB hammer bouncing

classification symbol & soil description
based on Unified Classification System

moisture
D dry
M moist
W wet
Wp plastic limit
Wl liquid limit

consistency / relative density
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

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A TETRA TECH COMPANY

Engineering Log - Borehole

Borehole ID.	**BH02A**
sheet:	12 of 13
project no.	**754-NTLGE220504**
date started:	**20 Sep 2018**
date completed:	**21 Sep 2018**
logged by:	**MJ**
checked by:	**RB**

client: ***Crescent Newcastle Pty Ltd***

principal:

project: ***Proposed Multi Building Residential Development***

location: ***11 - 13 Mosbri Crescent, Cooks Hill, NSW***

position: E: 385,619.90; N: 6,355,693.60 (MGA94) — surface elevation: 32.40 m (AHD) — angle from horizontal: 90°

drill model: Comacchio 450P, Track mounted — drilling fluid: non / water — hole diameter : 96 mm

drilling information | **material substance**

method & support	penetration 1 2 3	water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description (SOIL TYPE: plasticity or particle characteristic, colour, secondary and minor components)	moisture condition	consistency / relative density	hand penetrometer (kPa) 100 200 300 400	structure and additional observations
RR — N		Not Observed		-56				**SANDSTONE**. *(continued)*				**FRESH**
				-57	89.0							
				-58	90.0							
				-59	91.0							
				-60	92.0							
				-61	93.0							
				-62	94.0							
				-63	95.0			**COAL**: black.				

method
AD auger drilling*
AS auger screwing*
HA hand auger
W washbore
RR rock roller/tricone
* bit shown by suffix
e.g. AD/T
B blank bit
T TC bit
V V bit

support
M mud N nil
C casing

penetration
1 2 3 — no resistance ranging to refusal

water
10-Oct-12 water level on date shown
water inflow
water outflow

samples & field tests
B bulk disturbed sample
D disturbed sample
E environmental sample
SS split spoon sample
U## undisturbed sample ##mm diameter
HP hand penetrometer (kPa)
N standard penetration test (SPT)
N* SPT - sample recovered
Nc SPT with solid cone
VS vane shear; peak/remouded (kPa)
R refusal
HB hammer bouncing

classification symbol & soil description
based on Unified Classification System

moisture
D dry
M moist
W wet
Wp plastic limit
Wl liquid limit

consistency / relative density
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

coffey
A TETRA TECH COMPANY

Engineering Log - Borehole

Borehole ID.	**BH02A**
sheet:	13 of 13
project no.	**754-NTLGE220504**
date started:	**20 Sep 2018**
date completed:	**21 Sep 2018**
logged by:	**MJ**
checked by:	**RB**

client: ***Crescent Newcastle Pty Ltd***

principal:

project: ***Proposed Multi Building Residential Development***

location: ***11 - 13 Mosbri Crescent, Cooks Hill, NSW***

position: E: 385,619.90; N: 6,355,693.60 (MGA94) surface elevation: 32.40 m (AHD) angle from horizontal: 90°

drill model: Comacchio 450P, Track mounted drilling fluid: non / water hole diameter : 96 mm

method & support	penetration	water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description (SOIL TYPE: plasticity or particle characteristic, colour, secondary and minor components)	moisture condition	consistency / relative density	hand penetrometer (kPa)	structure and additional observations
RR / N		Not Observed		-64 to -68	96.6 – 100.7			**COAL**: black. *(continued)*				**FRESH**
				-68 to -69	100.7 – 102.0			**SANDSTONE**: grey.				
				-70 to -71	102.0			Borehole BH02A terminated at 102.0 m Target depth				

method
AD auger drilling*
AS auger screwing*
HA hand auger
W washbore
RR rock roller/tricone
* bit shown by suffix
e.g. AD/T
B blank bit
T TC bit
V V bit

support
M mud N nil
C casing

penetration
1 2 3 — no resistance ranging to refusal

water
10-Oct-12 water level on date shown
water inflow
water outflow

samples & field tests
B bulk disturbed sample
D disturbed sample
E environmental sample
SS split spoon sample
U## undisturbed sample ##mm diameter
HP hand penetrometer (kPa)
N standard penetration test (SPT)
N* SPT - sample recovered
Nc SPT with solid cone
VS vane shear; peak/remouded (kPa)
R refusal
HB hammer bouncing

classification symbol & soil description
based on Unified Classification System

moisture
D dry
M moist
W wet
Wp plastic limit
Wl liquid limit

consistency / relative density
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

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Engineering Log - Borehole

client:	*Crescent Newcastle Pty Ltd*	Borehole ID.	***BH03***
principal:		sheet:	1 of 14
project:	*Proposed Multi Building Residential Development*	project no.	***754-NTLGE220504***
location:	*11 - 13 Mosbri Crescent, Cooks Hill, NSW*	date started:	***17 Sep 2018***
		date completed:	***20 Sep 2018***
		logged by:	***MJ***
		checked by:	***RB***

position: E: 385,685.80; N: 6,355,574.40 (MGA94) surface elevation: 32.75 m (AHD) angle from horizontal: 90°
drill model: Comacchio 450P, Track mounted drilling fluid: non / water hole diameter : 96 mm

drilling information | **material substance**

method & support	penetration 1 2 3	water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description: SOIL TYPE: plasticity or particle characteristic, colour, secondary and minor components	moisture condition	consistency / relative density	hand penetrometer (kPa) 100 200 300 400	structure and additional observations
AD / N							GP	**FILL: BITUMEN**: black, 50mm.	M			**FILL- WEARING COURSE**
			E					**FILL: Sandy GRAVEL**: fine to coarse grained, grey, angular to sub-angular, fine grained sand.				**FILL- PAVEMENT**
			E	32			CI	**Sandy CLAY**: medium plasticity, mottled red and brown.	>Wp	St - VSt		**RESIDUAL SOIL**
			SPT 5, 7, 10 N=17		1.0							
			B				CI	**CLAY**: medium plasticity, pale grey and red mottled orange.	>Wp			
				31	2.0		CL	**Sandy CLAY**: low plasticity, orange mottled pale brown, fine grained sand.	<Wp	VSt - H		**EXTREMELY WEATHERED ROCK**
			SPT 21, 30/90mm N=R									
				30	3.0							
				29	4.0			Borehole BH03 continued as cored hole				
				28	5.0							
				27	6.0							
				26	7.0							
				25								

method
AD auger drilling*
AS auger screwing*
HA hand auger
W washbore
RR rock roller/tricone
* bit shown by suffix
e.g. AD/T
B blank bit
T TC bit
V V bit

support
M mud N nil
C casing

penetration
1 2 3 — no resistance ranging to refusal

water
10-Oct-12 water level on date shown
water inflow
water outflow

samples & field tests
B bulk disturbed sample
D disturbed sample
E environmental sample
SS split spoon sample
U## undisturbed sample ##mm diameter
HP hand penetrometer (kPa)
N standard penetration test (SPT)
N* SPT - sample recovered
Nc SPT with solid cone
VS vane shear; peak/remouded (kPa)
R refusal
HB hammer bouncing

classification symbol & soil description
based on Unified Classification System

moisture
D dry
M moist
W wet
Wp plastic limit
Wl liquid limit

consistency / relative density
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

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Engineering Log - Cored Borehole

Borehole ID.	**BH03**
sheet:	2 of 14
project no.	**754-NTLGE220504**
date started:	**17 Sep 2018**
date completed:	**20 Sep 2018**
logged by:	**MJ**
checked by:	**RB**

client: **Crescent Newcastle Pty Ltd**

principal:

project: **Proposed Multi Building Residential Development**

location: **11 - 13 Mosbri Crescent, Cooks Hill, NSW**

position: E: 385,685.80; N: 6,355,574.40 (MGA94) | surface elevation: 32.75 m (AHD) | angle from horizontal: 90°

drill model: Comacchio 450P, Track mounted | drilling fluid: non / water | hole diameter : 96 mm | vane id.:

method & support	RL (m)	depth (m)	material description	weathering & alteration	samples, field tests & Is(50) (MPa)	core run & RQD	additional observations and defect descriptions
	32, 31, 30	1.0, 2.0, 3.0	started coring at 3.40m				
HQ	29, 28	4.0	**SANDSTONE**: fine to medium grained, brown to pale brown, grey to dark grey, with siltstone bands.	DW			PT, 0°, PL, RO, CN
				XW			
				DW	a=0.80 d=0.10	72%	PT, 40°, IR, RO, SN; PT, 10°, IR, RO, SN; Drilling Break; PT, 0°, PL, RO, VN; JT, 70°, PL, RO, SN; Drilling Break; PT, 5 - 10°, ST, SN
HQ	27, 26, 25	5.0, 6.0, 7.0	**SANDSTONE**: fine to medium grained, grey, dark grey, with siltstone bands and carbonaceous laminations.	SW - FR	a=1.50 d=0.60		Drilling Break; Drilling Break
					a=0.40 d=0.70	97%	PT, 0°, PL, VR, CN; Drilling Break; PT, 5°, CU, RO, SN; PT, 5°, CU, RO, CN; Drilling Break

General: Defects are: PT, 0 - 10°, PL, RO, SN, unless otherwise described

method & support
AS auger screwing
AD auger drilling
CB claw or blade bit
W washbore
NMLC NMLC core (51.9 mm)
NQ wireline core (47.6mm)
HQ wireline core (63.5mm)
PQ wireline core (85.0mm)
SPT standard penetration test
RR rock roller/tricone

water
10/10/12, water level on date shown
water inflow
complete drilling fluid loss
partial drilling fluid loss
25uL water pressure test result (lugeons) for depth interval shown

graphic log / core recovery
core recovered (graphic symbols indicate material)
no core recovered

core run & RQD
barrel withdrawn
RQD = Rock Quality Designation (%)

weathering & alteration*
RS residual soil
XW extremely weathered
HW highly weathered
DW distinctly weathered
MW moderately weathered
SW slightly weathered
FR fresh
*W replaced with A for alteration

strength
VL very low
L low
M medium
H high
VH very high
EH extremely high

defect type
PT parting
JT joint
SZ shear zone
SS shear surface
CO contact
CS crushed seam
SM seam

planarity
PL planar
CU curved
UN undulating
ST stepped
IR Irregular

roughness
SL slickensided
POL polished
SO smooth
RO rough
VR very rough

coating
CN clean
SN stain
VN veneer
CO coating

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Engineering Log - Cored Borehole

client:	*Crescent Newcastle Pty Ltd*	Borehole ID.	**BH03**
principal:		sheet:	3 of 14
project:	*Proposed Multi Building Residential Development*	project no.	*754-NTLGE220504*
location:	*11 - 13 Mosbri Crescent, Cooks Hill, NSW*	date started:	*17 Sep 2018*
		date completed:	*20 Sep 2018*
		logged by:	*MJ*
		checked by:	*RB*

position: E: 385,685.80; N: 6,355,574.40 (MGA94) surface elevation: 32.75 m (AHD) angle from horizontal: 90°
drill model: Comacchio 450P, Track mounted drilling fluid: non / water hole diameter : 96 mm vane id.:

method & support	water	RL (m)	depth (m)	graphic log	material description (ROCK TYPE: grain characteristics, colour, structure, minor components)	weathering & alteration	samples, field tests & Is(50) (MPa)	core run & RQD	additional observations and defect descriptions (type, inclination, planarity, roughness, coating, thickness, other)
HQ		24			**SANDSTONE**: fine to medium grained, grey, dark grey, with siltstone bands and carbonaceous laminations. *(continued)* 8.10 m: 50mm siltstone band	SW - FR		97%	Drilling Break; Drilling Break
			9.0		9.15 m: 50mm carbonaceous laminations		a=0.90 d=0.50		
		23	10.0						
		22	11.0				a=1.00 d=0.80	100%	
		21			11.60 m: 170mm carbonaceous laminations				
			12.0		12.12 m: 200mm siltstone band		a=0.70 d=0.20		PT, 0°, PL, VR, CO
		20	13.0		13.25 m: 180mm siltstone band				
		19	14.0				a=0.70 d=1.40	87%	
		18							JT, 40°, IR, RO, SN; JT, 40°, PL, RO, SN; JT, 70°, PL, RO, SN; JT, 70°, ST, RO, SN
			15.0				a=2.00 d=0.60		
		17						85%	

Defects are: PT, 0 - 10°, PL, RO, SN, unless otherwise described

method & support
AS auger screwing
AD auger drilling
CB claw or blade bit
W washbore
NMLC NMLC core (51.9 mm)
NQ wireline core (47.6mm)
HQ wireline core (63.5mm)
PQ wireline core (85.0mm)
SPT standard penetration test
RR rock roller/tricone

water
10/10/12, water level on date shown
water inflow
complete drilling fluid loss
partial drilling fluid loss
25uL water pressure test result (lugeons) for depth interval shown

graphic log / core recovery
core recovered (graphic symbols indicate material)
no core recovered

core run & RQD
barrel withdrawn
RQD = Rock Quality Designation (%)

weathering & alteration*
RS residual soil
XW extremely weathered
HW highly weathered
DW distinctly weathered
MW moderately weathered
SW slightly weathered
FR fresh
*W replaced with A for alteration

strength
VL very low
L low
M medium
H high
VH very high
EH extremely high

defect type
PT parting
JT joint
SZ shear zone
SS shear surface
CO contact
CS crushed seam
SM seam

planarity
PL planar
CU curved
UN undulating
ST stepped
IR Irregular

roughness
SL slickensided
POL polished
SO smooth
RO rough
VR very rough

coating
CN clean
SN stain
VN veneer
CO coating

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Engineering Log - Cored Borehole

client:	*Crescent Newcastle Pty Ltd*	Borehole ID.	**BH03**
principal:		sheet:	4 of 14
project:	*Proposed Multi Building Residential Development*	project no.	**754-NTLGE220504**
location:	*11 - 13 Mosbri Crescent, Cooks Hill, NSW*	date started:	**17 Sep 2018**
		date completed:	**20 Sep 2018**
		logged by:	**MJ**
		checked by:	**RB**

position: E: 385,685.80; N: 6,355,574.40 (MGA94) | surface elevation: 32.75 m (AHD) | angle from horizontal: 90°

drill model: Comacchio 450P, Track mounted | drilling fluid: non / water | hole diameter : 96 mm | vane id.:

method & support	water	RL (m)	depth (m)	graphic log	material description (ROCK TYPE: grain characterisics, colour, structure, minor components)	weathering & alteration	samples, field tests & Is(50) (MPa)	core run & RQD	additional observations and defect descriptions (type, inclination, planarity, roughness, coating, thickness, other)
HQ		16	17.0		**SANDSTONE**: fine to medium grained, grey, dark grey, with siltstone bands and carbonaceous laminations. *(continued)*	SW - FR	a=0.20 d=0.20	85%	
		15	18.0		**COAL**: black, shiny, cleated.	XW / DW	a=0.10 d=0.00		CS, IR, SO, CN
					NO CORE: 0.25 m				
		14	19.0		**COAL**: black, shiny, cleated.	XW			CS, IR, SO, CN
					SANDSTONE: fine to coarse grained, grey, dark grey, with siltstone bands and carbonaceous laminations.	MW			JT, 80°, PL, RO, CN
		13	20.0		19.10 to 20.28 m: becoming fine to coarse grained	SW - FR	a=0.70 d=0.90	63%	
		12	21.0		20.26 m: 60mm carbonaceous laminations				
		11	22.0		21.15 m: 50mm siltstone band		a=1.10 d=0.90	100%	Drilling Break
		10 / 9	23.0		23.50 m: coal on density plot				

Defects are: PT, 0 - 10°, PL, RO, SN, unless otherwise described

method & support
AS auger screwing
AD auger drilling
CB claw or blade bit
W washbore
NMLC NMLC core (51.9 mm)
NQ wireline core (47.6mm)
HQ wireline core (63.5mm)
PQ wireline core (85.0mm)
SPT standard penetration test
RR rock roller/tricone

water
10/10/12, water level on date shown
water inflow
complete drilling fluid loss
partial drilling fluid loss
25uL water pressure test result (lugeons) for depth interval shown

graphic log / core recovery
core recovered (graphic symbols indicate material)
no core recovered

core run & RQD
barrel withdrawn
RQD = Rock Quality Designation (%)

weathering & alteration*
RS residual soil
XW extremely weathered
HW highly weathered
DW distinctly weathered
MW moderately weathered
SW slightly weathered
FR fresh
*W replaced with A for alteration

strength
VL very low
L low
M medium
H high
VH very high
EH extremely high

defect type
PT parting
JT joint
SZ shear zone
SS shear surface
CO contact
CS crushed seam
SM seam

planarity
PL planar
CU curved
UN undulating
ST stepped
IR Irregular

roughness
SL slickensided
POL polished
SO smooth
RO rough
VR very rough

coating
CN clean
SN stain
VN veneer
CO coating

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Engineering Log - Cored Borehole

Borehole ID. **BH03**
sheet: 5 of 14
project no. **754-NTLGE220504**

client: ***Crescent Newcastle Pty Ltd***
principal:
project: ***Proposed Multi Building Residential Development***
location: ***11 - 13 Mosbri Crescent, Cooks Hill, NSW***

date started: ***17 Sep 2018***
date completed: ***20 Sep 2018***
logged by: ***MJ***
checked by: ***RB***

position: E: 385,685.80; N: 6,355,574.40 (MGA94) | surface elevation: 32.75 m (AHD) | angle from horizontal: 90°
drill model: Comacchio 450P, Track mounted | drilling fluid: non / water | hole diameter : 96 mm | vane id.:

depth (m)	material description (ROCK TYPE: grain characterisics, colour, structure, minor components)	weathering & alteration	samples, field tests & Is(50) (MPa)	core run & RQD	additional observations and defect descriptions (type, inclination, planarity, roughness, coating, thickness, other)
24.1–26.0	**SANDSTONE**: fine to coarse grained, grey, dark grey, with siltstone bands and carbonaceous laminations. *(continued)*	SW - FR	a=0.80 d=1.00	100%	JT, 80°, PL, RO, CN (~25.0)
26.0–27.4	**SILTSTONE**: grey and pale brown, with carbonaceous laminations.	MW - SW	a=0.30 d=0.20	87%	SM, 0°, PL, VR, CO; SM, 0°, PL, RO, SN
27.4–27.9	**COAL**: black, shiny, cleated.	MW			PT, 5°, PL, RO, CN; PT, 5°, PL, RO, CN; PT, 0°, PL, RO, CN
27.9–28.1	**SILTSTONE**: grey to brown.			37%	
28.1–28.26	**NO CORE**: 0.16 m Coal in density plot.				
28.26–28.9	**COAL**: black.	MW	a=0.00 d=0.10		CS, IR, VR, CN
28.9–29.0	**SILTSTONE**: dark grey to black.				
29.0–29.4	**NO CORE**: 0.40 m Coal to siltstone in density plot.				
29.4–30.0	**SILTSTONE**: grey, with carbonaceous laminations.	MW		14%	PT, ST, RO, SN
30.0–30.1	**NO CORE**: 0.10 m Siltstone in density plot.				
30.1–31.7	**SILTSTONE**: grey, with carbonaceous laminations.	MW	a=0.30 d=0.40	52%	PT, ST, RO, SN
31.7–		SW - FR			

Method & support: HQ. Water: 21/09/18 (water level at approx. 29.8 m). RL (m): -8 to -1 markings.

Defects are: PT, 0 - 10°, PL, RO, SN, unless otherwise described

method & support
AS auger screwing
AD auger drilling
CB claw or blade bit
W washbore
NMLC NMLC core (51.9 mm)
NQ wireline core (47.6mm)
HQ wireline core (63.5mm)
PQ wireline core (85.0mm)
SPT standard penetration test
RR rock roller/tricone

water
10/10/12, water level on date shown
water inflow
complete drilling fluid loss
partial drilling fluid loss
25uL water pressure test result (lugeons) for depth interval shown

graphic log / core recovery
core recovered (graphic symbols indicate material)
no core recovered
core run & RQD
barrel withdrawn
RQD = Rock Quality Designation (%)

weathering & alteration*
RS residual soil
XW extremely weathered
HW highly weathered
DW distinctly weathered
MW moderately weathered
SW slightly weathered
FR fresh
*W replaced with A for alteration

strength
VL very low
L low
M medium
H high
VH very high
EH extremely high

defect type
PT parting
JT joint
SZ shear zone
SS shear surface
CO contact
CS crushed seam
SM seam

planarity
PL planar
CU curved
UN undulating
ST stepped
IR Irregular

roughness
SL slickensided
POL polished
SO smooth
RO rough
VR very rough

coating
CN clean
SN stain
VN veneer
CO coating

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Engineering Log - Cored Borehole

Borehole ID.	**BH03**
sheet:	6 of 14
project no.	**754-NTLGE220504**
client:	**Crescent Newcastle Pty Ltd**
date started:	**17 Sep 2018**
principal:	
date completed:	**20 Sep 2018**
project:	**Proposed Multi Building Residential Development**
logged by:	**MJ**
location:	**11 - 13 Mosbri Crescent, Cooks Hill, NSW**
checked by:	**RB**

position: E: 385,685.80; N: 6,355,574.40 (MGA94) surface elevation: 32.75 m (AHD) angle from horizontal: 90°
drill model: Comacchio 450P, Track mounted drilling fluid: non / water hole diameter : 96 mm vane id.:

drilling information | **material substance** | **rock mass defects**

method & support	RL (m)	depth (m)	material description (ROCK TYPE: grain characterisics, colour, structure, minor components)	weathering & alteration	samples, field tests & Is(50) (MPa) (a = axial; d = diametral)	core run & RQD	additional observations and defect descriptions (type, inclination, planarity, roughness, coating, thickness, other)
HQ			**SANDSTONE**: fine to medium grained, grey, with siltstone bands and carbonaceous laminations. *(continued)* 32.10 m: 100mm siltstone band with carbonaceous laminations	SW - FR		52%	
	0	33.0			a=2.70 d=1.70		PT, UN, RO, SN
	-1	34.0	33.80 m: 300mm siltstone band with carbonaceous laminations				JT, 40°, PL, RO, SN
	-2	35.0				96%	
	-3	36.0			a=8.50 d=7.80		JT, 40°, PL, RO, SN
	-4	37.0					JT, 40°, PL, RO, SN PT, 0°, IR, RO, SN
	-5	38.0			a=4.10 d=2.10	95%	
	-6	39.0	38.35 m: 150mm carbonaceous laminations				JT, 70°, PL, RO, CN
	-7		39.15 m: becoming dark grey sandstone, thinly bedded carbonaceous lamination		a=1.30 d=1.20	57%	PT, 10°, UN, RO, SN PT, 10°, PL, RO, SN

General: Defects are: PT, 0 - 10°, PL, RO, SN, unless otherwise described

method & support
AS auger screwing
AD auger drilling
CB claw or blade bit
W washbore
NMLC NMLC core (51.9 mm)
NQ wireline core (47.6mm)
HQ wireline core (63.5mm)
PQ wireline core (85.0mm)
SPT standard penetration test
RR rock roller/tricone

water
10/10/12, water level on date shown
water inflow
complete drilling fluid loss
partial drilling fluid loss
25uL water pressure test result (lugeons) for depth interval shown

graphic log / core recovery
core recovered (graphic symbols indicate material)
no core recovered

core run & RQD
barrel withdrawn
RQD = Rock Quality Designation (%)

weathering & alteration*
RS residual soil
XW extremely weathered
HW highly weathered
DW distinctly weathered
MW moderately weathered
SW slightly weathered
FR fresh
*W replaced with A for alteration

strength
VL very low
L low
M medium
H high
VH very high
EH extremely high

defect type
PT parting
JT joint
SZ shear zone
SS shear surface
CO contact
CS crushed seam
SM seam

planarity
PL planar
CU curved
UN undulating
ST stepped
IR Irregular

roughness
SL slickensided
POL polished
SO smooth
RO rough
VR very rough

coating
CN clean
SN stain
VN veneer
CO coating

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Engineering Log - Cored Borehole

Borehole ID.	**BH03**
sheet:	7 of 14
project no.	**754-NTLGE220504**
date started:	**17 Sep 2018**
date completed:	**20 Sep 2018**
logged by:	**MJ**
checked by:	**RB**

client: ***Crescent Newcastle Pty Ltd***

principal:

project: ***Proposed Multi Building Residential Development***

location: ***11 - 13 Mosbri Crescent, Cooks Hill, NSW***

position: E: 385,685.80; N: 6,355,574.40 (MGA94) surface elevation: 32.75 m (AHD) angle from horizontal: 90°

drill model: Comacchio 450P, Track mounted drilling fluid: non / water hole diameter : 96 mm vane id.:

method & support	water	RL (m)	depth (m)	material description (ROCK TYPE: grain characteristics, colour, structure, minor components)	weathering & alteration	samples, field tests & Is(50) (MPa)	core run & RQD	additional observations and defect descriptions (particular)
HQ				**SANDSTONE**: fine to medium grained, grey, with siltstone bands and carbonaceous laminations. *(continued)* 40.20 m: 100 mm siltstone band	SW - FR			PT, 0°, PL, RO, CN; PT, 0°, PL, RO, CN; PT, 0°, PL, RO; PT, 0°, ST, RO, SN
		-8	41.0				57%	JT, 70°, PL, RO, CN; CS, IR, RO; PT, 5°, PL, RO, SN; CS, PL, RO, CN
	100% loss	-9		**NO CORE**: 0.10 m Tool drop.		a=0.60 d=0.10		
				CAVE IN: SILTSTONE: grey.	MW			CS, IR, RO, CN
			42.0	**NO CORE**: 0.33 m **TOOL DROP**.				
				NO CORE: 0.35 m **CAVE IN**: Siltstone in density plot.				
		-10	43.0	**CAVE IN: SILTSTONE AND COAL**: dark grey and black.	XW		15%	CS, IR, RO, CO
					MW			
		-11	44.0	**SANDSTONE**: fine to medium grained, grey, dark grey, with siltstone bands and carbonaceous laminations.	SW - FR	a=2.00 d=0.90	89%	PT, 5°, PL, RO, CN
		-12	45.0					
				NO CORE: 0.15 m Sandstone in density plot.				
		-13	46.0	**SANDSTONE**: fine to medium grained, grey, dark grey, with siltstone bands and carbonaceous laminations.	SW - FR	a=3.30 d=2.90		
		-14	47.0	46.51 m: 20mm carbonaceous laminations; 46.72 m: 200mm carbonaceous laminations		a=3.50 d=1.90	92%	
		-15						

General: Defects are: PT, 0 - 10°, PL, RO, SN, unless otherwise described

method & support
AS auger screwing; AD auger drilling; CB claw or blade bit; W washbore; NMLC NMLC core (51.9 mm); NQ wireline core (47.6mm); HQ wireline core (63.5mm); PQ wireline core (85.0mm); SPT standard penetration test; RR rock roller/tricone

water
10/10/12, water level on date shown; water inflow; complete drilling fluid loss; partial drilling fluid loss; 25uL water pressure test result (lugeons) for depth interval shown

graphic log / core recovery
core recovered (graphic symbols indicate material); no core recovered

core run & RQD
barrel withdrawn; RQD = Rock Quality Designation (%)

weathering & alteration*
RS residual soil; XW extremely weathered; HW highly weathered; DW distinctly weathered; MW moderately weathered; SW slightly weathered; FR fresh
*W replaced with A for alteration

strength
VL very low; L low; M medium; H high; VH very high; EH extremely high

defect type
PT parting; JT joint; SZ shear zone; SS shear surface; CO contact; CS crushed seam; SM seam

planarity
PL planar; CU curved; UN undulating; ST stepped; IR Irregular

roughness
SL slickensided; POL polished; SO smooth; RO rough; VR very rough

coating
CN clean; SN stain; VN veneer; CO coating

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Engineering Log - Cored Borehole

client:	*Crescent Newcastle Pty Ltd*	Borehole ID.	***BH03***
principal:		sheet:	8 of 14
project:	*Proposed Multi Building Residential Development*	project no.	***754-NTLGE220504***
location:	*11 - 13 Mosbri Crescent, Cooks Hill, NSW*	date started:	***17 Sep 2018***
		date completed:	***20 Sep 2018***
		logged by:	***MJ***
		checked by:	***RB***

position: E: 385,685.80; N: 6,355,574.40 (MGA94) surface elevation: 32.75 m (AHD) angle from horizontal: 90°
drill model: Comacchio 450P, Track mounted drilling fluid: non / water hole diameter : 96 mm vane id.:

method & support	RL (m)	depth (m)	material description (ROCK TYPE: grain characterisics, colour, structure, minor components)	weathering & alteration	samples, field tests & Is(50) (MPa)	core run & RQD	additional observations and defect descriptions (particular)
HQ			**SANDSTONE**: fine to medium grained, grey, dark grey, with siltstone bands and carbonaceous laminations. *(continued)*	SW - FR			JT, 90°, CU, RO, SN
	-16	49.0			a=2.90 d=0.20		
	-17		49.50 m: 100mm carbonaceous laminations			98%	
		50.0	50.10 m: 20mm carbonaceous laminations				
	-18				a=0.60 d=0.40		
		51.0	51.00 m: becoming pale grey, grey-dark grey laminations 51.25 m: becoming fine grained				
	-19				a=0.60 d=0.20		
		52.0	52.25 m: 200 mm tuff band				
	-20		**COAL**: black, dull, cleated.	DW		95%	
		53.0	**SANDSTONE**: fine to medium grained, grey, dark grey, with siltstone bands and carbonaceous laminations.	SW - FR	a=0.70 d=0.30		
	-21						JT, 45°, PL, RO, CN
		54.0					
	-22						JT, 80°, PL, RO, SN
		55.0	55.00 m: 100 mm siltstone band, grey		a=1.40 d=0.40	83%	
	-23						

general: Defects are: PT, 0 - 10°, PL, RO, SN, unless otherwise described

method & support
AS auger screwing
AD auger drilling
CB claw or blade bit
W washbore
NMLC NMLC core (51.9 mm)
NQ wireline core (47.6mm)
HQ wireline core (63.5mm)
PQ wireline core (85.0mm)
SPT standard penetration test
RR rock roller/tricone

water
10/10/12, water level on date shown
water inflow
complete drilling fluid loss
partial drilling fluid loss
25uL water pressure test result (lugeons) for depth interval shown

graphic log / core recovery
core recovered (graphic symbols indicate material)
no core recovered

core run & RQD
barrel withdrawn
RQD = Rock Quality Designation (%)

weathering & alteration*
RS residual soil
XW extremely weathered
HW highly weathered
DW distinctly weathered
MW moderately weathered
SW slightly weathered
FR fresh
*W replaced with A for alteration

strength
VL very low
L low
M medium
H high
VH very high
EH extremely high

defect type
PT parting
JT joint
SZ shear zone
SS shear surface
CO contact
CS crushed seam
SM seam

planarity
PL planar
CU curved
UN undulating
ST stepped
IR Irregular

roughness
SL slickensided
POL polished
SO smooth
RO rough
VR very rough

coating
CN clean
SN stain
VN veneer
CO coating

coffey
A TETRA TECH COMPANY

Engineering Log - Cored Borehole

Borehole ID.	**BH03**
sheet:	9 of 14
project no.	**754-NTLGE220504**
date started:	**17 Sep 2018**
date completed:	**20 Sep 2018**
logged by:	**MJ**
checked by:	**RB**

client: ***Crescent Newcastle Pty Ltd***

principal:

project: ***Proposed Multi Building Residential Development***

location: ***11 - 13 Mosbri Crescent, Cooks Hill, NSW***

position: E: 385,685.80; N: 6,355,574.40 (MGA94) surface elevation: 32.75 m (AHD) angle from horizontal: 90°

drill model: Comacchio 450P, Track mounted drilling fluid: non / water hole diameter : 96 mm vane id.:

method & support	water	RL (m)	depth (m)	graphic log	material description (ROCK TYPE: grain characterisics, colour, structure, minor components)	weathering & alteration	samples, field tests & Is(50) (MPa)	core run & RQD	additional observations and defect descriptions (type, inclination, planarity, roughness, coating, thickness, other)
HQ					**SANDSTONE**: fine to medium grained, grey, dark grey, with siltstone bands and carbonaceous laminations. *(continued)*	SW - FR			CS, IR, SO, CN
					56.10 m: 200mm coal, black, dull band			83%	JT, 80°, PL, RO, SN
		-24	57.0				a=2.40 d=1.70		
		-25	58.0						
		-26			58.52 m: 1.48m siltstone, dark grey band			100%	
			59.0				a=2.80 d=1.50		
		-27	60.0						
		-28			60.60 m: 50 mm coal band				CS, 0°, PL, RO, CN
									CS, 0°, PL, CN
			61.0					90%	
		-29	62.0		62.00 m: 500mm carbonaceous laminations		a=2.20 d=0.10		
									PT, 40°, PL, RO, SN
		-30	63.0		63.10 m: 1.55m siltstone, dark grey band		a=2.20 d=0.50	100%	
		-31							

general: Defects are: PT, 0 - 10°, PL, RO, SN, unless otherwise described

method & support
AS auger screwing
AD auger drilling
CB claw or blade bit
W washbore
NMLC NMLC core (51.9 mm)
NQ wireline core (47.6mm)
HQ wireline core (63.5mm)
PQ wireline core (85.0mm)
SPT standard penetration test
RR rock roller/tricone

water
10/10/12, water level on date shown
water inflow
complete drilling fluid loss
partial drilling fluid loss
25uL water pressure test result (lugeons) for depth interval shown

graphic log / core recovery
core recovered (graphic symbols indicate material)
no core recovered

core run & RQD
barrel withdrawn
RQD = Rock Quality Designation (%)

weathering & alteration*
RS residual soil
XW extremely weathered
HW highly weathered
DW distinctly weathered
MW moderately weathered
SW slightly weathered
FR fresh
*W replaced with A for alteration

strength
VL very low
L low
M medium
H high
VH very high
EH extremely high

defect type
PT parting
JT joint
SZ shear zone
SS shear surface
CO contact
CS crushed seam
SM seam

planarity
PL planar
CU curved
UN undulating
ST stepped
IR Irregular

roughness
SL slickensided
POL polished
SO smooth
RO rough
VR very rough

coating
CN clean
SN stain
VN veneer
CO coating

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Engineering Log - Cored Borehole

Borehole ID.	**BH03**
sheet:	10 of 14
project no.	**754-NTLGE220504**
date started:	**17 Sep 2018**
date completed:	**20 Sep 2018**
logged by:	**MJ**
checked by:	**RB**

client: **Crescent Newcastle Pty Ltd**

principal:

project: **Proposed Multi Building Residential Development**

location: **11 - 13 Mosbri Crescent, Cooks Hill, NSW**

position: E: 385,685.80; N: 6,355,574.40 (MGA94) | surface elevation: 32.75 m (AHD) | angle from horizontal: 90°

drill model: Comacchio 450P, Track mounted | drilling fluid: non / water | hole diameter : 96 mm | vane id.:

method & support	RL (m)	depth (m)	material description	weathering & alteration	samples, field tests & Is(50) (MPa)	core run & RQD	additional observations and defect descriptions (particular)
HQ			**SANDSTONE**: fine to medium grained, grey, dark grey, with siltstone bands and carbonaceous laminations. *(continued)*	SW - FR			
	-32				a=1.90 d=0.50	100%	
		65.0					
	-33	66.0					
	-34		66.38 m: 20mm carbonaceous laminations		a=2.50 d=0.40		
		67.0					
	-35				a=1.40 d=0.40	100%	
		68.0					
	-36		68.50 m: becoming fine to coarse grained				
		69.0	69.00 to 69.20 m: 200 mm siltstone band		a=0.80 d=0.20		
	-37	70.0					PT, 0°, PL, RO, CN
	-38					97%	PT, 5°, ST, RO, CN
		71.0			a=1.00 d=0.50		
	-39		71.55 to 71.65 m: 100 mm siltstone band				JT, 80°, CU, VR, CN
							PT, 0°, PL, SO, CN

general: Defects are: PT, 0 - 10°, PL, RO, SN, unless otherwise described

method & support
AS auger screwing
AD auger drilling
CB claw or blade bit
W washbore
NMLC NMLC core (51.9 mm)
NQ wireline core (47.6mm)
HQ wireline core (63.5mm)
PQ wireline core (85.0mm)
SPT standard penetration test
RR rock roller/tricone

water
10/10/12, water level on date shown
water inflow
complete drilling fluid loss
partial drilling fluid loss
25uL water pressure test result (lugeons) for depth interval shown

graphic log / core recovery
core recovered (graphic symbols indicate material)
no core recovered

core run & RQD
barrel withdrawn
RQD = Rock Quality Designation (%)

weathering & alteration*
RS residual soil
XW extremely weathered
HW highly weathered
DW distinctly weathered
MW moderately weathered
SW slightly weathered
FR fresh
*W replaced with A for alteration

strength
VL very low
L low
M medium
H high
VH very high
EH extremely high

defect type
PT parting
JT joint
SZ shear zone
SS shear surface
CO contact
CS crushed seam
SM seam

planarity
PL planar
CU curved
UN undulating
ST stepped
IR Irregular

roughness
SL slickensided
POL polished
SO smooth
RO rough
VR very rough

coating
CN clean
SN stain
VN veneer
CO coating

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Engineering Log - Cored Borehole

Borehole ID.	**BH03**
sheet:	11 of 14
project no.	**754-NTLGE220504**
client:	**Crescent Newcastle Pty Ltd**
date started:	**17 Sep 2018**
principal:	
date completed:	**20 Sep 2018**
project:	**Proposed Multi Building Residential Development**
logged by:	**MJ**
location:	**11 - 13 Mosbri Crescent, Cooks Hill, NSW**
checked by:	**RB**

position: E: 385,685.80; N: 6,355,574.40 (MGA94) surface elevation: 32.75 m (AHD) angle from horizontal: 90°
drill model: Comacchio 450P, Track mounted drilling fluid: non / water hole diameter : 96 mm vane id.:

method & support	water	RL (m)	depth (m)	graphic log	material description (ROCK TYPE: grain characterisics, colour, structure, minor components)	weathering & alteration	estimated strength & Is50	samples, field tests & Is(50) (MPa)	core run & RQD	defect spacing (mm)	additional observations and defect descriptions (particular)	general
HQ					**SANDSTONE**: fine to medium grained, grey, dark grey, with siltstone bands and carbonaceous laminations. *(continued)*	SW - FR					JT, 80°, PL, RO, SN	Defects are: PT, 0 - 10°, PL, RO, SN, unless otherwise described
								a=1.70 d=0.40				
		-40										
			73.0		73.03 m: 100mm carbonaceous laminations							
									100%			
		-41										
			74.0		73.90 m: 150 mm siltstone band							
					74.25 m: becoming medium to coarse grained							
								a=3.20 d=2.30				
		-42										
			75.0									
											JT, 70°, CU, RO, CN	
		-43						a=3.20 d=3.00				
			76.0									
					76.12 m: 60mm siltstone, dark grey band							
					76.40 m: 100 mm tuff band							
		-44							91%			
			77.0									
					77.10 m: 50mm carbonaceous laminations			a=3.70 d=1.80				
											JT, 55°, PL, RO, CN	
		-45										
			78.0		77.85 m: 300 mm siltstone band							
		-46			78.65 m: 310mm carbonaceous laminations							
			79.0					a=4.60 d=1.10				
					78.96 m: 140mm siltstone, dark grey band				80%			
		-47										

method & support
AS auger screwing
AD auger drilling
CB claw or blade bit
W washbore
NMLC NMLC core (51.9 mm)
NQ wireline core (47.6mm)
HQ wireline core (63.5mm)
PQ wireline core (85.0mm)
SPT standard penetration test
RR rock roller/tricone

water
10/10/12, water level on date shown
water inflow
complete drilling fluid loss
partial drilling fluid loss
25uL water pressure test result (lugeons) for depth interval shown

graphic log / core recovery
core recovered (graphic symbols indicate material)
no core recovered
core run & RQD
barrel withdrawn
RQD = Rock Quality Designation (%)

weathering & alteration*
RS residual soil
XW extremely weathered
HW highly weathered
DW distinctly weathered
MW moderately weathered
SW slightly weathered
FR fresh
*W replaced with A for alteration

strength
VL very low
L low
M medium
H high
VH very high
EH extremely high

defect type
PT parting
JT joint
SZ shear zone
SS shear surface
CO contact
CS crushed seam
SM seam

planarity
PL planar
CU curved
UN undulating
ST stepped
IR Irregular

roughness
SL slickensided
POL polished
SO smooth
RO rough
VR very rough

coating
CN clean
SN stain
VN veneer
CO coating

Engineering Log - Cored Borehole

Borehole ID.	**BH03**
sheet:	12 of 14
project no.	**754-NTLGE220504**
client:	**Crescent Newcastle Pty Ltd**
date started:	**17 Sep 2018**
principal:	
date completed:	**20 Sep 2018**
project:	**Proposed Multi Building Residential Development**
logged by:	**MJ**
location:	**11 - 13 Mosbri Crescent, Cooks Hill, NSW**
checked by:	**RB**

position: E: 385,685.80; N: 6,355,574.40 (MGA94) surface elevation: 32.75 m (AHD) angle from horizontal: 90°
drill model: Comacchio 450P, Track mounted drilling fluid: non / water hole diameter : 96 mm vane id.:

method & support	RL (m)	depth (m)	material description	weathering & alteration	samples, field tests & Is(50) (MPa)	core run & RQD	defect descriptions
HQ			**SANDSTONE**: fine to medium grained, grey, dark grey, with siltstone bands and carbonaceous laminations. *(continued)*	SW - FR			JT, 90°, UN, RO, CN
					a=3.50 d=3.10	80%	
			80.53 m: 100 mm siltstone band				
	-48	81.0					
			81.20 m: 400mm carbonaceous laminations				
	-49	82.0			a=4.00 d=3.00		
			82.30 m: 600mm carbonaceous laminations			63%	
	-50	83.0	82.90 m: 100 mm siltstone band				
							CS, 0 - 25°, IR, RO, CN
	-51		83.60 m: 200mm carbonaceous laminations				CS, IR, RO, CN
		84.0					JT, 80°, PL, RO, SN
					a=0.70 d=0.10		
	-52		84.60 m: 230mm carbonaceous laminations				JT, 60°, UN, RO, SN
		85.0	85.00 m: 30 mm siltstone band				
							JT, 70°, PL, RO, CN
	-53		85.60 m: 100 mm siltstone band			84%	PT, 10°, PL, RO, SN
			85.78 m: 40mm carbonaceous laminations		a=1.30 d=0.00		JT, 80°, PL, RO, SN
		86.0					
			86.27 m: 30mm carbonaceous laminations				JT, 60°, PL, RO, CN
			86.30 m: 200mm siltstone band				JT, 60°, PL, RO, CN
			86.56 m: 20mm siltstone band				
	-54		86.70 m: 100mm carbonaceous laminations				JT, 70°, PL, RO, SN
		87.0	86.80 m: 30mm siltstone band				
			86.90 m: 100mm siltstone band				
			87.00 m: 30mm carbonaceous laminations				
	-55				a=3.90 d=3.90	100%	

Defects are: PT, 0 - 10°, PL, RO, SN, unless otherwise described

method & support
AS auger screwing
AD auger drilling
CB claw or blade bit
W washbore
NMLC NMLC core (51.9 mm)
NQ wireline core (47.6mm)
HQ wireline core (63.5mm)
PQ wireline core (85.0mm)
SPT standard penetration test
RR rock roller/tricone

water
10/10/12, water level on date shown
water inflow
complete drilling fluid loss
partial drilling fluid loss
25uL water pressure test result (lugeons) for depth interval shown

graphic log / core recovery
core recovered (graphic symbols indicate material)
no core recovered

core run & RQD
barrel withdrawn
RQD = Rock Quality Designation (%)

weathering & alteration*
RS residual soil
XW extremely weathered
HW highly weathered
DW distinctly weathered
MW moderately weathered
SW slightly weathered
FR fresh
*W replaced with A for alteration

strength
VL very low
L low
M medium
H high
VH very high
EH extremely high

defect type
PT parting
JT joint
SZ shear zone
SS shear surface
CO contact
CS crushed seam
SM seam

planarity
PL planar
CU curved
UN undulating
ST stepped
IR Irregular

roughness
SL slickensided
POL polished
SO smooth
RO rough
VR very rough

coating
CN clean
SN stain
VN veneer
CO coating

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Engineering Log - Cored Borehole

Borehole ID.	**BH03**		
sheet:	13 of 14		
project no.	**754-NTLGE220504**		
client:	**Crescent Newcastle Pty Ltd**	date started:	**17 Sep 2018**
principal:		date completed:	**20 Sep 2018**
project:	**Proposed Multi Building Residential Development**	logged by:	**MJ**
location:	**11 - 13 Mosbri Crescent, Cooks Hill, NSW**	checked by:	**RB**

position: E: 385,685.80; N: 6,355,574.40 (MGA94) surface elevation: 32.75 m (AHD) angle from horizontal: 90°
drill model: Comacchio 450P, Track mounted drilling fluid: non / water hole diameter : 96 mm vane id.:

method & support	RL (m)	depth (m)	material description (ROCK TYPE: grain characterisics, colour, structure, minor components)	weathering & alteration	samples, field tests & Is(50) (MPa)	core run & RQD	additional observations and defect descriptions (type, inclination, planarity, roughness, coating, thickness, other)
HQ	-56 to -59.6	88.0–92.6	**SANDSTONE**: fine to medium grained, grey, dark grey, with siltstone bands and carbonaceous laminations. *(continued)* 88.18 m: 100mm siltstone band 88.42 m: 100mm siltstone band 88.90 m: 200mm siltstone band 89.30 m: 180mm siltstone band 89.60 m: 130mm carbonaceous laminations 90.16 m: 200mm siltstone band 90.45 m: 130mm carbonaceous laminations 91.60 m: 50mm coal band 91.70 m: 300mm siltstone, dark grey band	SW - FR	a=4.50 d=2.50 (approx. 89.2 m) a=0.90 d=0.10 (approx. 91.9 m)	100% 68%	JT, 80°, PL, RO, SN PT, 15°, PL, RO, SN JT, 50°, CU, RO, SN SM, 0°, PL, RO, SN JT, 50°, PL, RO, SN PT, 5°, PL, RO, SN JT, 50°, PL, RO, SN
	-60	92.6–93.6	**COAL**: black, shiny, cleated.	DW		0%	CS, IR, RO, CO
	-61	93.6–94.1	**NO CORE:** 0.56 m Coal in density plot.			0%	
	-62 to -63	94.1–95.8	**COAL**: black, shiny, cleated.	DW		30%	JT, 50°, PL, RO, CN JT, 50°, PL, RO, CN JT, 80°, PL, RO, CN JT, 80°, PL, RO, CN

General: Defects are: PT, 0 - 10°, PL, RO, SN, unless otherwise described

method & support
AS auger screwing
AD auger drilling
CB claw or blade bit
W washbore
NMLC NMLC core (51.9 mm)
NQ wireline core (47.6mm)
HQ wireline core (63.5mm)
PQ wireline core (85.0mm)
SPT standard penetration test
RR rock roller/tricone

water
10/10/12, water level on date shown
water inflow
complete drilling fluid loss
partial drilling fluid loss
25uL water pressure test result (lugeons) for depth interval shown

graphic log / core recovery
core recovered (graphic symbols indicate material)
no core recovered

core run & RQD
barrel withdrawn
RQD = Rock Quality Designation (%)

weathering & alteration*
RS residual soil
XW extremely weathered
HW highly weathered
DW distinctly weathered
MW moderately weathered
SW slightly weathered
FR fresh
*W replaced with A for alteration

strength
VL very low
L low
M medium
H high
VH very high
EH extremely high

defect type
PT parting
JT joint
SZ shear zone
SS shear surface
CO contact
CS crushed seam
SM seam

planarity
PL planar
CU curved
UN undulating
ST stepped
IR Irregular

roughness
SL slickensided
POL polished
SO smooth
RO rough
VR very rough

coating
CN clean
SN stain
VN veneer
CO coating

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Engineering Log - Cored Borehole

Borehole ID.	**BH03**
sheet:	14 of 14
project no.	**754-NTLGE220504**
date started:	**17 Sep 2018**
date completed:	**20 Sep 2018**
logged by:	**MJ**
checked by:	**RB**

client: ***Crescent Newcastle Pty Ltd***

principal:

project: ***Proposed Multi Building Residential Development***

location: ***11 - 13 Mosbri Crescent, Cooks Hill, NSW***

position: E: 385,685.80; N: 6,355,574.40 (MGA94) | surface elevation: 32.75 m (AHD) | angle from horizontal: 90°

drill model: Comacchio 450P, Track mounted | drilling fluid: non / water | hole diameter : 96 mm | vane id.:

method & support	water	RL (m)	depth (m)	material description (ROCK TYPE: grain characteristics, colour, structure, minor components)	weathering & alteration	estimated strength & Is50	samples, field tests & Is(50) (MPa)	core run & RQD	additional observations and defect descriptions (type, inclination, planarity, roughness, coating, thickness, other)
HQ				**COAL**: black, shiny, cleated. *(continued)*	DW	VL–L			CS, IR, SO, CO
				96.34 m: 130mm siltstone band					
		-64							SZ, IR, RO, CN
			97.0	96.90 m: 220mm siltstone band				41%	
									JT, 80°, PL, RO, CN
		-65							JT, 70°, IR, RO, CN
									CS, IR, RO, CN
			98.0	98.00 m: 20mm siltstone band					CS, IR, RO, CN
				98.25 m: 50mm sandstone band					
				98.50 m: 120mm sandstone band					
		-66		**SANDSTONE**: medium to coarse grained, pale grey, with siltstone and conglomerate bands.	FR	H	a=2.20 d=1.70		
			99.0						
		-67							
			100.0					100%	
		-68							
			101.0	100.85 m: 50mm siltstone band			a=2.60 d=4.10		
		-69							
			102.0	101.78 m: 50mm conglomerate band					
				Borehole BH03 terminated at 102.14 m Target depth			a=3.10 d=2.20		
		-70							
			103.0						
		-71							

Defects are: PT, 0 - 10°, PL, RO, SN, unless otherwise described

method & support
AS auger screwing
AD auger drilling
CB claw or blade bit
W washbore
NMLC NMLC core (51.9 mm)
NQ wireline core (47.6mm)
HQ wireline core (63.5mm)
PQ wireline core (85.0mm)
SPT standard penetration test
RR rock roller/tricone

water
10/10/12, water level on date shown
water inflow
complete drilling fluid loss
partial drilling fluid loss
25uL — water pressure test result (lugeons) for depth interval shown

graphic log / core recovery
core recovered (graphic symbols indicate material)
no core recovered

core run & RQD
barrel withdrawn
RQD = Rock Quality Designation (%)

weathering & alteration*
RS residual soil
XW extremely weathered
HW highly weathered
DW distinctly weathered
MW moderately weathered
SW slightly weathered
FR fresh
*W replaced with A for alteration

strength
VL very low
L low
M medium
H high
VH very high
EH extremely high

defect type
PT parting
JT joint
SZ shear zone
SS shear surface
CO contact
CS crushed seam
SM seam

planarity
PL planar
CU curved
UN undulating
ST stepped
IR Irregular

roughness
SL slickensided
POL polished
SO smooth
RO rough
VR very rough

coating
CN clean
SN stain
VN veneer
CO coating

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Engineering Log - Borehole

Borehole ID.	**BH04**
sheet:	1 of 13
project no.	**754-NTLGE220504**
date started:	**12 Sep 2018**
date completed:	**14 Sep 2018**
logged by:	**MJ**
checked by:	**RB**

client: ***Crescent Newcastle Pty Ltd***

principal:

project: ***Proposed Multi Building Residential Development***

location: ***11 - 13 Mosbri Crescent, Cooks Hill, NSW***

position: E: 385,684.5; N: 6,355,567.6 (MGA94) | surface elevation: 32.8 m (AHD) | angle from horizontal: 90°

drill model: Comacchio 450P, Track mounted | drilling fluid: non / water | hole diameter : 96 mm

drilling information | **material substance**

method & support	samples & field tests	RL (m)	depth (m)	classification symbol	material description (SOIL TYPE: plasticity or particle characteristic, colour, secondary and minor components)	moisture condition	consistency / relative density	structure and additional observations
AD / N	E			GW	**FILL: BITUMEN PAVEMENT**: black, 20mm.			**FILL- WEARING COURSE**
				SW	**FILL: Sandy GRAVEL**: fine to coarse grained, sub-angular to angular, grey, with fine grained sand.	M <Wp	F - St	**FILL- PAVEMENT**
	E	32		CL	**FILL: CLAYEY SAND**: fine to coarse grained, brown and red.			**FILL - UNCONTROLLED**
			1.0		**FILL: Sandy CLAY**: low plasticity, brown, dark brown, pale grey, fine to coarse grained sand, with fine grained grained angular to sub-angular gravel.			
	E; SPT 5, 5, 5 N=10	31		CL	**FILL: Sandy CLAY**: low plasticity, dark brown, mottled orange, fine grained sand, with fine grained sub-angular to sub-rounded gravel and glass pieces.		St - H	
	E		2.0					
	SPT 3, 4, 5 N=9	30	3.0	CL-CI	**Sandy CLAY**: low to medium plasticity, dark brown and dark grey, fine to coarse grained sand.	~Wp		**RESIDUAL SOIL**
				CL-CI	**CLAY**: low to medium plasticity, mottled orange and brown, with fine rounded to sub-rounded gravel.			
	B	29	4.0	CL-CI	**Sandy CLAY**: low to medium plasticity, dark grey, with medium to course grained sand, with fine angular to sub-angular gravel.	>Wp		
				CL-CI	**Gravelly CLAY**: fine to medium grained, low to medium plasticity, pale grey and grey, with rounded to sub-rounded gravel, trace of fine to coarse grained sand.			**EXTREMELY WEATHERED MATERIAL**
RR	SPT 7, 25/30mm N=R	28	5.0		**SANDSTONE**: fine grained, pale grey and orange.			**HIGHLY WEATHERED BECOMING MODERATELY WEATHERED MATERIAL**
					SANDSTONE.			
		27	6.0					
		26	7.0					
		25						

method
AD auger drilling*
AS auger screwing*
HA hand auger
W washbore
RR rock roller/tricone
* bit shown by suffix
e.g. AD/T
B blank bit
T TC bit
V V bit

support
M mud N nil
C casing

penetration
1 2 3 — no resistance ranging to refusal

water
10-Oct-12 water level on date shown
water inflow
water outflow

samples & field tests
B bulk disturbed sample
D disturbed sample
E environmental sample
SS split spoon sample
U## undisturbed sample ##mm diameter
HP hand penetrometer (kPa)
N standard penetration test (SPT)
N* SPT - sample recovered
Nc SPT with solid cone
VS vane shear; peak/remouded (kPa)
R refusal
HB hammer bouncing

classification symbol & soil description
based on Unified Classification System

moisture
D dry
M moist
W wet
Wp plastic limit
Wl liquid limit

consistency / relative density
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

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Engineering Log - Borehole

Borehole ID.	**BH04**
sheet:	2 of 13
project no.	**754-NTLGE220504**
date started:	**12 Sep 2018**
date completed:	**14 Sep 2018**
logged by:	**MJ**
checked by:	**RB**

client: ***Crescent Newcastle Pty Ltd***

principal:

project: ***Proposed Multi Building Residential Development***

location: ***11 - 13 Mosbri Crescent, Cooks Hill, NSW***

position: E: 385,684.5; N: 6,355,567.6 (MGA94) | surface elevation: 32.8 m (AHD) | angle from horizontal: 90°

drill model: Comacchio 450P, Track mounted | drilling fluid: non / water | hole diameter : 96 mm

drilling information						material substance						
method & support	penetration 1 2 3	water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description **SOIL TYPE**: plasticity or particle characteristic, colour, secondary and minor components	moisture condition	consistency / relative density	hand penetrometer (kPa) 100 200 300 400	structure and additional observations
RR / N				24 23 22 21 20 19 18 17	9.0 10.0 11.0 12.0 13.0 14.0 15.0			**SANDSTONE**. *(continued)*				**MODERATELY WEATHERED TO SLIGHTLY WEATHERED**

method
AD auger drilling*
AS auger screwing*
HA hand auger
W washbore
RR rock roller/tricone

* bit shown by suffix
e.g. AD/T
B blank bit
T TC bit
V V bit

support
M mud N nil
C casing

penetration
1 2 3 no resistance ranging to refusal

water
10-Oct-12 water level on date shown
water inflow
water outflow

samples & field tests
B bulk disturbed sample
D disturbed sample
E environmental sample
SS split spoon sample
U## undisturbed sample ##mm diameter
HP hand penetrometer (kPa)
N standard penetration test (SPT)
N* SPT - sample recovered
Nc SPT with solid cone
VS vane shear; peak/remouded (kPa)
R refusal
HB hammer bouncing

classification symbol & soil description
based on Unified Classification System

moisture
D dry
M moist
W wet
Wp plastic limit
Wl liquid limit

consistency / relative density
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

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Engineering Log - Borehole

Borehole ID.	**BH04**
sheet:	3 of 13
project no.	**754-NTLGE220504**
date started:	**12 Sep 2018**
date completed:	**14 Sep 2018**
logged by:	**MJ**
checked by:	**RB**

client: **Crescent Newcastle Pty Ltd**

principal:

project: **Proposed Multi Building Residential Development**

location: **11 - 13 Mosbri Crescent, Cooks Hill, NSW**

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drilling information / **material substance**

method & support	penetration 1 2 3	water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description (SOIL TYPE: plasticity or particle characteristic, colour, secondary and minor components)	moisture condition	consistency / relative density	hand penetrometer (kPa) 100 200 300 400	structure and additional observations
RR / N								**SANDSTONE**. *(continued)*				**MODERATELY WEATHERED TO SLIGHTLY WEATHERED**
				16	17.0			**COAL**: black.				
				15	18.0			**SILTSTONE**.				
				14	19.0			**SANDSTONE**.				**FRESH**
				13	20.0							
				12	21.0							
				11	22.0							
				10	23.0							
				9								

method
AD auger drilling*
AS auger screwing*
HA hand auger
W washbore
RR rock roller/tricone
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e.g. AD/T
B blank bit
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V V bit

support
M mud
C casing
N nil

penetration
1 2 3 — no resistance ranging to refusal

water
10-Oct-12 water level on date shown
water inflow
water outflow

samples & field tests
B bulk disturbed sample
D disturbed sample
E environmental sample
SS split spoon sample
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R refusal
HB hammer bouncing

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H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

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Engineering Log - Borehole

Borehole ID.	**BH04**
sheet:	4 of 13
project no.	**754-NTLGE220504**
date started:	**12 Sep 2018**
date completed:	**14 Sep 2018**
logged by:	**MJ**
checked by:	**RB**

client: ***Crescent Newcastle Pty Ltd***

principal:

project: ***Proposed Multi Building Residential Development***

location: ***11 - 13 Mosbri Crescent, Cooks Hill, NSW***

position: E: 385,684.5; N: 6,355,567.6 (MGA94) | surface elevation: 32.8 m (AHD) | angle from horizontal: 90°

drill model: Comacchio 450P, Track mounted | drilling fluid: non / water | hole diameter : 96 mm

drilling information						material substance							
method & support	penetration (1 2 3)	water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description **SOIL TYPE**: plasticity or particle characteristic, colour, secondary and minor components	moisture condition	consistency / relative density	hand penetrometer (kPa) 100 200 300 400	structure and additional observations
RR / N				8	25.0			**SANDSTONE**. *(continued)*				**FRESH**
				7	26.0							
				6	27.0			**TUFF**.				
				5	28.0			**COAL**: black, with some sand.				
				4	29.0			**SILTSTONE**.				
		14/09/18		3	30.0							
				2	31.0							
				1				**SANDSTONE**.				

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method
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HA hand auger
W washbore
RR rock roller/tricone
* bit shown by suffix
e.g. AD/T
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M mud N nil
C casing

penetration
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water
10-Oct-12 water level on date shown
water inflow
water outflow

samples & field tests
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Engineering Log - Borehole

client:	*Crescent Newcastle Pty Ltd*	Borehole ID.	**BH04**
principal:		sheet:	5 of 13
project:	*Proposed Multi Building Residential Development*	project no.	*754-NTLGE220504*
location:	*11 - 13 Mosbri Crescent, Cooks Hill, NSW*	date started:	*12 Sep 2018*
		date completed:	*14 Sep 2018*
		logged by:	*MJ*
		checked by:	*RB*

position: E: 385,684.5; N: 6,355,567.6 (MGA94) | surface elevation: 32.8 m (AHD) | angle from horizontal: 90°

drill model: Comacchio 450P, Track mounted | drilling fluid: non / water | hole diameter : 96 mm

drilling information						material substance							
method & support	penetration 1 2 3	water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description SOIL TYPE: plasticity or particle characteristic, colour, secondary and minor components	moisture condition	consistency / relative density	hand penetrometer (kPa) 100 200 300 400	structure and additional observations
RR N								**SANDSTONE**. *(continued)*				**FRESH**
				0	33.0							
				-1	34.0							
				-2	35.0							
				-3	36.0							
		◄ (water outflow)		-4	37.0							
				-5	38.0			38.15 m: 200mm tool drop				
				-6	39.0							
				-7								

method
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AS auger screwing*
HA hand auger
W washbore
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V V bit

support
M mud N nil
C casing

penetration
1 2 3 no resistance ranging to refusal

water
10-Oct-12 water level on date shown
water inflow
water outflow

samples & field tests
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R refusal
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Engineering Log - Borehole

client:	*Crescent Newcastle Pty Ltd*	Borehole ID.	**BH04**
principal:		sheet:	6 of 13
project:	*Proposed Multi Building Residential Development*	project no.	*754-NTLGE220504*
location:	*11 - 13 Mosbri Crescent, Cooks Hill, NSW*	date started:	*12 Sep 2018*
		date completed:	*14 Sep 2018*
		logged by:	*MJ*
		checked by:	*RB*

position: E: 385,684.5; N: 6,355,567.6 (MGA94) | surface elevation: 32.8 m (AHD) | angle from horizontal: 90°
drill model: Comacchio 450P, Track mounted | drilling fluid: non / water | hole diameter : 96 mm

drilling information | **material substance**

method & support	penetration 1 2 3	water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description (SOIL TYPE: plasticity or particle characteristic, colour, secondary and minor components)	moisture condition	consistency / relative density	hand penetrometer (kPa) 100 200 300 400	structure and additional observations
RR / N				-8	41.0			**SANDSTONE**. *(continued)*				**FRESH**
				-9	42.0			**COAL**: black.				
								SILTSTONE.				
				-10				**COAL**. 42.5 m: 110mm tool drop				
					43.0			**SANDSTONE**.				
				-11	44.0							
				-12	45.0							
				-13	46.0							
				-14	47.0							
				-15								

method
AD auger drilling*
AS auger screwing*
HA hand auger
W washbore
RR rock roller/tricone
* bit shown by suffix
e.g. AD/T
B blank bit
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V V bit

support
M mud N nil
C casing

penetration
1 2 3 no resistance ranging to refusal

water
10-Oct-12 water level on date shown
water inflow
water outflow

samples & field tests
B bulk disturbed sample
D disturbed sample
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A TETRA TECH COMPANY

Engineering Log - Borehole

client:	*Crescent Newcastle Pty Ltd*	Borehole ID.	***BH04***
principal:		sheet:	7 of 13
project:	*Proposed Multi Building Residential Development*	project no.	***754-NTLGE220504***
location:	*11 - 13 Mosbri Crescent, Cooks Hill, NSW*	date started:	***12 Sep 2018***
		date completed:	***14 Sep 2018***
		logged by:	***MJ***
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position: E: 385,684.5; N: 6,355,567.6 (MGA94) | surface elevation: 32.8 m (AHD) | angle from horizontal: 90°
drill model: Comacchio 450P, Track mounted | drilling fluid: non / water | hole diameter : 96 mm

method & support	penetration 1 2 3	water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description (SOIL TYPE: plasticity or particle characteristic, colour, secondary and minor components)	moisture condition	consistency / relative density	hand penetrometer (kPa) 100 200 300 400	structure and additional observations
RR N				-16 / -17 / -18 / -19	49.0 / 50.0 / 51.0 / 52.0			**SANDSTONE**. *(continued)*				FRESH
				-20	53.0			**COAL**.				
				-21	54.0			**SANDSTONE**.				
								SILTSTONE.				
				-22 / -23	55.0			**SANDSTONE**.				

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method
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Engineering Log - Borehole

Borehole ID.	**BH04**
sheet:	8 of 13
project no.	**754-NTLGE220504**
client:	**Crescent Newcastle Pty Ltd**
principal:	
project:	**Proposed Multi Building Residential Development**
location:	**11 - 13 Mosbri Crescent, Cooks Hill, NSW**
date started:	**12 Sep 2018**
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position: E: 385,684.5; N: 6,355,567.6 (MGA94) surface elevation: 32.8 m (AHD) angle from horizontal: 90°
drill model: Comacchio 450P, Track mounted drilling fluid: non / water hole diameter : 96 mm

drilling information | **material substance**

method & support	penetration 1 2 3	water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description (SOIL TYPE: plasticity or particle characteristic, colour, secondary and minor components)	moisture condition	consistency / relative density	hand penetrometer (kPa) 100 200 300 400	structure and additional observations
RR N								**SANDSTONE**. *(continued)*				**FRESH**
								SILTSTONE.				
								SANDSTONE.				
				-24	57.0							
				-25	58.0							
				-26	59.0							
				-27	60.0							
				-28	61.0							
				-29	62.0							
				-30	63.0							
				-31								

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A TETRA TECH COMPANY

Engineering Log - Borehole

client:	*Crescent Newcastle Pty Ltd*	Borehole ID.	***BH04***
principal:		sheet:	9 of 13
project:	*Proposed Multi Building Residential Development*	project no.	***754-NTLGE220504***
location:	*11 - 13 Mosbri Crescent, Cooks Hill, NSW*	date started:	***12 Sep 2018***
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method & support	penetration 1 2 3	water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description (SOIL TYPE: plasticity or particle characteristic, colour, secondary and minor components)	moisture condition	consistency / relative density	hand penetrometer (kPa) 100 200 300 400	structure and additional observations
RR N				-32	65.0			**SANDSTONE**. *(continued)*				**FRESH**
				-33	66.0							
				-34	67.0							
				-35	68.0							
				-36	69.0			**SILTSTONE**.				
				-37	70.0			**SANDSTONE**.				
				-38				**SILTSTONE**.				
					71.0			**SANDSTONE**.				
				-39								

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method
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Engineering Log - Borehole

client:	*Crescent Newcastle Pty Ltd*
principal:	
project:	*Proposed Multi Building Residential Development*
location:	*11 - 13 Mosbri Crescent, Cooks Hill, NSW*

Borehole ID.	**BH04**
sheet:	10 of 13
project no.	**754-NTLGE220504**
date started:	**12 Sep 2018**
date completed:	**14 Sep 2018**
logged by:	**MJ**
checked by:	**RB**

position: E: 385,684.5; N: 6,355,567.6 (MGA94) surface elevation: 32.8 m (AHD) angle from horizontal: 90°
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drilling information						material substance						
method & support	penetration 1 2 3	water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description **SOIL TYPE**: plasticity or particle characteristic, colour, secondary and minor components	moisture condition	consistency / relative density	hand penetrometer (kPa) 100 200 300 400	structure and additional observations
RR N				-40 -41 -42 -43 -44 -45 -46 -47	73.0 74.0 75.0 76.0 77.0 78.0 79.0			**SANDSTONE**. *(continued)*				**FRESH**

CDF_0_9_06_LIBRARY.GLB rev:AS Log COF BOREHOLE: NON CORED 754-NTLGE220504.GPJ <<DrawingFile>> 31/10/2018 13:47

method
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Engineering Log - Borehole

Borehole ID.	**BH04**
sheet:	11 of 13
project no.	**754-NTLGE220504**
client:	**Crescent Newcastle Pty Ltd**
date started:	**12 Sep 2018**
principal:	
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method & support	penetration 1 2 3	water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description — SOIL TYPE: plasticity or particle characteristic, colour, secondary and minor components	moisture condition	consistency / relative density	hand penetrometer (kPa) 100 200 300 400	structure and additional observations
RR / N				-48	81.0			**SANDSTONE**. *(continued)*				**FRESH**
				-49	82.0							
				-50	83.0			**SILTSTONE**.				
				-51	84.0							
				-52	85.0							
				-53	86.0			**SANDSTONE**.				
				-54	87.0							
				-55								

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Engineering Log - Borehole

Borehole ID.	**BH04**
sheet:	12 of 13
project no.	**754-NTLGE220504**
date started:	**12 Sep 2018**
date completed:	**14 Sep 2018**
logged by:	**MJ**
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client: ***Crescent Newcastle Pty Ltd***

principal:

project: ***Proposed Multi Building Residential Development***

location: ***11 - 13 Mosbri Crescent, Cooks Hill, NSW***

position: E: 385,684.5; N: 6,355,567.6 (MGA94) | surface elevation: 32.8 m (AHD) | angle from horizontal: 90°

drill model: Comacchio 450P, Track mounted | drilling fluid: non / water | hole diameter : 96 mm

method & support	penetration 1 2 3	water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description — SOIL TYPE: plasticity or particle characteristic, colour, secondary and minor components	moisture condition	consistency / relative density	hand penetrometer (kPa) 100 200 300 400	structure and additional observations
RR N								**SANDSTONE**. *(continued)*				**FRESH**
				-56	89.0			**SANDSTONE**.				
				-57	90.0							
		◀		-58	91.0							
				-59	92.0							
				-60	93.0			**NO CORE:** 1.65m (92.10-93.75 m) Tool drop.				
				-61	94.0			**CAVE IN: SILTSTONE AND COAL**				
				-62	95.0							
				-63								

method
AD auger drilling*
AS auger screwing*
HA hand auger
W washbore
RR rock roller/tricone
* bit shown by suffix
e.g. AD/T
B blank bit
T TC bit
V V bit

support
M mud
N nil
C casing

penetration
1 2 3 — no resistance ranging to refusal

water
10-Oct-12 water level on date shown
water inflow
water outflow

samples & field tests
B bulk disturbed sample
D disturbed sample
E environmental sample
SS split spoon sample
U## undisturbed sample ##mm diameter
HP hand penetrometer (kPa)
N standard penetration test (SPT)
N* SPT - sample recovered
Nc SPT with solid cone
VS vane shear; peak/remouded (kPa)
R refusal
HB hammer bouncing

classification symbol & soil description
based on Unified Classification System

moisture
D dry
M moist
W wet
Wp plastic limit
Wl liquid limit

consistency / relative density
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

CDF_0_9_06_LIBRARY.GLB rev:AS Log COF BOREHOLE: NON CORED 754-NTLGE220504.GPJ <<DrawingFile>> 31/10/2018 13:47

coffey
A TETRA TECH COMPANY

Engineering Log - Borehole

		Borehole ID.	**BH04**
		sheet:	13 of 13
		project no.	**754-NTLGE220504**
client:	***Crescent Newcastle Pty Ltd***	date started:	***12 Sep 2018***
principal:		date completed:	***14 Sep 2018***
project:	***Proposed Multi Building Residential Development***	logged by:	***MJ***
location:	***11 - 13 Mosbri Crescent, Cooks Hill, NSW***	checked by:	***RB***

position: E: 385,684.5; N: 6,355,567.6 (MGA94) surface elevation: 32.8 m (AHD) angle from horizontal: 90°
drill model: Comacchio 450P, Track mounted drilling fluid: non / water hole diameter : 96 mm

drilling information						material substance						
method & support	penetration 1 2 3	water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description: SOIL TYPE: plasticity or particle characteristic, colour, secondary and minor components	moisture condition	consistency / relative density	hand penetro-meter (kPa) 100 200 300 400	structure and additional observations
RR N				-64, -65, -66, -67, -68	97.0, 98.0, 99.0, 100.0, 101.0			**CAVE IN: SILTSTONE AND COAL** *(continued)*				**FRESH**
								SANDSTONE				
				-69, -70, -71	102.0, 103.0			Borehole BH04 terminated at 101.60 m Target depth				

method
AD auger drilling*
AS auger screwing*
HA hand auger
W washbore
RR rock roller/tricone
* bit shown by suffix
e.g. AD/T
B blank bit
T TC bit
V V bit

support
M mud N nil
C casing

penetration
1 2 3 — no resistance ranging to refusal

water
10-Oct-12 water level on date shown
water inflow
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B bulk disturbed sample
D disturbed sample
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U## undisturbed sample ##mm diameter
HP hand penetrometer (kPa)
N standard penetration test (SPT)
N* SPT - sample recovered
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moisture
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H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

Appendix B – Downhole geophysics

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Coffey Geotechnics

Borehole BH01 TOP

ACOUSTIC TELEVIEWER
PETROPHYSICAL REPORT

Groundsearch Australia Pty. Limited

15 October 2018

DISCLAIMER

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For and on behalf of Groundsearch Australia Pty. Limited

John Lea BSc (Hons) FAusIMM
Principal Geologist
Managing Director

Executive summary

The data contained in this report were obtained from one 9.6 cm diameter, vertical, cored borehole that was drilled as a component of the 2018 geotechnical exploration programme for Coffey Geotechnics at NBN office, Newcastle NSW.

Century Geophysical Corporation downhole 9804 acoustic televiewer and 9329 density tools were run to collect data in the field on 14 September 2018. The bottom section was logged on 9 September 2018. This report is for data from 29.00 to 44.50 mbgl. The 9239 density tool was run inside steel casing and data were corrected for the steel. Therefore, there are no caliper or resistivity data.

The 31 identified features are interpreted as the SWL, bedding, fractures and a void at the base of the log. The bedding to fractures ratio is 3:1.

The Century Display program has automatically recalculated the dip angle data to represent the borehole in the vertical position and the dip direction data is referenced to magnetic north.

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The televiewer digitises 256 measurements around the borehole at each high-resolution sample interval. These data can be oriented to North and displayed real-time while logging using the Visual Compu-Log System.

Analysis software includes colour adjustment, fracture dip and strike determination, and classification of features. It allows information to be displayed on the graphical screen, plot, and in report format.

2.0 Interpretation methodology

It should be noted that the ATV is a bowspring-type, centralised tool and is affected by poor wallrock conditions known as rugosity.

The ATV data interpretation procedure is based on the superposition of curves on feature logs directly onto the computer screen by using a subjective, manual; two-point definition of a feature’s top and base to produce a sine curve. The sides of the time and amplitude plots represent magnetic north and magnetic south is in the centre of each plot. The low side, or trough, of the sine curve defines the dip direction of the feature.

The logging program automatically records the televiewer tool slant angle and bearing and corrects for any borehole deviations. The curves are automatically given an identification number for subsequent referencing in a report file.

There are possibly more bedding planes and structural fractures appearing in the televiewer logs that have not been included in this report due to their poor graphic definition or the inability to resolve their geometry by superposing a sine curve using the program's two point method.

This report contains a;

- Text summary of the interpreted features
- Circular representation of interpreted features
- Logs that show geological features with their subjective, numbered interpretation curves shown at 1:20 scale. The logs are in standard format whereby the optical image of the borehole wall is "flattened" onto the plot. The logs have the following additional features to enhance geological interpretations of the strata;
    - Amplitude image differentials
    - Time image differentials that indicate higher strength zones in **GREEN** and lower strength zones in **RED**
    - Tadpoles that represent feature dip and dip direction
    - Open fractures in **RED**
    - Partially open fractures in **MAGENTA**
  - Natural gamma
  - Slant (dip angle)
  - Slant angle bearing
  - Long and short space density
- Table containing feature curve ID, top, base, dip angle, dip azimuth, feature description and the generalised rock type that hosts the feature
- Graphical representations of the interpreted features

3.0 Borehole BH01 TOP interpretation

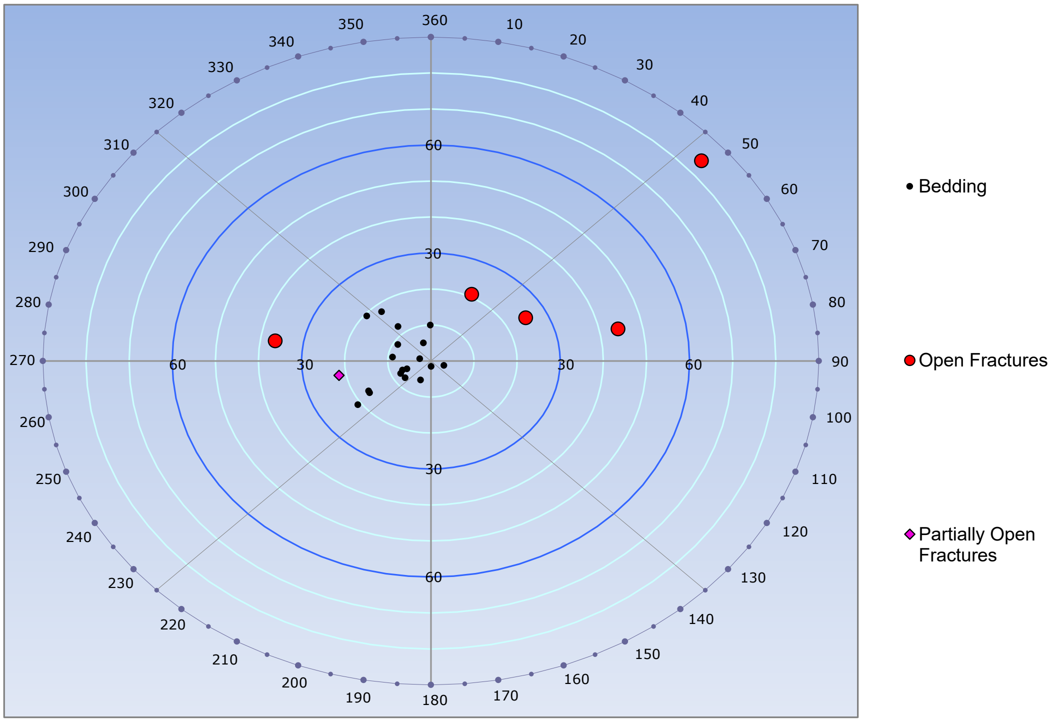
The 31 identified features are interpreted as the SWL, bedding, fractures and a void at the base of the log. The bedding to fractures ratio is 3:1.

A description of each interpreted feature is presented in Table 1 and the log is presented in Appendix 1.

Table 1 Interpreted features report for BH01 TOP

FEATURE ID	DIP (DEG)	AZIMUTH (DEG)	MIDPOINT (MBGL)	TOP (M)	BASE (M)	TYPE OF FEATURE	GENERALISED ROCK TYPE
1	2	1	29.45	29.45	29.45	SWL	Overburden
2	18	320	34.61	34.60	34.63	Bedding plane	Overburden
3	19	310	34.65	34.63	34.67	Bedding plane	Overburden
4	10	359	34.69	34.68	34.70	Bedding plane	Overburden
5	17	238	37.98	37.97	38.00	Bedding plane	Overburden
6	20	45	39.70	39.68	39.72	Top of washout	Overburden
7	10	74	39.91	39.90	39.92	Base of washout	Overburden
8	44	78	39.95	39.91	40.00	Fracture plane - open	Overburden
9	3	284	40.19	40.19	40.20	Bedding plane	Overburden
10	25	61	40.45	40.43	40.48	Fracture plane - open	Overburden
11	21	27	40.55	40.53	40.57	Fracture plane - open	Overburden
12	3	112	40.61	40.61	40.62	Bedding plane	Overburden
13	6	204	40.66	40.66	40.67	Bedding plane	Overburden
14	37	279	40.79	40.75	40.82	Fracture plane - open	Overburden
15	22	259	40.85	40.83	40.87	Fracture plane - partially open	Overburden
16	8	244	40.95	40.94	40.96	Bedding plane	Overburden
17	9	301	41.01	41.00	41.01	Bedding plane	Overburden
18	8	232	41.03	41.02	41.04	Bedding plane	Overburden
19	6	249	41.15	41.14	41.16	Bedding plane	Overburden
20	7	249	41.31	41.31	41.32	Bedding plane	Overburden
21	9	277	41.49	41.48	41.50	Bedding plane	Overburden
22	10	247	41.51	41.50	41.52	Top of washout	Overburden
23	15	115	42.65	42.64	42.66	Base of washout	Overburden
24	84	48	42.73	42.36	43.10	Fracture plane - open	Overburden
25	46	244	42.97	42.92	43.02	Top of washout	Overburden
26	12	316	43.73	43.72	43.74	Base of washout	Overburden
27	12	321	43.98	43.97	43.99	Bedding plane	Overburden
28	5	341	44.06	44.06	44.06	Bedding plane	Overburden
29	2	178	44.10	44.10	44.10	Bedding plane	Overburden
30	21	234	44.17	44.15	44.19	Bedding plane	Overburden
31	17	240	44.21	44.20	44.23	Bedding plane	Overburden
FEATURE ID	DIP (DEG)	AZIMUTH (DEG)	MIDPOINT (MBGL)	TOP (M)	BASE (M)	TYPE OF FEATURE	GENERALISED ROCK TYPE

Figure 1 BH01 TOP circular plan representation of interpreted features



The 18 identified sedimentary features are predominantly bedding planes that appear to range in dip from flat-lying to 21^0. Figures 2 and 3 show the distribution of the planes' dip angles and dip direction with depth.

Table 2 details the variation in the dip angle and dip direction data. Figure 4 shows the dip direction data in a rose diagram with the bedding planes' dip angle and dip direction data shown as histograms in Figures 5 and 6.

The six fractures are identified as open (5) andpartially open (1). The fracture dip angles range from 21 to 84^0.

Table 3 details the variation in the fractures' dip angle and dip direction data. Figure 7 shows the dip direction data in a rose diagram with the fractures' plane dip angle and dip direction data as histograms in Figures 8 and 9.

Figure 2 BH01 TOP feature dip angle data distribution

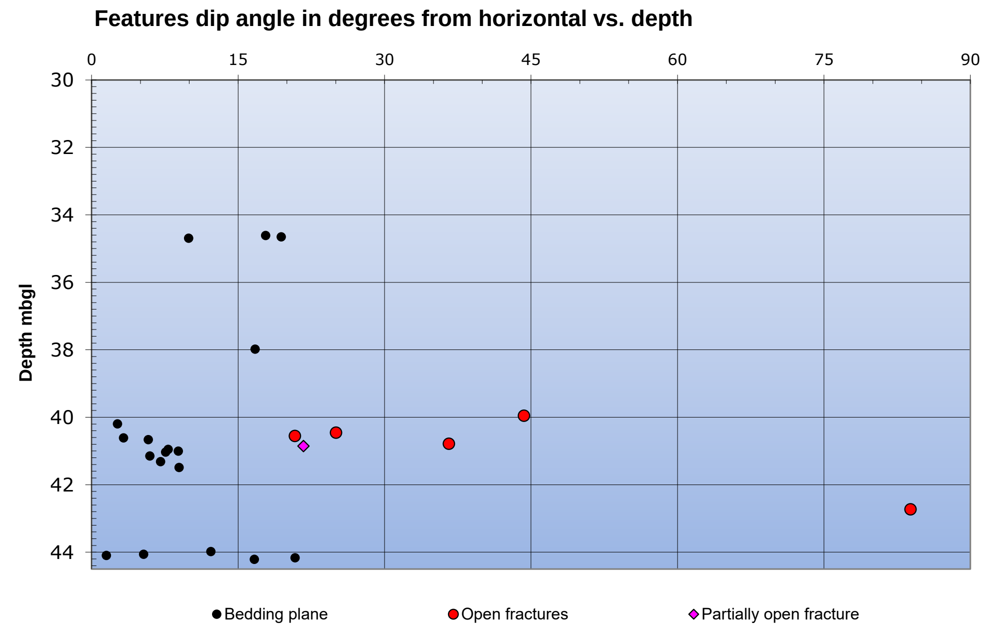


Figure 3 BH01 TOP feature dip direction data distribution

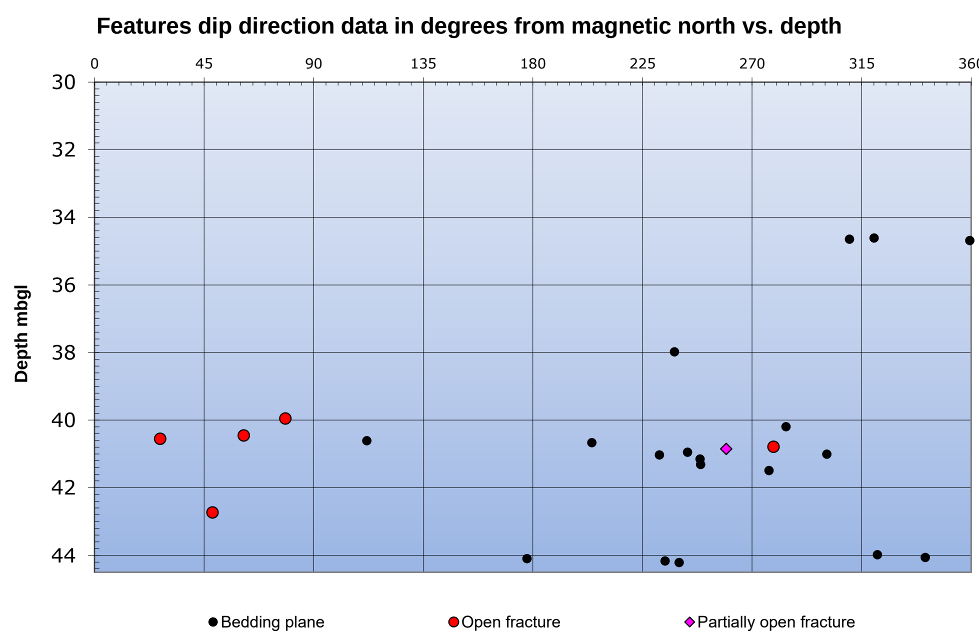


Table 2 BH01 TOP bedding histogram data

Dip Distribution			Orientation Distribution		
Total: 18			Total: 18		
Dip Range	Count	%	Bearing Range	Count	%
0 to 10	12	66.7	0 to 10	0	0.0
10 to 20	5	27.8	10 to 20	0	0.0
20 to 30	1	5.6	20 to 30	0	0.0
30 to 40	0	0.0	30 to 40	0	0.0
40 to 50	0	0.0	40 to 50	0	0.0
50 to 60	0	0.0	50 to 60	0	0.0
60 to 70	0	0.0	60 to 70	0	0.0
70 to 80	0	0.0	70 to 80	0	0.0
80 to 90	0	0.0	80 to 90	0	0.0
			90 to 100	0	0.0
			100 to 110	0	0.0
			110 to 120	1	5.6
			120 to 130	0	0.0
			130 to 140	0	0.0
			140 to 150	0	0.0
			150 to 160	0	0.0
			160 to 170	0	0.0
			170 to 180	1	5.6
			180 to 190	0	0.0
			190 to 200	0	0.0
			200 to 210	1	5.6
			210 to 220	0	0.0
			220 to 230	0	0.0
			230 to 240	3	16.7
			240 to 250	4	22.2
			250 to 260	0	0.0
			260 to 270	0	0.0
			270 to 280	1	5.6
			280 to 290	1	5.6
			290 to 300	0	0.0
			300 to 310	2	11.1
			310 to 320	0	0.0
			320 to 330	2	11.1
			330 to 340	0	0.0
			340 to 350	1	5.6
			350 to 360	1	5.6

Figure 5 BH01 TOP bedding dip angles histogram

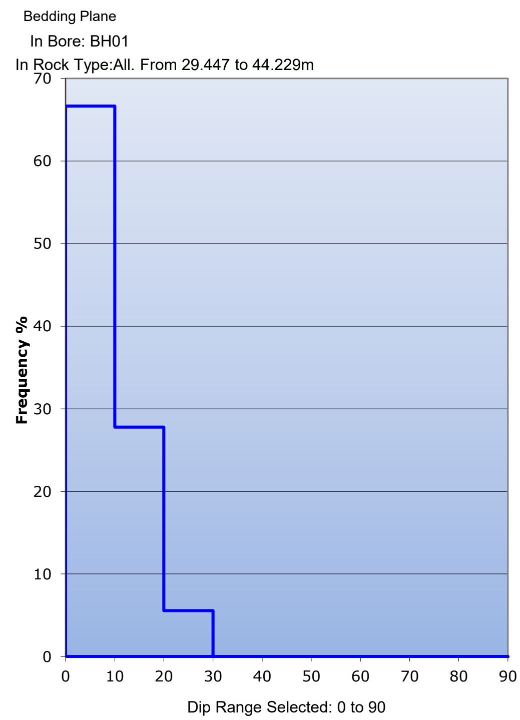


Figure 4 BH01 TOP bedding dip direction data rose diagram

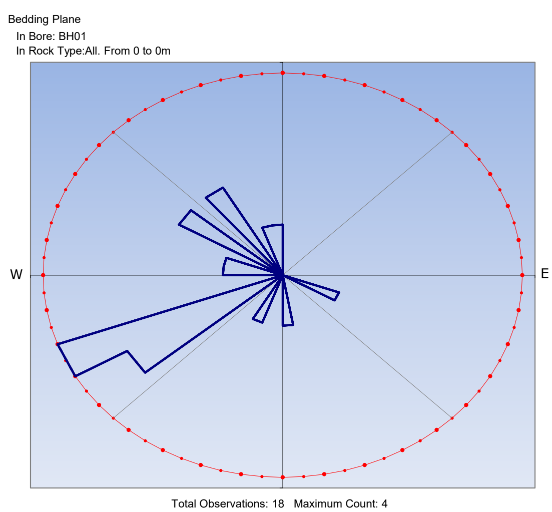


Figure 6 BH01 TOP bedding dip directions histogram

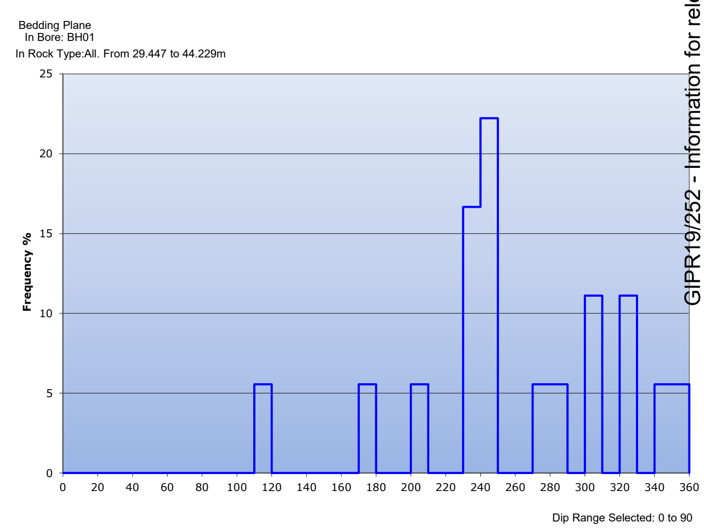


Table 3 BH01 TOP fractures histogram data

Dip Distribution Total: 6			Orientation Distribution Total: 6		
Dip Range	**Count**	**%**	**Bearing Range**	**Count**	**%**
0 to 10	0	0.0	0 to 10	0	0.0
10 to 20	0	0.0	10 to 20	0	0.0
20 to 30	3	50.0	20 to 30	1	16.7
30 to 40	1	16.7	30 to 40	0	0.0
40 to 50	1	16.7	40 to 50	1	16.7
50 to 60	0	0.0	50 to 60	0	0.0
60 to 70	0	0.0	60 to 70	1	16.7
70 to 80	0	0.0	70 to 80	1	16.7
80 to 90	1	16.7	80 to 90	0	0.0
			90 to 100	0	0.0
			100 to 110	0	0.0
			110 to 120	0	0.0
			120 to 130	0	0.0
			130 to 140	0	0.0
			140 to 150	0	0.0
			150 to 160	0	0.0
			160 to 170	0	0.0
			170 to 180	0	0.0
			180 to 190	0	0.0
			190 to 200	0	0.0
			200 to 210	0	0.0
			210 to 220	0	0.0
			220 to 230	0	0.0
			230 to 240	0	0.0
			240 to 250	0	0.0
			250 to 260	1	16.7
			260 to 270	0	0.0
			270 to 280	1	16.7
			280 to 290	0	0.0
			290 to 300	0	0.0
			300 to 310	0	0.0
			310 to 320	0	0.0
			320 to 330	0	0.0
			330 to 340	0	0.0
			340 to 350	0	0.0
			350 to 360	0	0.0

Figure 8 BH01 TOP fractures dip angles histogram

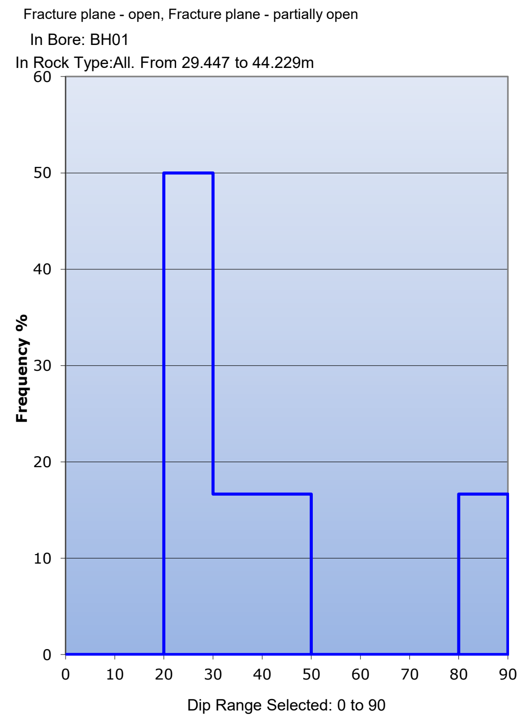


Figure 7 BH01 TOP fractures dip direction data rose diagram

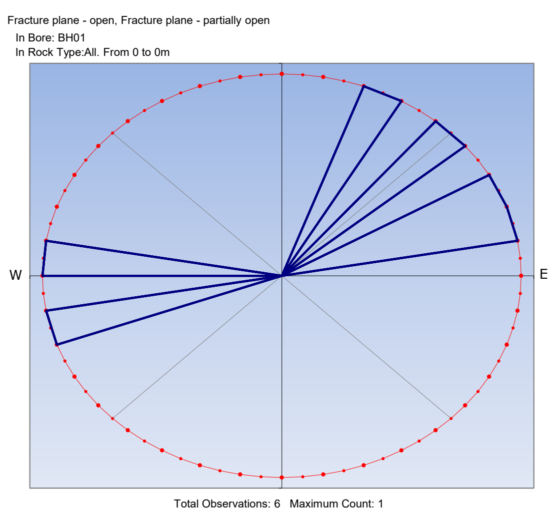
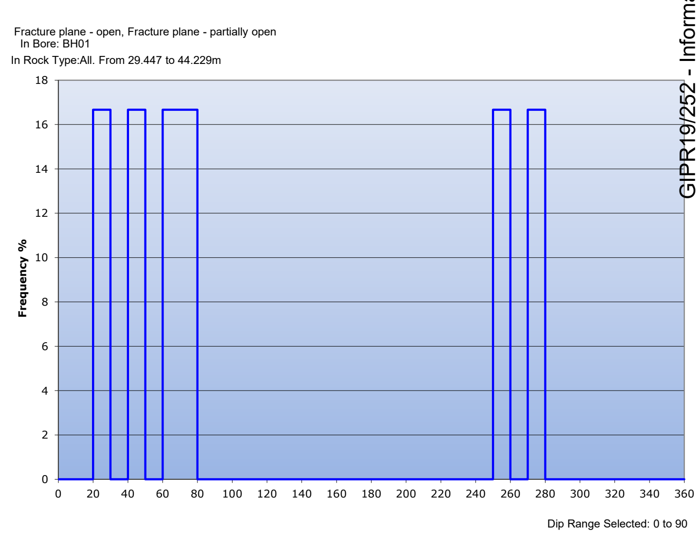


Figure 9 BH01 TOP fractures dip directions histogram



Appendix 1

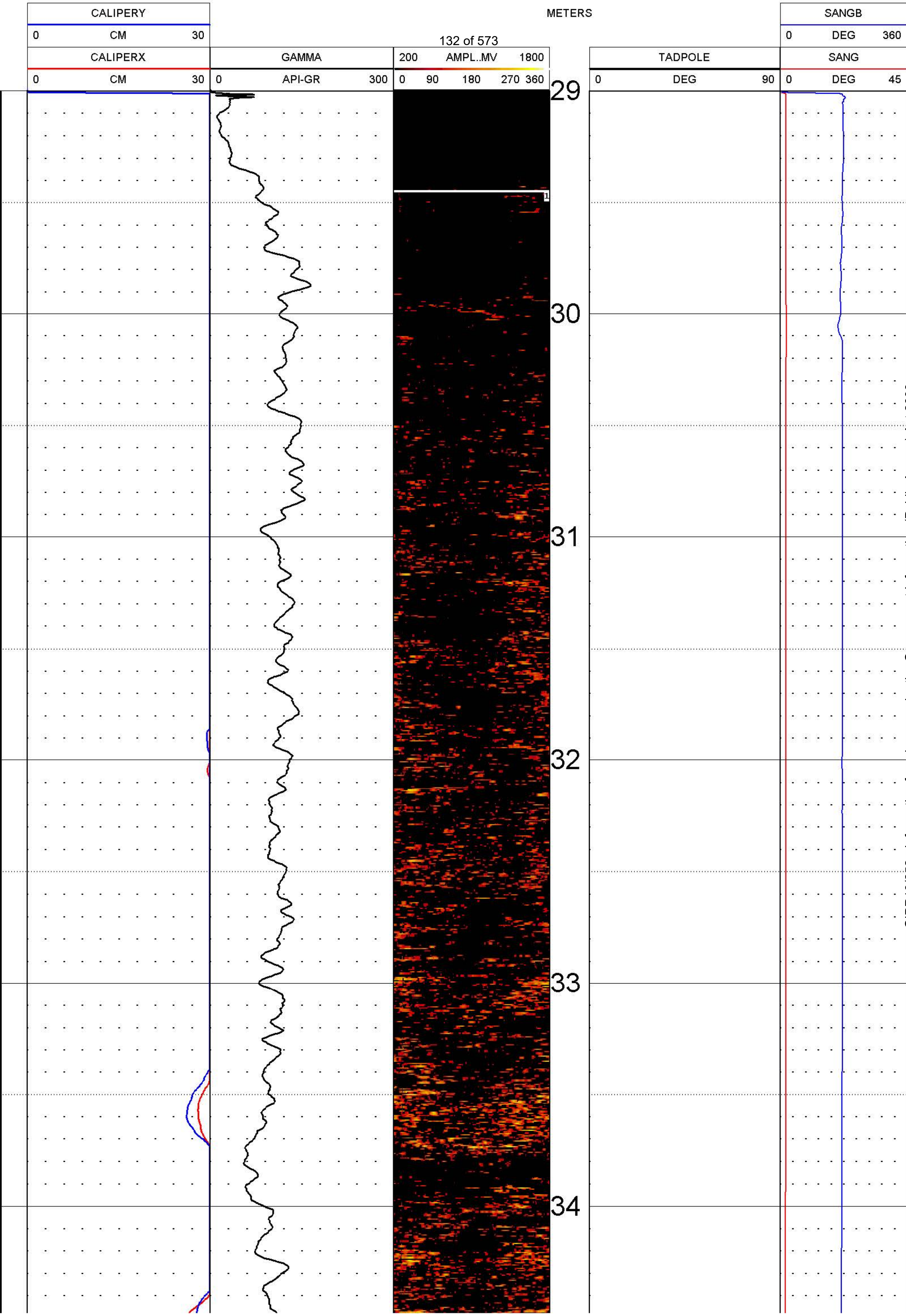
Appendix 1 *1:20 Interpretation logs – 29.00 to 44.50 mbgl*

BH01 Top ATV 1:20

COMPANY	: COFFEY GEOTECHNICS	OTHER SERVICES:	DEN ATV SON,TV ne	UTM-E	: N/A
WELL	: BH01 Top ATV 1:20			UTM-N	: N/A
LOCATION/FIELD	:				
COUNTY	:				
LOCATION	: NEWCASTLE				
SECTION	: N/A	TOWNSHIP	: N/A	RANGE	: N/A
DATE	: 09/14/18	PERMANENT DATUM	: -0.9		
DEPTH DRILLER	: 101.6			KB	: N/A
LOG BOTTOM	: 44.500	LOG MEASURED FROM:	N/A	DF	: N/A
LOG TOP	: 29.000	DRL MEASURED FROM:	N/A	GL	: NA
CASING DIAMETER	: 10.	LOGGING UNIT	: T107		
CASING TYPE	: PVC	FIELD OFFICE	: RUTHERFORD		
CASING THICKNESS:	.5	RECORDED BY	: P WOODWARD		
BIT SIZE	: 9.9	BOREHOLE FLUID	: 0	FILE	: PROCESSED
MAGNETIC DECL.	: 0	RM	: N/A	TYPE	: 9804A
MATRIX DENSITY	: 2.65	RM TEMPERATURE	: N/A	LGDATE:	09/14/18
NEUTRON MATRIX	: SANDSTONE	MATRIX DELTA T	: 177	LGTIME	: 13:08
				THRESH:	99999

NE, 743'FNL, 661'FEL

ALL SERVICES PROVIDED SUBJECT TO STANDARD TERMS AND CONDITIONS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CALIPERX
0 CM 30
GAMMA
0 API-GR 300
METERS
200 AMPL..MV 1800
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TADPOLE
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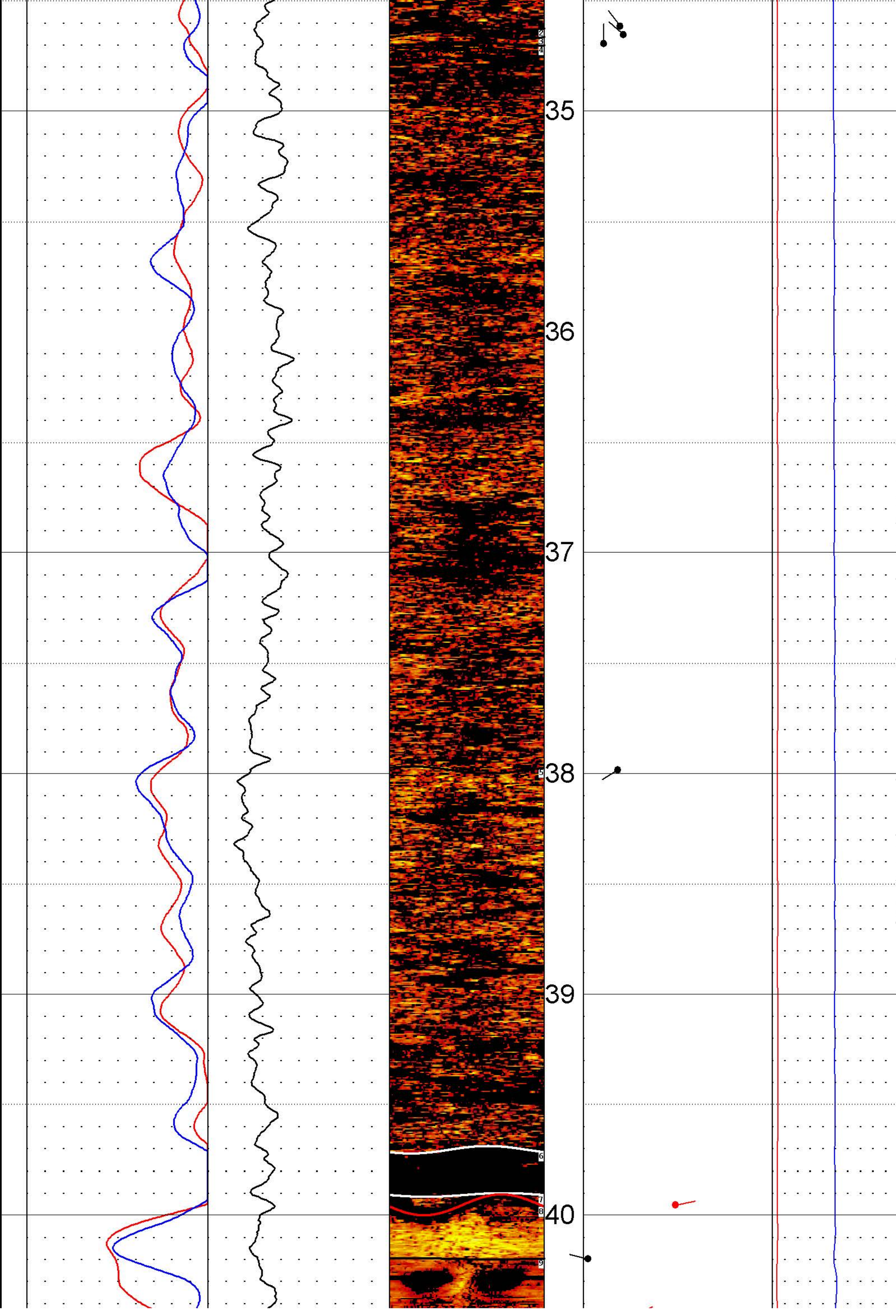

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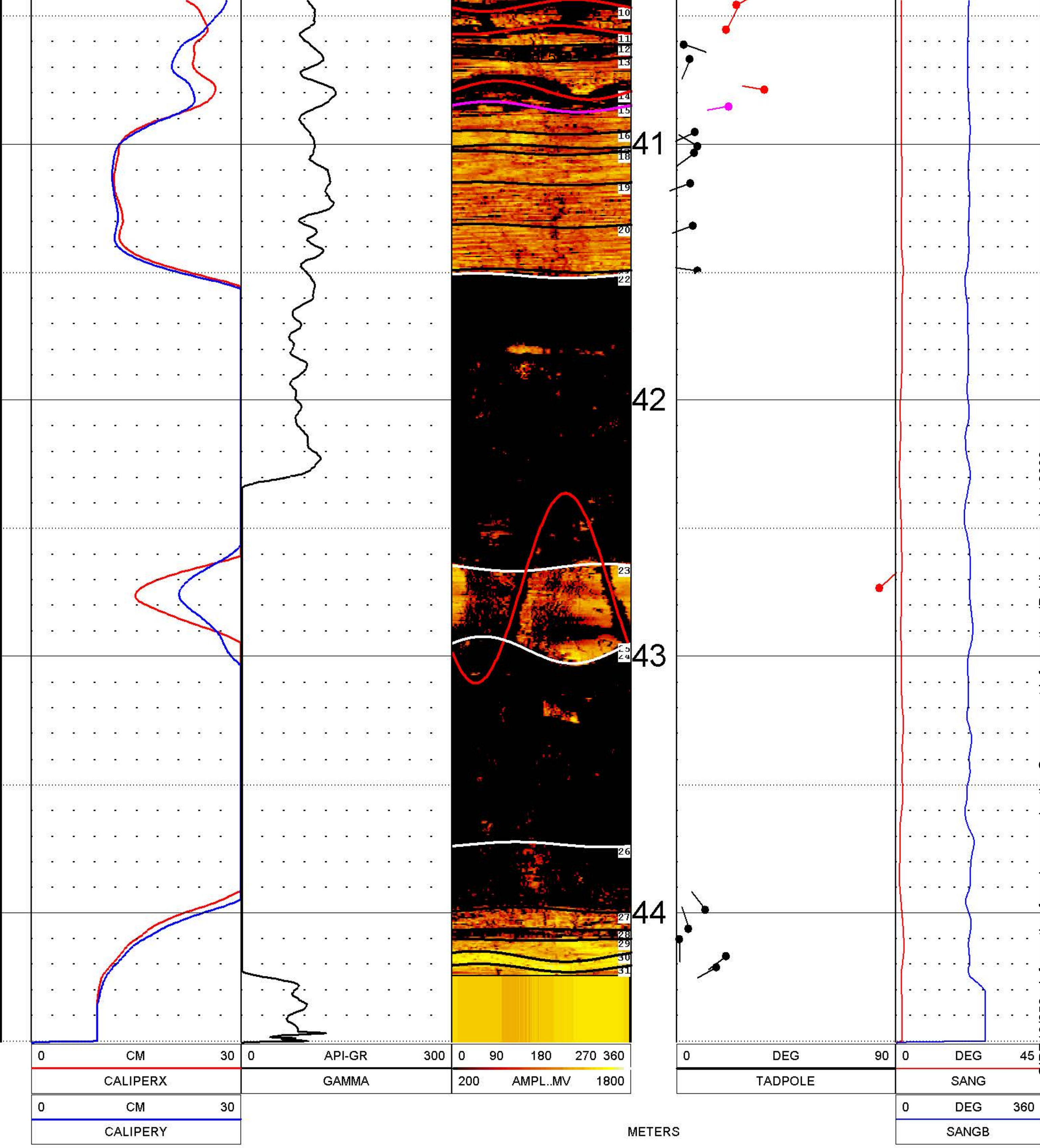
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GAMMA
0 90 180 270 360
200 AMPL..MV 1800
0 DEG 90
TADPOLE
0 DEG 45
SANG
0 CM 30
CALIPERY
METERS
0 DEG 360
SANGB

Coffey Geotechnics

Borehole BH01

ACOUSTIC TELEVIEWER
PETROPHYSICAL REPORT

Groundsearch Australia Pty. Limited

27 September 2018

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For and on behalf of Groundsearch Australia Pty. Limited

John Lea BSc (Hons) FAusIMM
Principal Geologist
Managing Director

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Analysis software includes colour adjustment, fracture dip and strike determination, and classification of features. It allows information to be displayed on the graphical screen, plot, and in report format.

2.0 Interpretation methodology

It should be noted that the ATV is a bowspring-type, centralised tool and is affected by poor wallrock conditions known as rugosity.

The ATV data interpretation procedure is based on the superposition of curves on feature logs directly onto the computer screen by using a subjective, manual; two-point definition of a feature’s top and base to produce a sine curve. The sides of the time and amplitude plots represent magnetic north and magnetic south is in the centre of each plot. The low side, or trough, of the sine curve defines the dip direction of the feature.

The logging program automatically records the televiewer tool slant angle and bearing and corrects for any borehole deviations. The curves are automatically given an identification number for subsequent referencing in a report file.

There are possibly more bedding planes and structural fractures appearing in the televiewer logs that have not been included in this report due to their poor graphic definition or the inability to resolve their geometry by superposing a sine curve using the program's two point method.

This report contains a;

- Text summary of the interpreted features
- Circular representation of interpreted features
- Logs that show geological features with their subjective, numbered interpretation curves shown at 1:20 scale. The logs are in standard format whereby the optical image of the borehole wall is "flattened" onto the plot. The logs have the following additional features to enhance geological interpretations of the strata;
    - Amplitude image differentials
    - Time image differentials that indicate higher strength zones in **GREEN** and lower strength zones in **RED**
    - Tadpoles that represent feature dip and dip direction
    - Open fractures in **RED**
    - Partially open fractures in **MAGENTA**
    - Discontinuous fractures in **DARK BLUE**
    - Closed fracture in **GREEN**
  - Natural gamma
  - Slant (dip angle)
  - Slant angle bearing
  - Long and short space density
- Table containing feature curve ID, top, base, dip angle, dip azimuth, feature description and the generalised rock type that hosts the feature
- Graphical representations of the interpreted features

3.0 Borehole BH01interpretation

The 203 identified features are interpreted as the SWL, bedding, fractures and a void at the base of the log. The bedding to fractures ratio is 6.2:1.

A description of each interpreted feature is presented in Table 1 and the log is presented in Appendix 1.

Table 1 Interpreted features report for BH01

FEATURE ID	DIP (DEG)	AZIMUTH (DEG)	MIDPOINT (MBGL)	TOP (M)	BASE (M)	TYPE OF FEATURE	GENERALISED ROCK TYPE
1	2	16	45.04	45.04	45.04	SWL	Overburden
2	3	62	45.48	45.48	45.48	Bedding plane	Overburden
3	5	303	45.69	45.69	45.70	Bedding plane	Overburden
4	2	343	46.24	46.24	46.24	Bedding plane	Overburden
5	7	255	46.45	46.44	46.45	Bedding plane	Overburden
6	13	349	47.13	47.12	47.14	Bedding plane	Overburden
7	15	349	47.16	47.15	47.17	Bedding plane	Overburden
8	10	46	47.21	47.21	47.22	Bedding plane	Overburden
9	4	313	50.53	50.52	50.53	Bedding plane	Overburden
10	6	25	50.67	50.67	50.67	Bedding plane	Overburden
11	5	25	50.68	50.68	50.69	Bedding plane	Overburden
12	7	15	50.71	50.71	50.72	Bedding plane	Overburden
13	7	337	50.76	50.76	50.77	Bedding plane	Overburden
14	10	66	50.79	50.78	50.80	Bedding plane	Overburden
15	11	357	50.85	50.84	50.86	Bedding plane	Overburden
16	9	357	50.95	50.95	50.96	Bedding plane	Overburden
17	13	352	51.03	51.02	51.04	Bedding plane	Overburden
18	19	92	51.50	51.48	51.51	Fracture plane - partially open	Overburden
19	23	305	51.52	51.50	51.54	Fracture plane - partially open	Overburden
20	12	295	51.53	51.52	51.54	Bedding plane	Overburden
21	21	301	52.33	52.31	52.34	Fracture plane - partially open	Overburden
22	74	231	52.48	52.30	52.66	Fracture plane - partially open	Overburden
23	8	98	53.32	53.31	53.33	Bedding plane	Overburden
24	12	124	53.36	53.35	53.38	Bedding plane	Overburden
25	5	340	53.44	53.44	53.44	Bedding plane	Overburden
26	6	288	53.46	53.45	53.46	Bedding plane	Overburden
27	3	23	53.49	53.49	53.49	Bedding plane	Overburden
28	2	269	53.53	53.53	53.54	Bedding plane	Overburden
29	11	349	53.75	53.74	53.75	Top of coal unit	COAL SEAM
30	8	335	53.80	53.79	53.80	Bedding plane	COAL SEAM
31	72	264	53.91	53.76	54.07	Fracture plane - partially open	COAL SEAM
32	5	349	54.05	54.05	54.05	Bedding plane	COAL SEAM
33	7	331	54.11	54.10	54.11	Bedding plane	COAL SEAM
34	11	342	54.20	54.19	54.21	Bedding plane	COAL SEAM
35	10	347	54.21	54.21	54.22	Bedding plane	COAL SEAM
36	9	354	54.32	54.32	54.33	Base of coal unit	COAL SEAM
37	9	350	54.37	54.37	54.38	Bedding plane	Interburden

38	9	352	54.41	54.41	54.42	Bedding plane	Interburden
39	4	202	54.45	54.44	54.45	Bedding plane	Interburden
40	6	234	54.49	54.48	54.49	Bedding plane	Interburden
41	5	154	54.50	54.49	54.51	Bedding plane	Interburden
42	9	178	54.53	54.52	54.54	Bedding plane	Interburden
43	6	156	54.57	54.56	54.58	Bedding plane	Interburden
44	4	296	54.64	54.64	54.64	Bedding plane	Interburden
45	4	280	54.65	54.65	54.65	Bedding plane	Interburden
46	13	102	55.06	55.05	55.07	Bedding plane	Interburden
47	3	268	55.58	55.57	55.58	Bedding plane	Interburden
48	9	78	55.71	55.70	55.71	Bedding plane	Interburden
49	8	138	55.77	55.76	55.78	Bedding plane	Interburden
50	13	274	55.89	55.87	55.90	Bedding plane	Interburden
51	10	301	55.91	55.90	55.91	Bedding plane	Interburden
52	7	288	55.92	55.92	55.93	Bedding plane	Interburden
53	8	278	55.94	55.94	55.95	Bedding plane	Interburden
54	11	323	56.52	56.52	56.53	Bedding plane	Interburden
55	7	305	56.78	56.77	56.78	Bedding plane	Interburden
56	6	259	56.81	56.80	56.81	Bedding plane	Interburden
57	11	83	56.87	56.86	56.88	Bedding plane	Interburden
58	10	70	56.90	56.89	56.91	Bedding plane	Interburden
59	10	77	56.92	56.91	56.93	Bedding plane	Interburden
60	40	33	57.46	57.42	57.49	Bedding plane	Interburden
61	4	312	57.55	57.55	57.56	Bedding plane	Interburden
62	4	38	57.63	57.63	57.63	Bedding plane	Interburden
63	8	52	57.69	57.68	57.69	Bedding plane	Interburden
64	7	334	57.74	57.74	57.75	Bedding plane	Interburden
65	2	343	57.95	57.95	57.96	Bedding plane	Interburden
66	12	360	58.50	58.50	58.51	Bedding plane	Interburden
67	16	12	58.57	58.55	58.58	Bedding plane	Interburden
68	8	320	58.83	58.82	58.83	Bedding plane	Interburden
69	3	28	59.31	59.31	59.31	Bedding plane	Interburden
70	4	40	60.08	60.08	60.08	Bedding plane	Interburden
71	7	68	60.11	60.10	60.11	Bedding plane	Interburden
72	2	276	60.47	60.47	60.47	Bedding plane	Interburden
73	4	42	60.78	60.78	60.79	Bedding plane	Interburden
74	8	94	61.84	61.83	61.84	Bedding plane	Interburden
75	2	30	61.86	61.86	61.86	Bedding plane	Interburden
76	4	254	61.98	61.98	61.98	Bedding plane	Interburden
77	1	116	62.02	62.02	62.02	Bedding plane	Interburden
78	29	318	62.09	62.06	62.11	Fracture plane - open	Interburden
79	15	326	62.13	62.11	62.14	Bedding plane	Interburden
80	66	243	62.13	62.02	62.25	Fracture plane - partially open	Interburden
81	11	333	62.14	62.14	62.15	Bedding plane	Interburden
82	13	341	62.17	62.16	62.18	Bedding plane	Interburden
83	5	318	62.27	62.26	62.27	Bedding plane	Interburden
84	5	336	62.42	62.42	62.43	Bedding plane	Interburden
85	8	345	63.09	63.09	63.09	Bedding plane	Interburden
86	10	28	63.20	63.19	63.21	Bedding plane	Interburden
87	8	32	63.22	63.21	63.22	Bedding plane	Interburden

88	4	38	63.24	63.24	63.24	Bedding plane	Interburden
89	5	40	63.25	63.25	63.25	Bedding plane	Interburden
90	5	333	63.36	63.35	63.36	Bedding plane	Interburden
91	3	8	63.38	63.38	63.38	Bedding plane	Interburden
92	71	241	63.39	63.24	63.53	Fracture plane - partially open	Interburden
93	73	241	63.41	63.24	63.57	Fracture plane - partially open	Interburden
94	45	48	63.65	63.61	63.69	Fracture plane - partially open	Interburden
95	11	346	64.09	64.08	64.10	Bedding plane	Interburden
96	11	36	65.10	65.09	65.10	Bedding plane	Interburden
97	20	33	65.16	65.15	65.17	Bedding plane	Interburden
98	18	32	65.17	65.16	65.18	Bedding plane	Interburden
99	3	54	65.38	65.38	65.38	Bedding plane	Interburden
100	3	55	65.40	65.40	65.41	Bedding plane	Interburden
101	68	240	65.45	65.32	65.58	Fracture plane - discontinuous	Interburden
102	7	22	65.48	65.48	65.48	Bedding plane	Interburden
103	65	241	65.66	65.55	65.76	Fracture plane - partially open	Interburden
104	70	241	66.07	65.93	66.21	Fracture plane - open	Interburden
105	40	62	66.38	66.34	66.41	Fracture plane - closed	Interburden
106	18	60	66.40	66.39	66.42	Bedding plane	Interburden
107	63	9	66.97	66.89	67.05	Fracture plane - closed	Interburden
108	4	340	67.06	67.05	67.06	Bedding plane	Interburden
109	5	264	67.78	67.77	67.78	Bedding plane	Interburden
110	3	259	67.85	67.85	67.86	Bedding plane	Interburden
111	2	343	68.13	68.13	68.13	Bedding plane	Interburden
112	1	239	68.15	68.15	68.16	Bedding plane	Interburden
113	67	56	68.44	68.34	68.54	Fracture plane - partially open	Interburden
114	60	61	68.45	68.38	68.53	Fracture plane - partially open	Interburden
115	63	61	68.53	68.44	68.61	Fracture plane - partially open	Interburden
116	64	56	68.56	68.47	68.65	Fracture plane - partially open	Interburden
117	2	342	68.58	68.58	68.58	Bedding plane	Interburden
118	4	33	68.61	68.61	68.61	Bedding plane	Interburden
119	67	79	68.69	68.59	68.80	Fracture plane - partially open	Interburden
120	7	33	68.75	68.74	68.75	Bedding plane	Interburden
121	73	235	69.37	69.20	69.53	Fracture plane - partially open	Interburden
122	71	233	69.47	69.32	69.62	Fracture plane - partially open	Interburden
123	46	245	69.51	69.46	69.56	Fracture plane - discontinuous	Interburden
124	76	240	69.58	69.36	69.80	Fracture plane - partially open	Interburden
125	4	316	69.70	69.70	69.71	Bedding plane	Interburden
126	5	328	69.78	69.77	69.78	Bedding plane	Interburden
127	3	40	70.06	70.06	70.06	Bedding plane	Interburden
128	76	241	70.19	69.99	70.40	Fracture plane - partially open	Interburden
129	74	241	70.20	70.02	70.38	Fracture plane - partially open	Interburden
130	12	263	71.52	71.51	71.53	Bedding plane	Interburden
131	12	256	71.54	71.53	71.55	Bedding plane	Interburden
132	9	300	71.94	71.93	71.94	Bedding plane	Interburden
133	9	280	71.97	71.96	71.98	Bedding plane	Interburden
134	10	273	71.98	71.97	71.99	Bedding plane	Interburden
135	9	272	72.20	72.19	72.21	Bedding plane	Interburden
136	10	268	72.27	72.26	72.28	Bedding plane	Interburden
137	12	265	72.29	72.28	72.30	Bedding plane	Interburden

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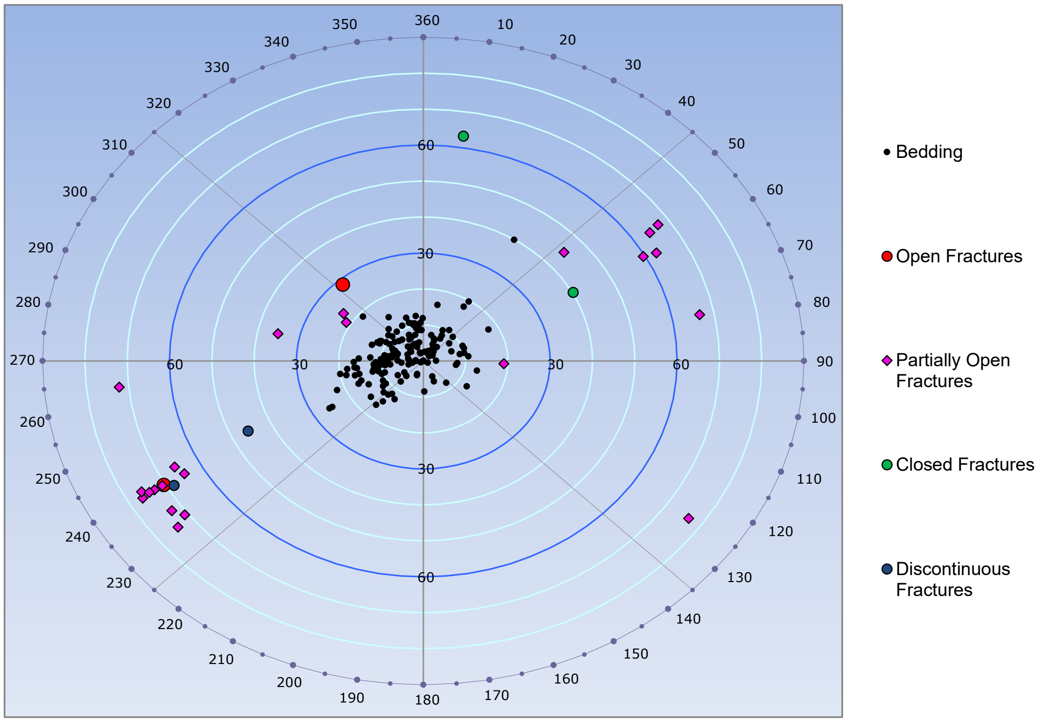
138	8	279	73.58	73.57	73.58	Bedding plane	Interburden
139	12	317	73.69	73.68	73.69	Bedding plane	Interburden
140	9	308	73.72	73.71	73.72	Bedding plane	Interburden
141	7	289	74.15	74.14	74.15	Bedding plane	Interburden
142	6	285	74.17	74.16	74.17	Bedding plane	Interburden
143	8	295	74.74	74.73	74.75	Bedding plane	Interburden
144	13	290	74.82	74.81	74.83	Bedding plane	Interburden
145	11	299	74.83	74.82	74.84	Bedding plane	Interburden
146	15	273	76.35	76.34	76.37	Bedding plane	Interburden
147	16	263	76.38	76.37	76.40	Bedding plane	Interburden
148	16	257	76.39	76.38	76.40	Bedding plane	Interburden
149	11	240	76.55	76.54	76.56	Bedding plane	Interburden
150	11	311	76.79	76.79	76.80	Bedding plane	Interburden
151	10	323	76.81	76.80	76.82	Bedding plane	Interburden
152	9	274	77.53	77.53	77.54	Bedding plane	Interburden
153	19	311	77.64	77.63	77.65	Bedding plane	Interburden
154	12	234	78.90	78.89	78.91	Bedding plane	Interburden
155	11	235	78.92	78.91	78.93	Bedding plane	Interburden
156	19	258	79.29	79.27	79.30	Bedding plane	Interburden
157	17	256	79.31	79.30	79.33	Bedding plane	Interburden
158	10	250	79.51	79.51	79.52	Bedding plane	Interburden
159	8	273	80.15	80.15	80.16	Bedding plane	Interburden
160	7	278	80.17	80.16	80.17	Bedding plane	Interburden
161	8	263	80.24	80.24	80.25	Bedding plane	Interburden
162	11	268	80.30	80.29	80.31	Bedding plane	Interburden
163	6	271	80.60	80.59	80.60	Bedding plane	Interburden
164	8	314	81.80	81.80	81.81	Bedding plane	Interburden
165	2	47	81.90	81.89	81.90	Bedding plane	Interburden
166	3	89	81.91	81.91	81.91	Bedding plane	Interburden
167	77	125	83.20	82.98	83.42	Fracture plane - partially open	Interburden
168	13	227	83.79	83.78	83.81	Bedding plane	Interburden
169	12	221	83.85	83.84	83.86	Bedding plane	Interburden
170	35	282	84.29	84.25	84.32	Fracture plane - partially open	Interburden
171	11	260	85.02	85.01	85.03	Bedding plane	Interburden
172	12	259	85.04	85.03	85.05	Bedding plane	Interburden
173	9	273	85.13	85.13	85.14	Bedding plane	Interburden
174	16	222	85.24	85.22	85.25	Bedding plane	Interburden
175	7	293	85.32	85.32	85.33	Bedding plane	Interburden
176	10	313	86.28	86.28	86.29	Bedding plane	Interburden
177	11	295	86.30	86.30	86.31	Bedding plane	Interburden
178	12	298	86.32	86.31	86.33	Bedding plane	Interburden
179	25	239	86.67	86.65	86.69	Bedding plane	Interburden
180	26	239	86.69	86.67	86.71	Bedding plane	Interburden
181	11	260	87.34	87.33	87.35	Bedding plane	Interburden
182	10	250	87.39	87.38	87.40	Bedding plane	Interburden
183	11	254	87.41	87.40	87.41	Bedding plane	Interburden
184	10	264	87.43	87.42	87.44	Bedding plane	Interburden
185	9	262	87.45	87.44	87.46	Bedding plane	Interburden
186	17	248	87.91	87.90	87.93	Bedding plane	Interburden

FEATURE ID	DIP (DEG)	AZIMUTH (DEG)	MIDPOINT (MBGL)	TOP (M)	BASE (M)	TYPE OF FEATURE	GENERALISED ROCK TYPE
187	16	250	87.93	87.92	87.94	Bedding plane	Interburden
188	22	248	88.26	88.24	88.28	Bedding plane	Interburden
189	16	231	88.35	88.34	88.37	Bedding plane	Interburden
190	20	259	88.96	88.95	88.98	Bedding plane	Interburden
191	18	263	89.00	88.99	89.02	Bedding plane	Interburden
192	16	269	89.02	89.01	89.03	Bedding plane	Interburden
193	16	264	89.05	89.04	89.06	Bedding plane	Interburden
194	14	243	89.50	89.49	89.51	Bedding plane	Interburden
195	17	247	89.67	89.66	89.68	Bedding plane	Interburden
196	12	219	89.99	89.98	90.00	Bedding plane	Interburden
197	15	220	90.00	89.98	90.01	Bedding plane	Interburden
198	6	224	92.11	92.10	92.12	Bedding plane	Interburden
199	4	200	92.12	92.11	92.13	Bedding plane	Interburden
200	7	236	92.15	92.14	92.15	Bedding plane	Interburden
201	8	223	92.16	92.15	92.16	Bedding plane	Interburden
202	13	212	92.17	92.16	92.18	Bedding plane	Interburden
203	18	196	92.45	92.43	92.47	Top of void	Interburden

Figure 1 BH01 circular plan representation of interpreted features



The 173 identified sedimentary features are predominantly bedding planes that appear to range in dip from flat-lying to 40^0. Figures 2 and 3 show the distribution of the planes' dip angles and dip direction with depth.

Table 2 details the variation in the dip angle and dip direction data. Figure 4 shows the dip direction data in a rose diagram with the bedding planes' dip angle and dip direction data shown as histograms in Figures 5 and 6.

The 28 fractures are identified as open (7%), partially open (79%), discontinuous (7%) and closed (7%). The fracture dip angles range from 19 to 77^0.

Table 3 details the variation in the fractures' dip angle and dip direction data. Figure 7 shows the dip direction data in a rose diagram with the fractures' plane dip angle and dip direction data as histograms in Figures 8 and 9.

Figure 2 BH01 feature dip angle data distribution

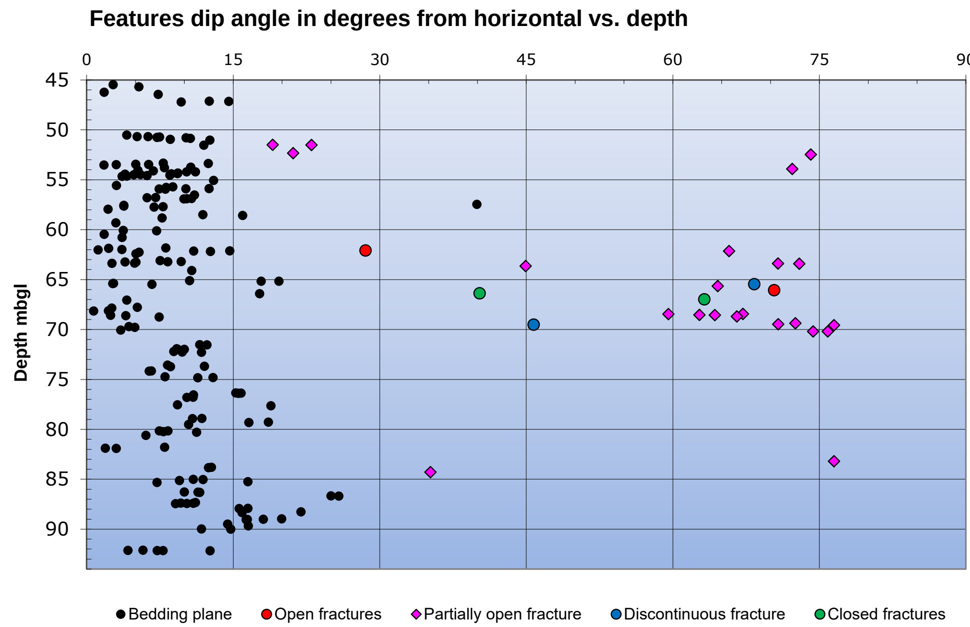


Figure 3 BH01 feature dip direction data distribution

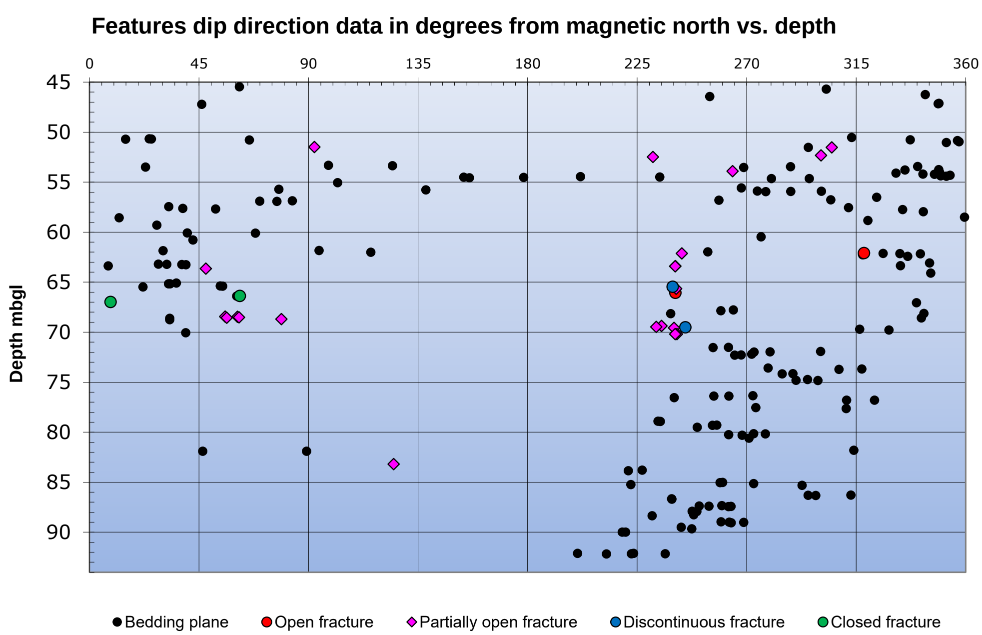


Table 2 BH01 bedding histogram data

Dip Distribution
Total: 173

Dip Range	Count	%
0 to 10	101	58.4
10 to 20	68	39.3
20 to 30	3	1.7
30 to 40	1	0.6
40 to 50	0	0.0
50 to 60	0	0.0
60 to 70	0	0.0
70 to 80	0	0.0
80 to 90	0	0.0

Orientation Distribution
Total: 173

Bearing Range	Count	%
0 to 10	1	0.6
10 to 20	2	1.2
20 to 30	6	3.5
30 to 40	12	6.9
40 to 50	4	2.3
50 to 60	3	1.7
60 to 70	5	2.9
70 to 80	2	1.2
80 to 90	2	1.2
90 to 100	2	1.2
100 to 110	1	0.6
110 to 120	1	0.6
120 to 130	1	0.6
130 to 140	1	0.6
140 to 150	0	0.0
150 to 160	2	1.2
160 to 170	0	0.0
170 to 180	1	0.6
180 to 190	0	0.0
190 to 200	0	0.0
200 to 210	2	1.2
210 to 220	2	1.2
220 to 230	6	3.5
230 to 240	8	4.6
240 to 250	7	4.0
250 to 260	13	7.5
260 to 270	15	8.7
270 to 280	13	7.5
280 to 290	5	2.9
290 to 300	8	4.6
300 to 310	5	2.9
310 to 320	10	5.8
320 to 330	4	2.3
330 to 340	8	4.6
340 to 350	15	8.7
350 to 360	6	3.5

Figure 5 BH01 bedding dip angles histogram

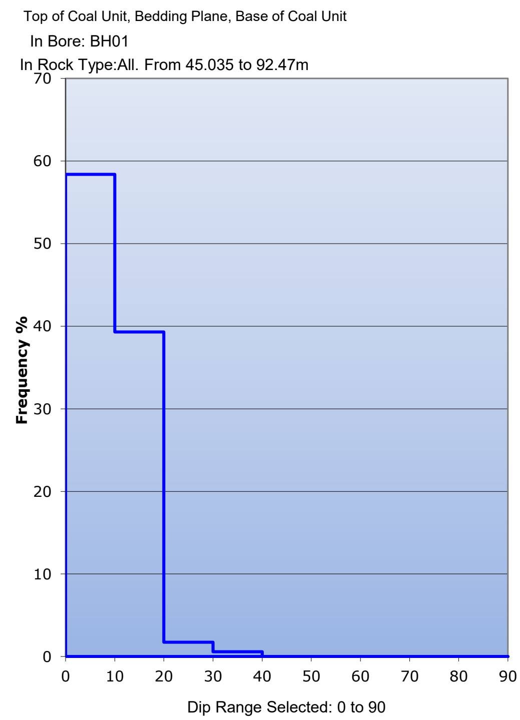


Figure 4 BH01 bedding dip direction data rose diagram

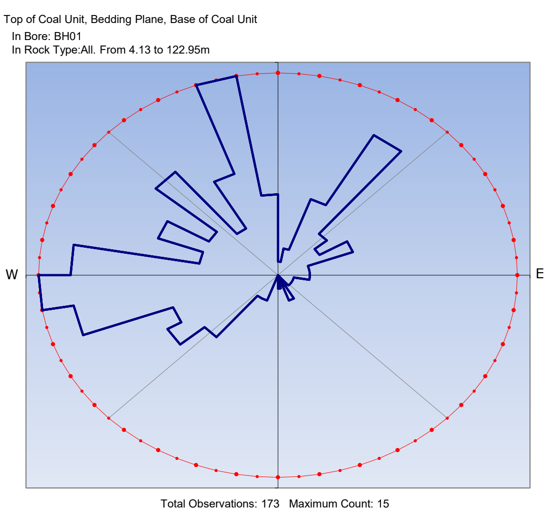


Figure 6 BH01 bedding dip directions histogram

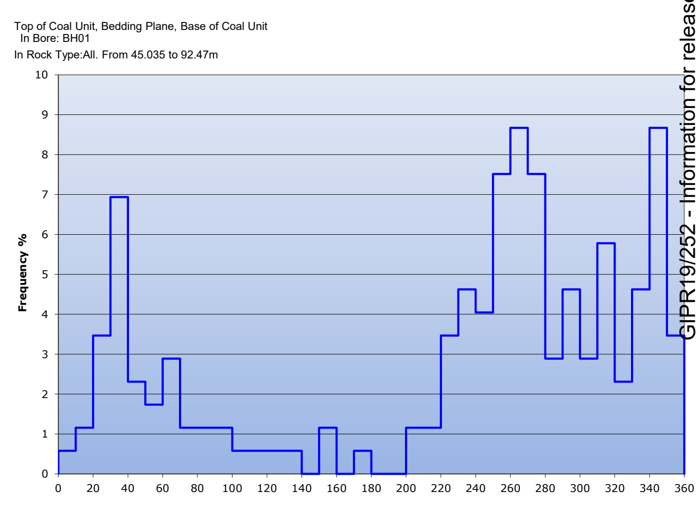


Table 3 BH01 fractures histogram data

Dip Distribution Total: 28			Orientation Distribution Total: 28		
Dip Range	**Count**	**%**	**Bearing Range**	**Count**	**%**
0 to 10	0	0.0	0 to 10	1	3.6
10 to 20	1	3.6	10 to 20	0	0.0
20 to 30	3	10.7	20 to 30	0	0.0
30 to 40	1	3.6	30 to 40	0	0.0
40 to 50	3	10.7	40 to 50	1	3.6
50 to 60	1	3.6	50 to 60	2	7.1
60 to 70	8	28.6	60 to 70	3	10.7
70 to 80	11	39.3	70 to 80	1	3.6
80 to 90	0	0.0	80 to 90	0	0.0
			90 to 100	1	3.6
			100 to 110	0	0.0
			110 to 120	0	0.0
			120 to 130	1	3.6
			130 to 140	0	0.0
			140 to 150	0	0.0
			150 to 160	0	0.0
			160 to 170	0	0.0
			170 to 180	0	0.0
			180 to 190	0	0.0
			190 to 200	0	0.0
			200 to 210	0	0.0
			210 to 220	0	0.0
			220 to 230	0	0.0
			230 to 240	4	14.3
			240 to 250	9	32.1
			250 to 260	0	0.0
			260 to 270	1	3.6
			270 to 280	0	0.0
			280 to 290	1	3.6
			290 to 300	0	0.0
			300 to 310	2	7.1
			310 to 320	1	3.6
			320 to 330	0	0.0
			330 to 340	0	0.0
			340 to 350	0	0.0
			350 to 360	0	0.0

Figure 8 BH01 fractures dip angles histogram

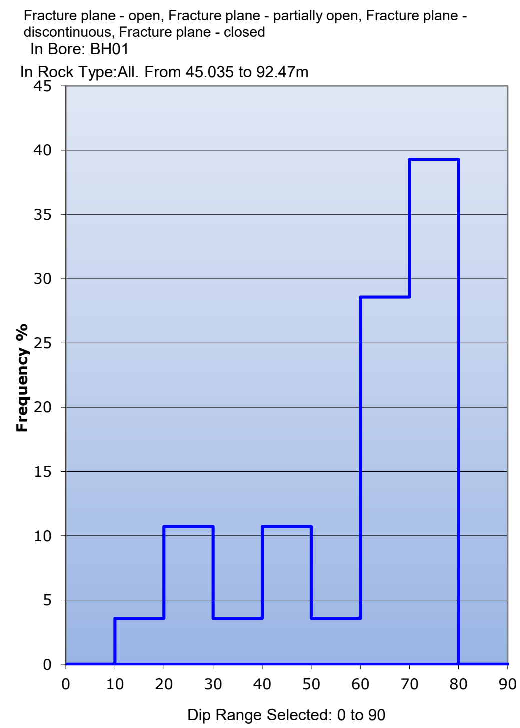


Figure 7 BH01 fractures dip direction data rose diagram

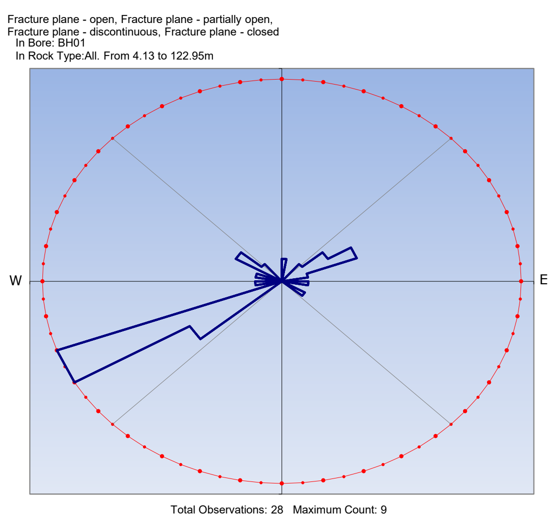
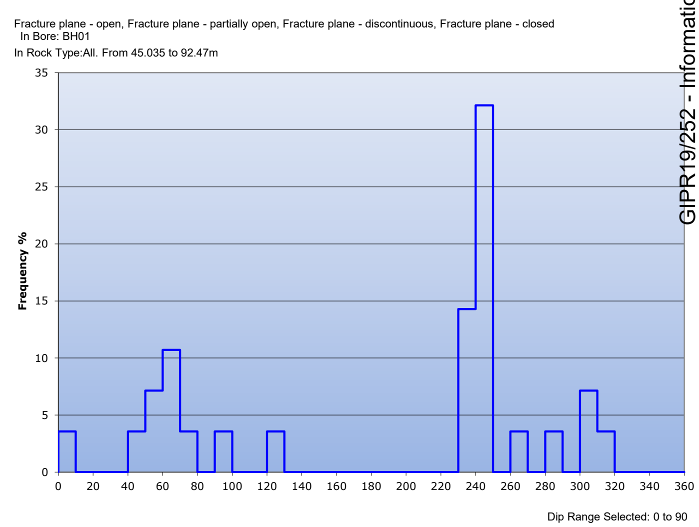


Figure 9 BH01 fractures dip directions histogram



Appendix 1

Appendix 1 *1:20 Interpretation logs – 44.00 to 93.61 mbgl*

GROUNDSEARCH AUSTRALIA

BH01 ATV 1:20

COMPANY	COFFEY GEOTECHNICS	OTHER SERVICES:	DEN TV ON,TV ne	UTM-E	N/A
WELL	BH01 ATV 1:20			UTM-N	N/A
LOCATION/FIELD	NBN OFFICE				
COUNTY					
LOCATION	NEWCASTLE				
SECTION	N/A	TOWNSHIP	N/A	RANGE	N/A
DATE	09/07/18	PERMANENT DATUM			
DEPTH DRILLER	102.1			KB	N/A
LOG BOTTOM	93.610	LOG MEASURED FROM	N/A	DF	N/A
LOG TOP	44.000	DRL MEASURED FROM	N/A	GL	NA
CASING DIAMETER	10.	LOGGING UNIT	T107		
CASING TYPE	STEEL	FIELD OFFICE	RUTHERFORD		
CASING THICKNESS	.5	RECORDED BY	A DAVIS		
BIT SIZE	9.6	BOREHOLE FLUID	0	FILE	PROCESSED
MAGNETIC DECL.	0	RM	N/A	TYPE	9804A
MATRIX DENSITY	2.65	RM TEMPERATURE	N/A	LGDATE	09/07/18
NEUTRON MATRIX	SANDSTONE	MATRIX DELTA T	177	LGTIME	16:15
				THRESH	99999

X4 GAINS
220504

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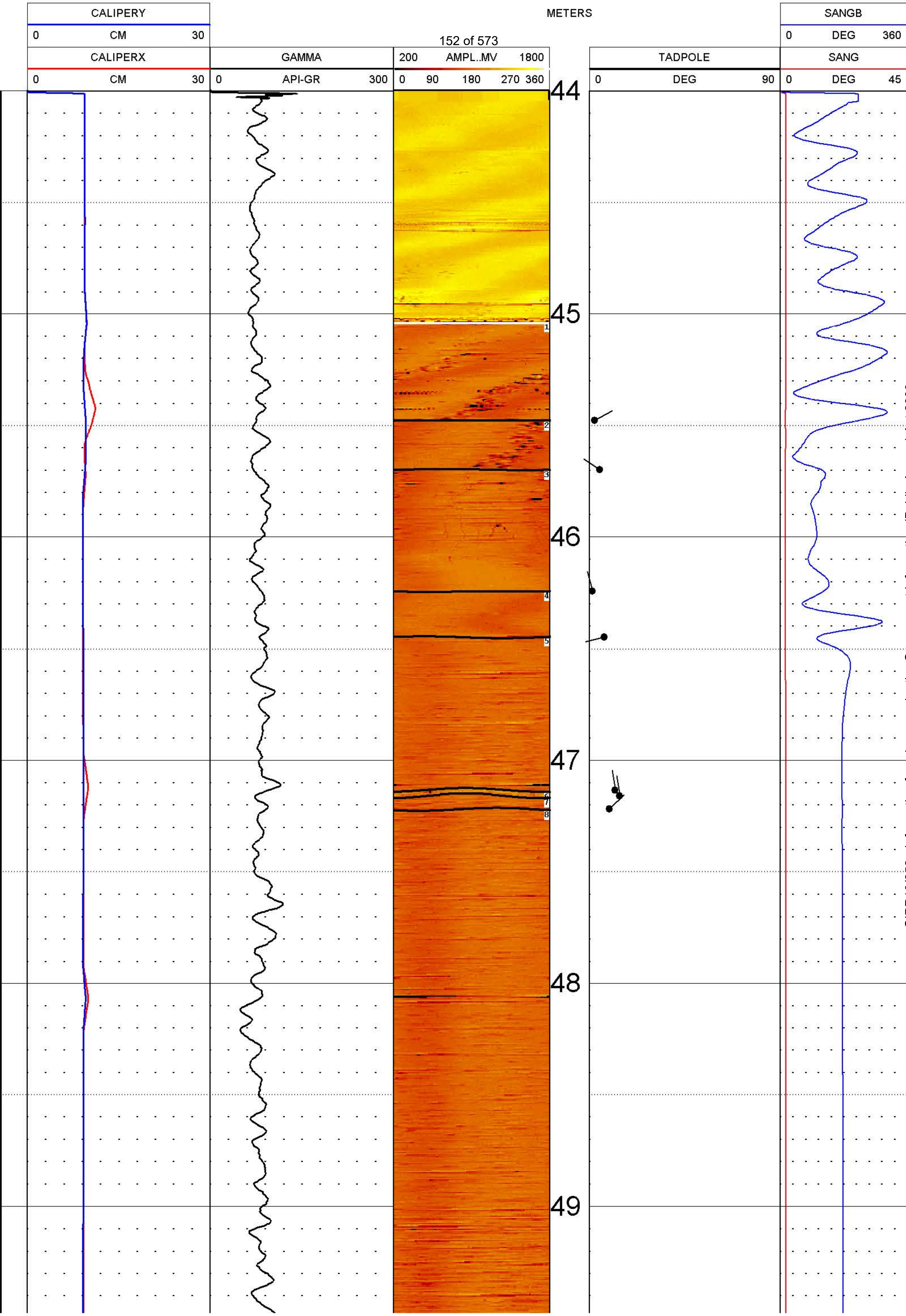
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CALIPERX
0 CM 30
GAMMA
0 API-GR 300
METERS
200 AMPL..MV 1800
0 90 180 270 360
TADPOLE
0 DEG 90
SANGB
0 DEG 360
SANG
0 DEG 45
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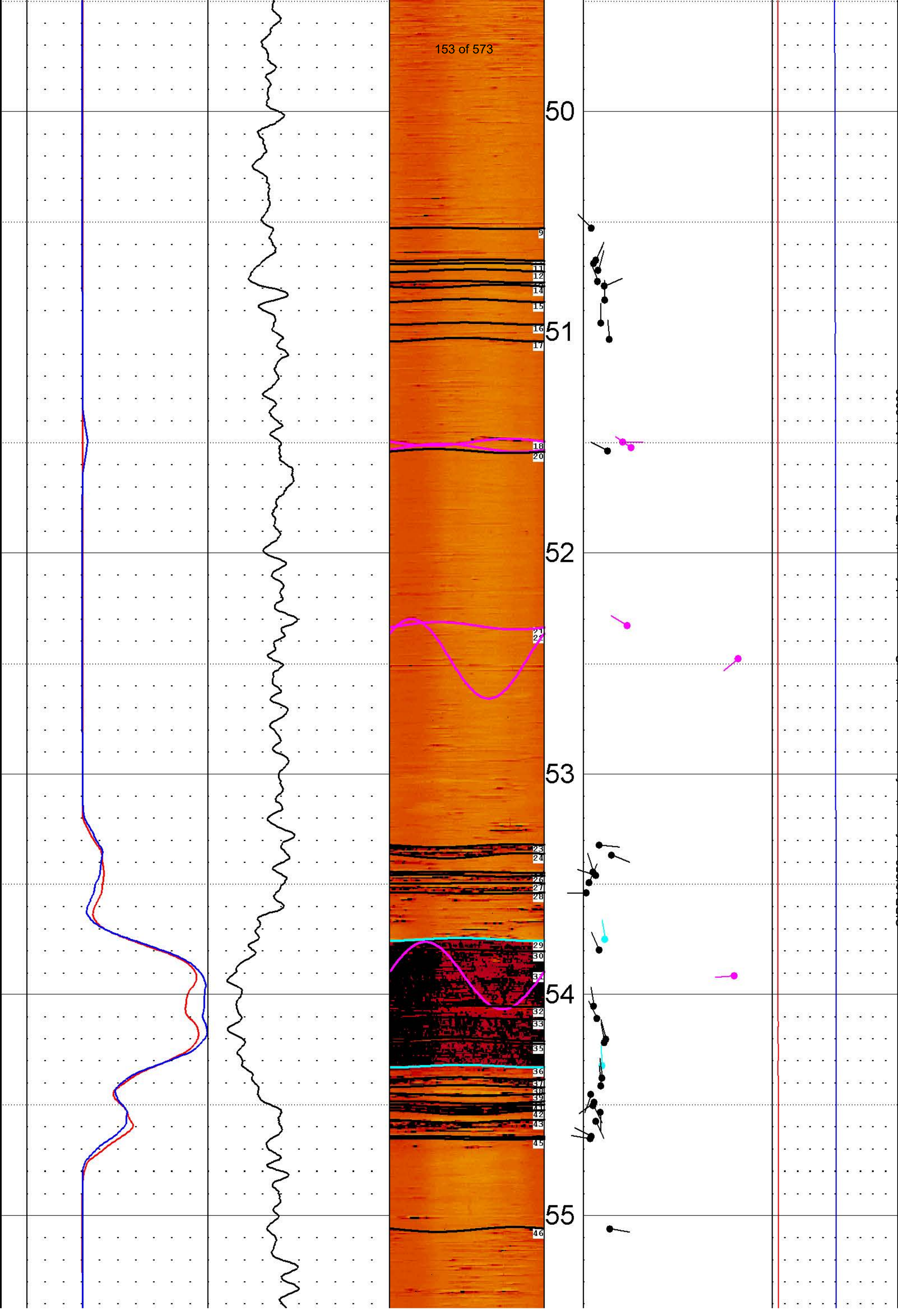
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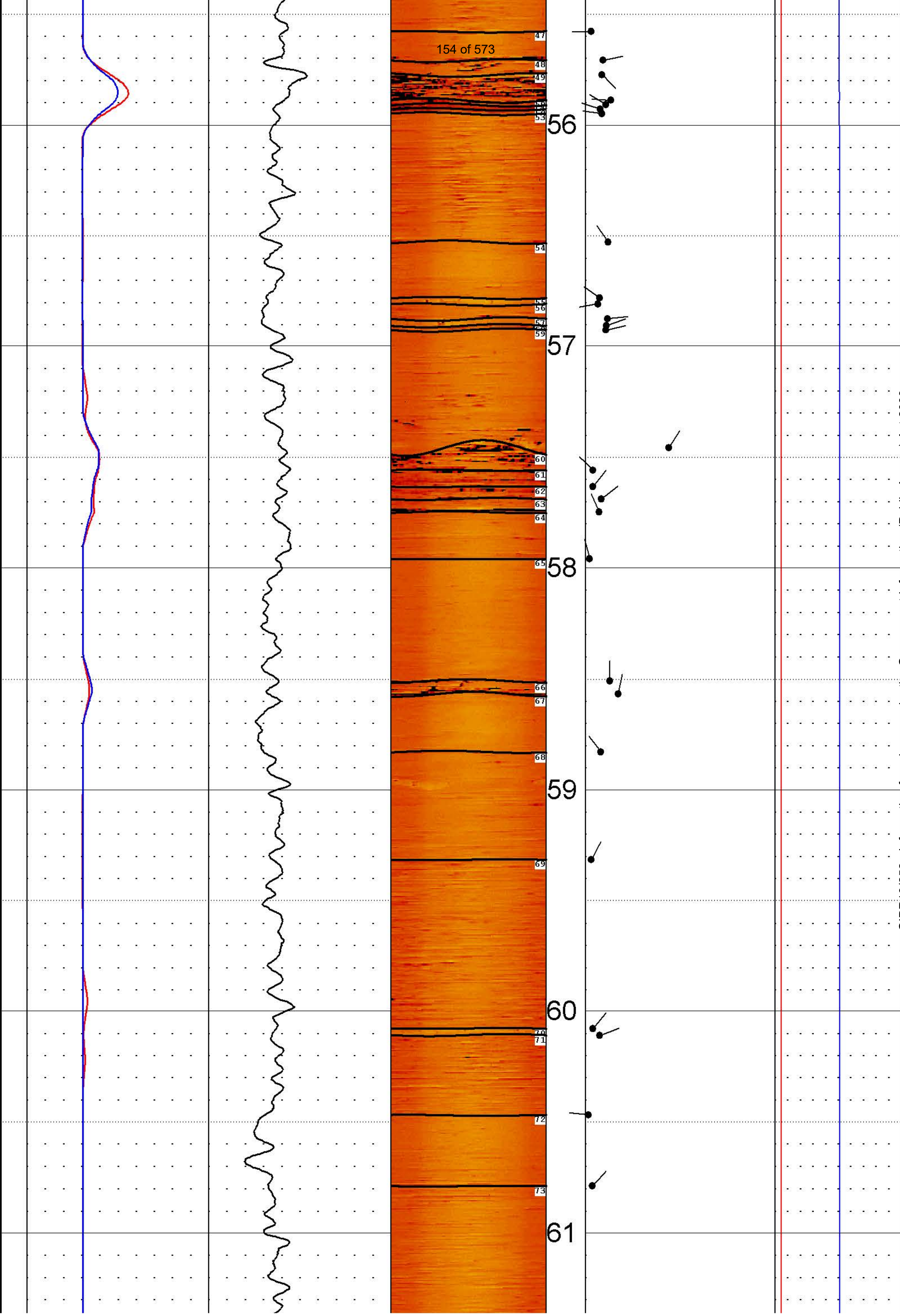

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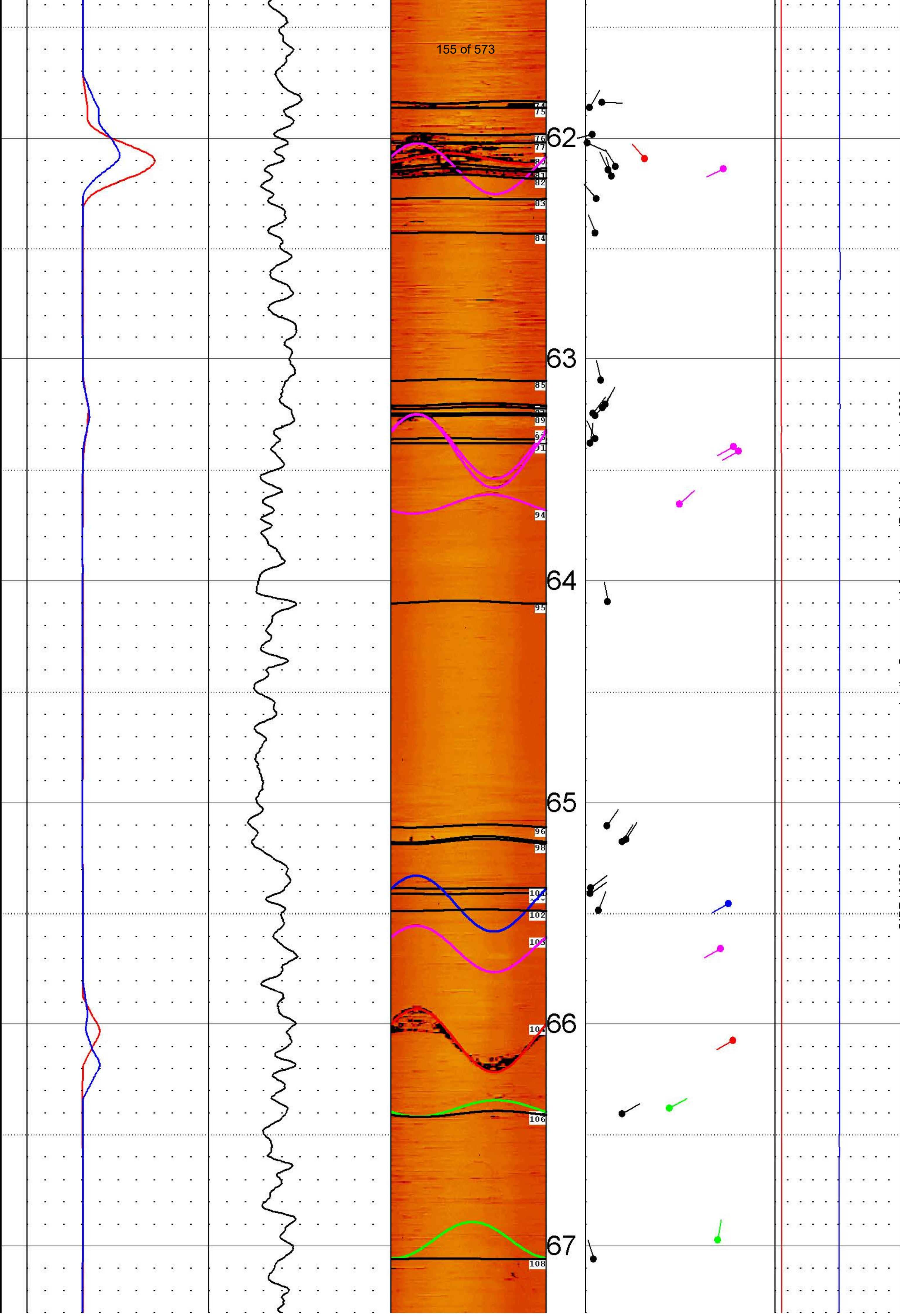
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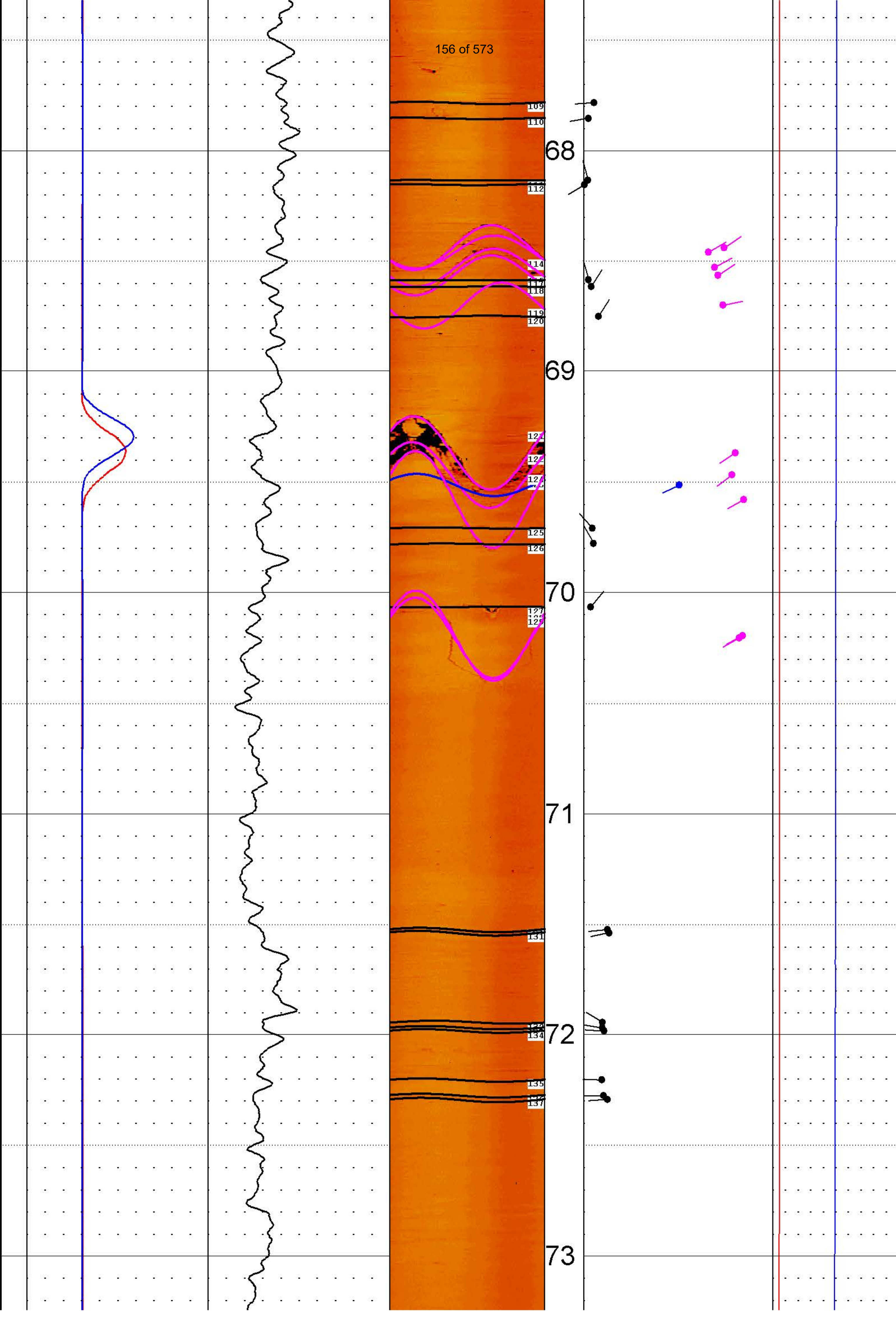
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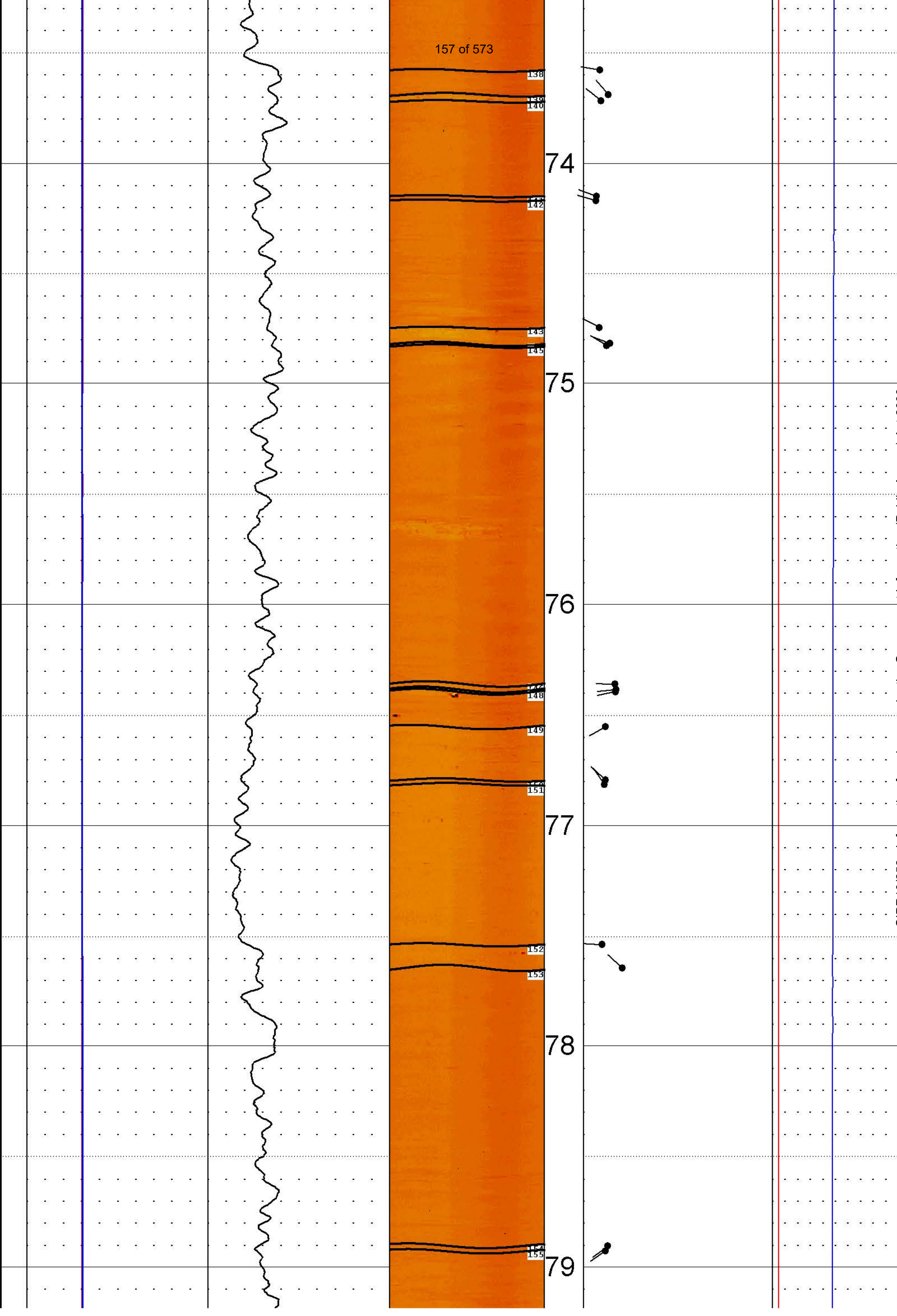
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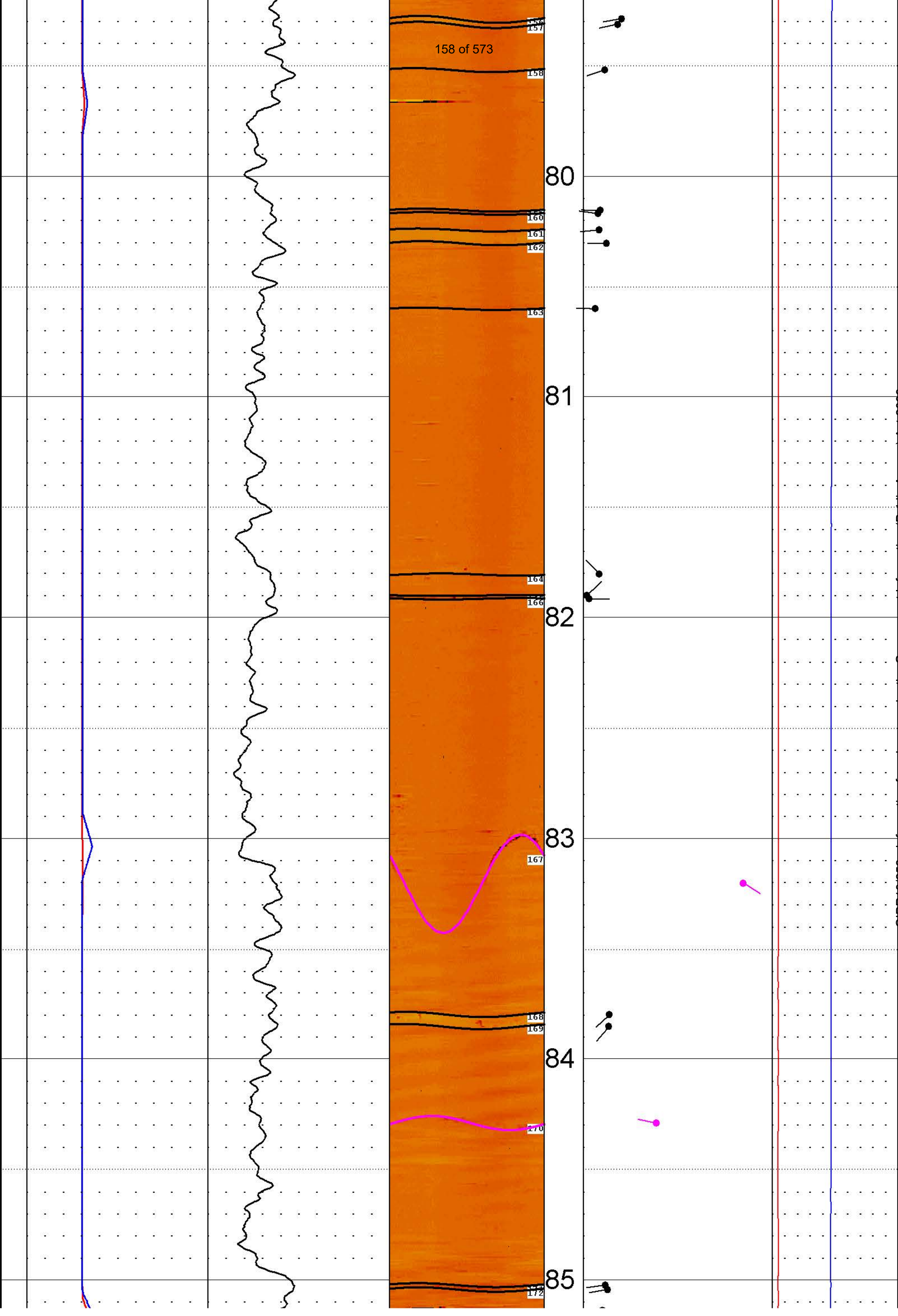
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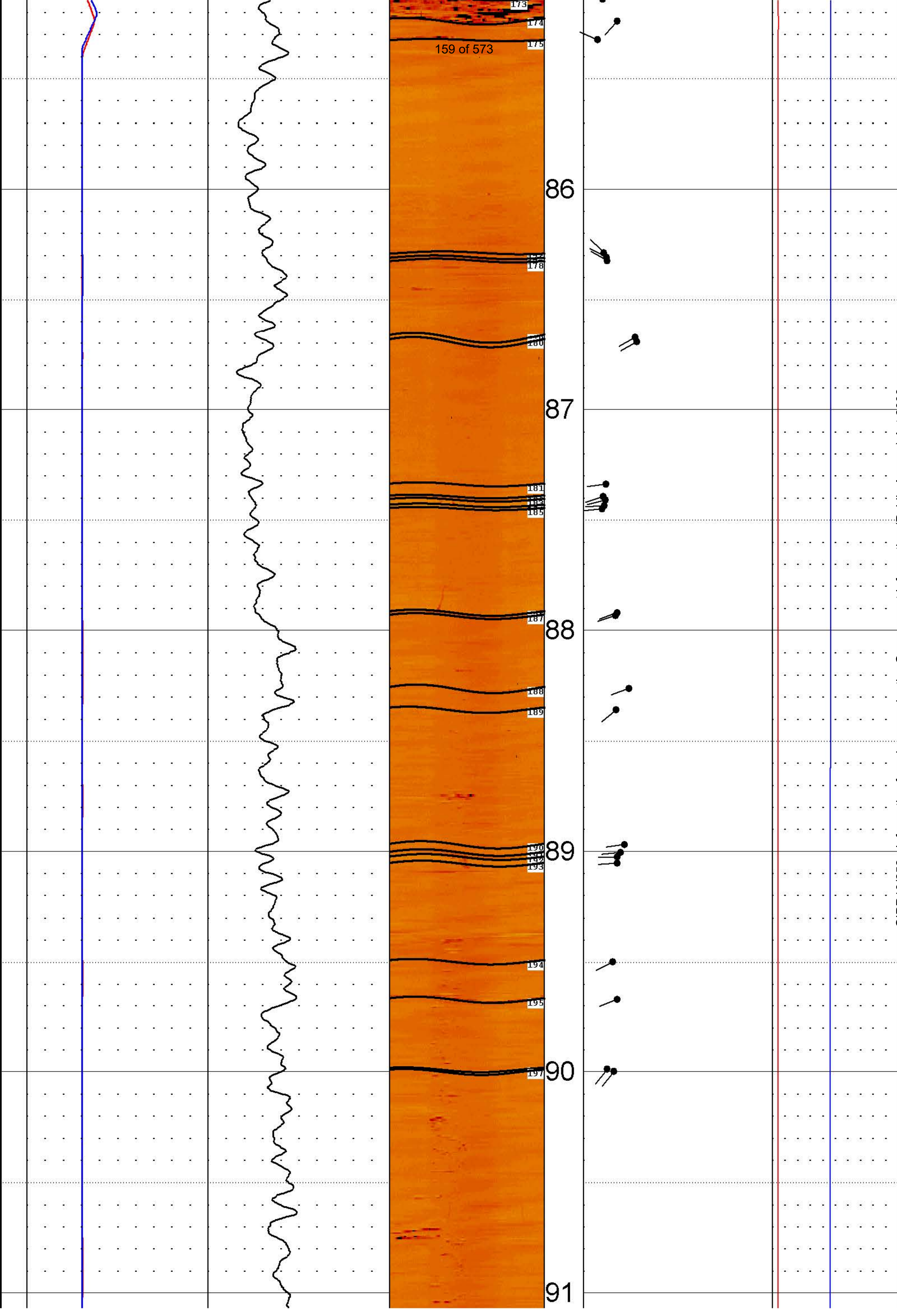

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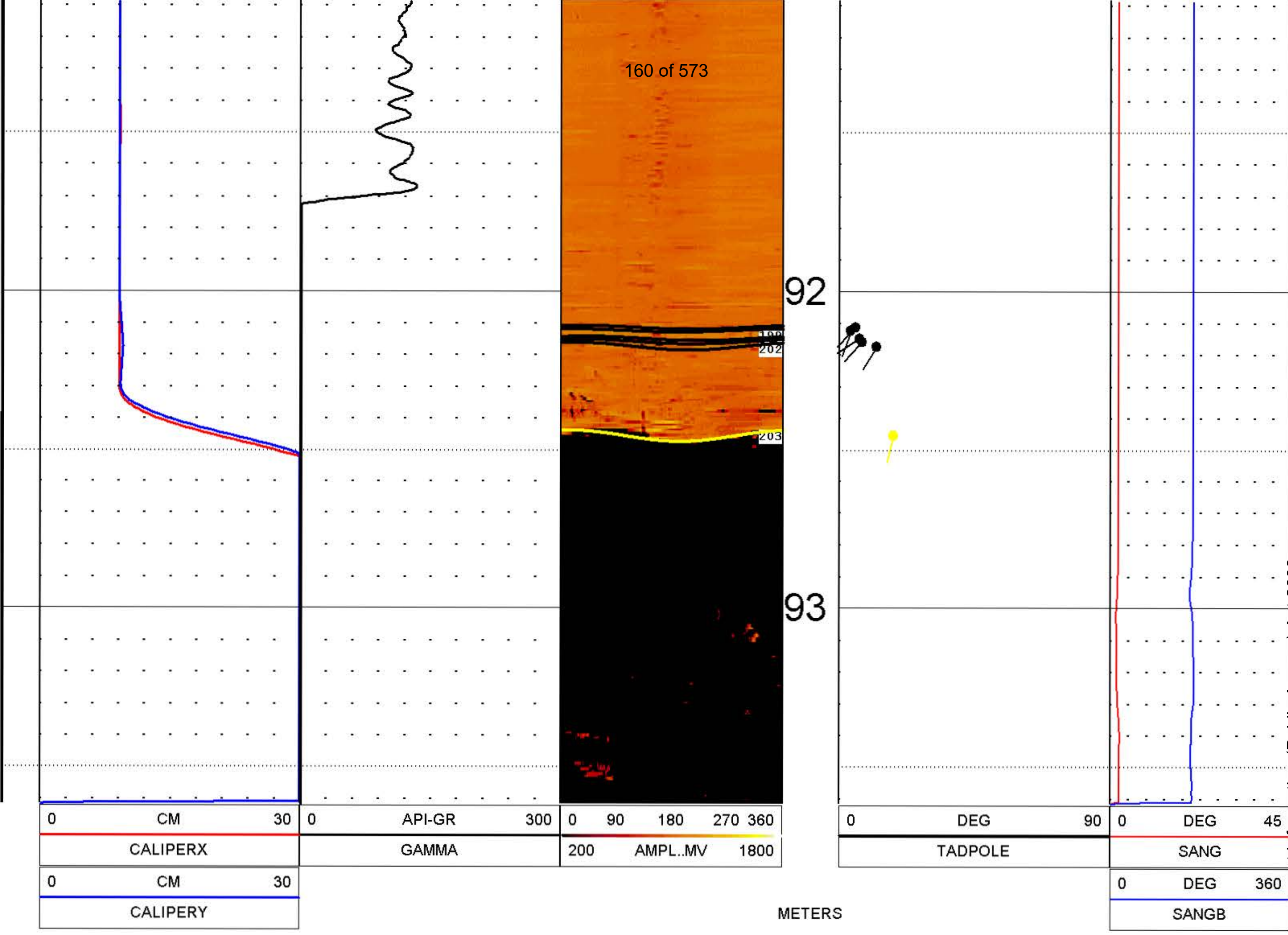
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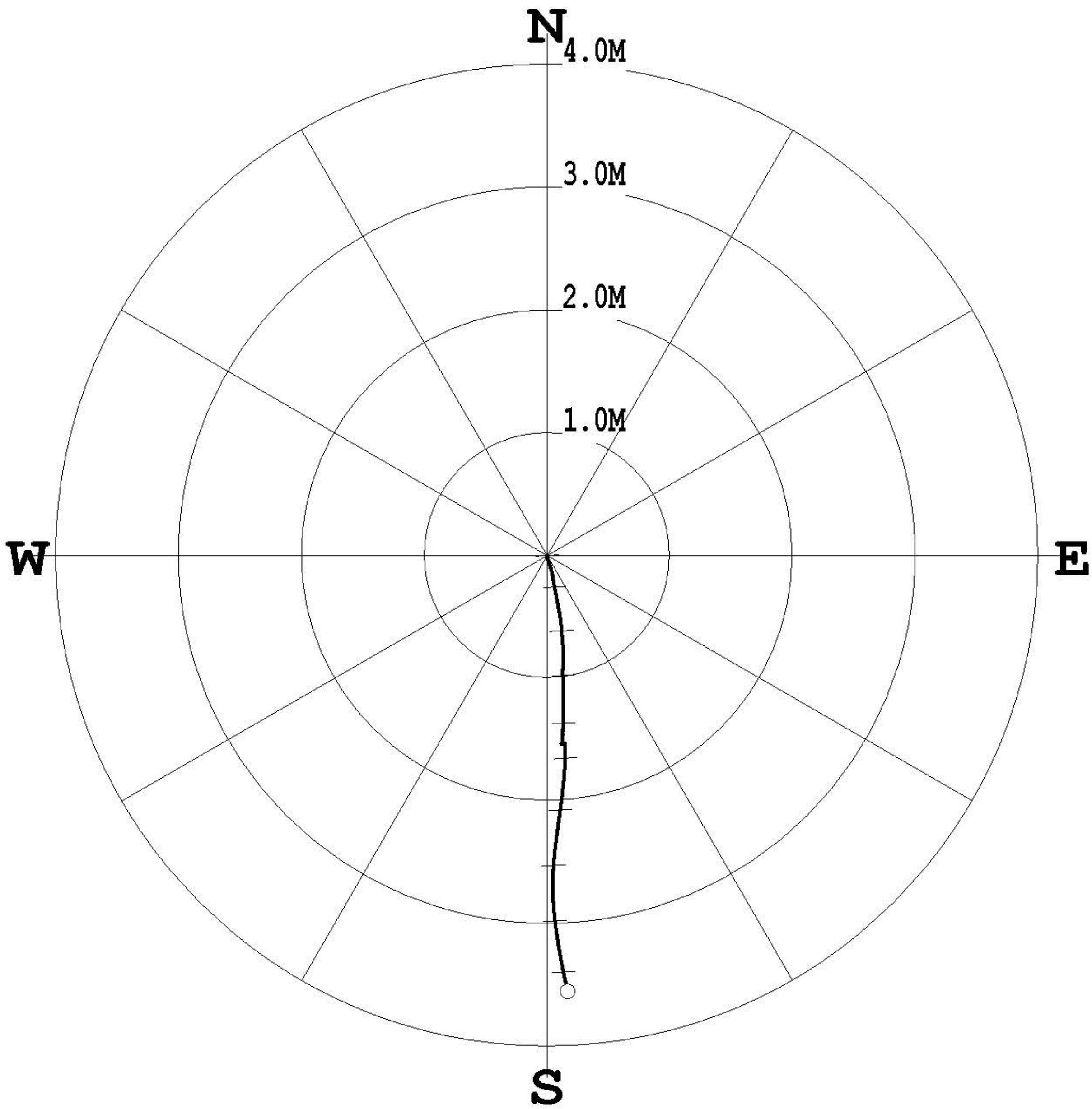
93
199
202
203
0 CM 30
CALIPERX
0 CM 30
CALIPERY
0 API-GR 300
GAMMA
0 90 180 270 360
200 AMPL..MV 1800
METERS
0 DEG 90
TADPOLE
0 DEG 45
SANG
0 DEG 360
SANGB

PLAN VIEW
COMPU-LOG DEVIATION

CLIENT: COFFEY GEOTECH
LOCATION: LINGARD
HOLE ID: BOREHOLE01#2 TELEVIEWER
DATE OF LOG: 09/14/18
PROBE: 9804A 4402

MAG DECL: 0.0

SCALE: 1 M/CM
TRUE DEPTH: 94.18 M
AZIMUTH: 177.3
DISTANCE: 3.6 M
+ = 10 M INCR
○ = BOTTOM OF HOLE



* * * * * * * COMPU-LOG - VERTICAL DEVIATION * * * * * * *

CLIENT : COFFEY GEOTECH
FIELD OFFICE : RUTHERFORD
DATA FROM : N/A
MAG. DECL. : 0.000
HOLE ID. : BOREHOLE01#2
DATE OF LOG : 09/14/18
PROBE : 9804A , 4402
DEPTH UNITS : METERS
LOG: BOREHOLE01#2TELEVIEWER_09-14-18_13-08_9804A_005_0.00_94.25_DEVI.log

CABLE DEPTH	TRUE DEPTH	NORTH DEV.	EAST DEV.	DISTANCE	AZIMUTH	SANG	SANGB
0.00	-0.00	-0.00	0.00	0.0	177.5	0.3	177.5
10.00	10.00	-0.26	0.06	0.3	166.8	2.1	167.9
20.00	19.99	-0.61	0.11	0.6	169.4	1.8	180.2
30.00	29.98	-0.98	0.13	1.0	172.5	2.6	175.0
40.00	39.98	-1.37	0.13	1.4	174.5	2.2	181.8
50.00	49.97	-1.65	0.15	1.7	174.9	2.3	181.3
60.00	59.96	-2.07	0.11	2.1	177.0	2.6	187.9
70.00	69.95	-2.52	0.05	2.5	178.8	2.7	184.2
80.00	79.94	-2.97	0.06	3.0	178.8	2.5	173.8
90.00	89.93	-3.39	0.13	3.4	177.8	2.3	168.6
94.25	94.17	-3.55	0.17	3.6	177.3	2.5	165.4

GROUNDSEARCH AUSTRALIA

BH01DENSITY_C 1 20

COMPANY	: COFFEY GEOTECH	OTHER SERVICES:	DEN		
WELL	: BH01DENSITY_C 1 20				
LOCATION/FIELD	: NBN DEV				
COUNTY	:				
LOCATION	: NEWCASTLE				
SECTION	: N/A	TOWNSHIP	: N/A	RANGE	: N/A
DATE	: 09/07/18	PERMANENT DATUM	: -1.2		
DEPTH DRILLER	: 102.1			KB	: N/A
LOG BOTTOM	: 100.91	LOG MEASURED FROM:	N/A	DF	: N/A
LOG TOP	: 0.00	DRL MEASURED FROM:	N/A	GL	: NA
CASING DIAMETER	: 10.	LOGGING UNIT	: T107		
CASING TYPE	: STEEL	FIELD OFFICE	: RUTHERFORD		
CASING THICKNESS:	.5	RECORDED BY	: A DAVIS		
BIT SIZE	: 9.60	BOREHOLE FLUID	: 0	FILE	: PROCESSED
MAGNETIC DECL.	: 0	RM	: N/A	TYPE	: 9239B
MATRIX DENSITY	: 2.65	RM TEMPERATURE	: N/A	LGDATE:	09/07/18
NEUTRON MATRIX	: SANDSTONE	MATRIX DELTA T	: 177	LGTIME :	13:46:
				THRESH:	99999

IN RODS (corrected for steel)
220504

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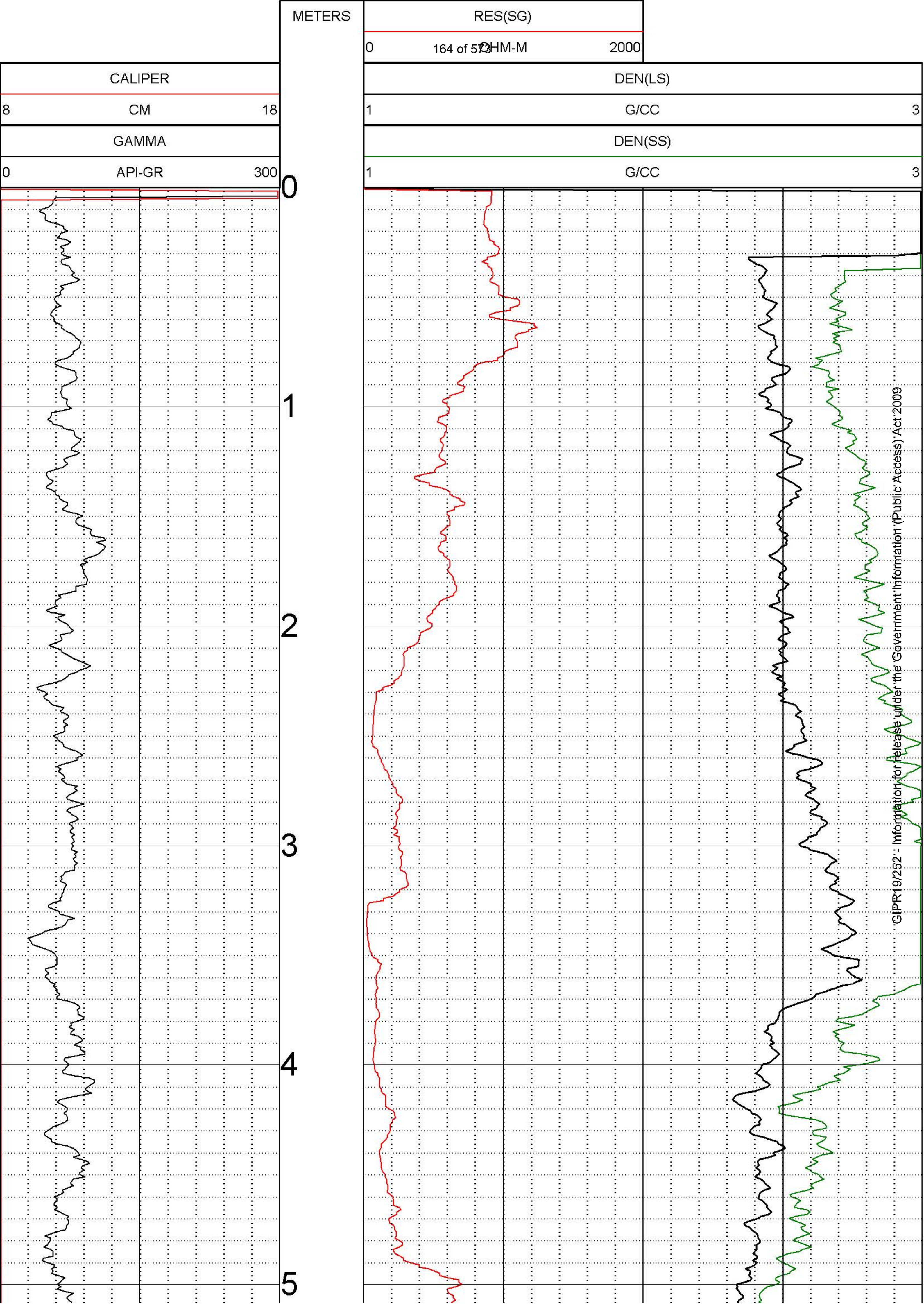
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CALIPER
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GAMMA
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DEN(SS)
1 G/CC 3
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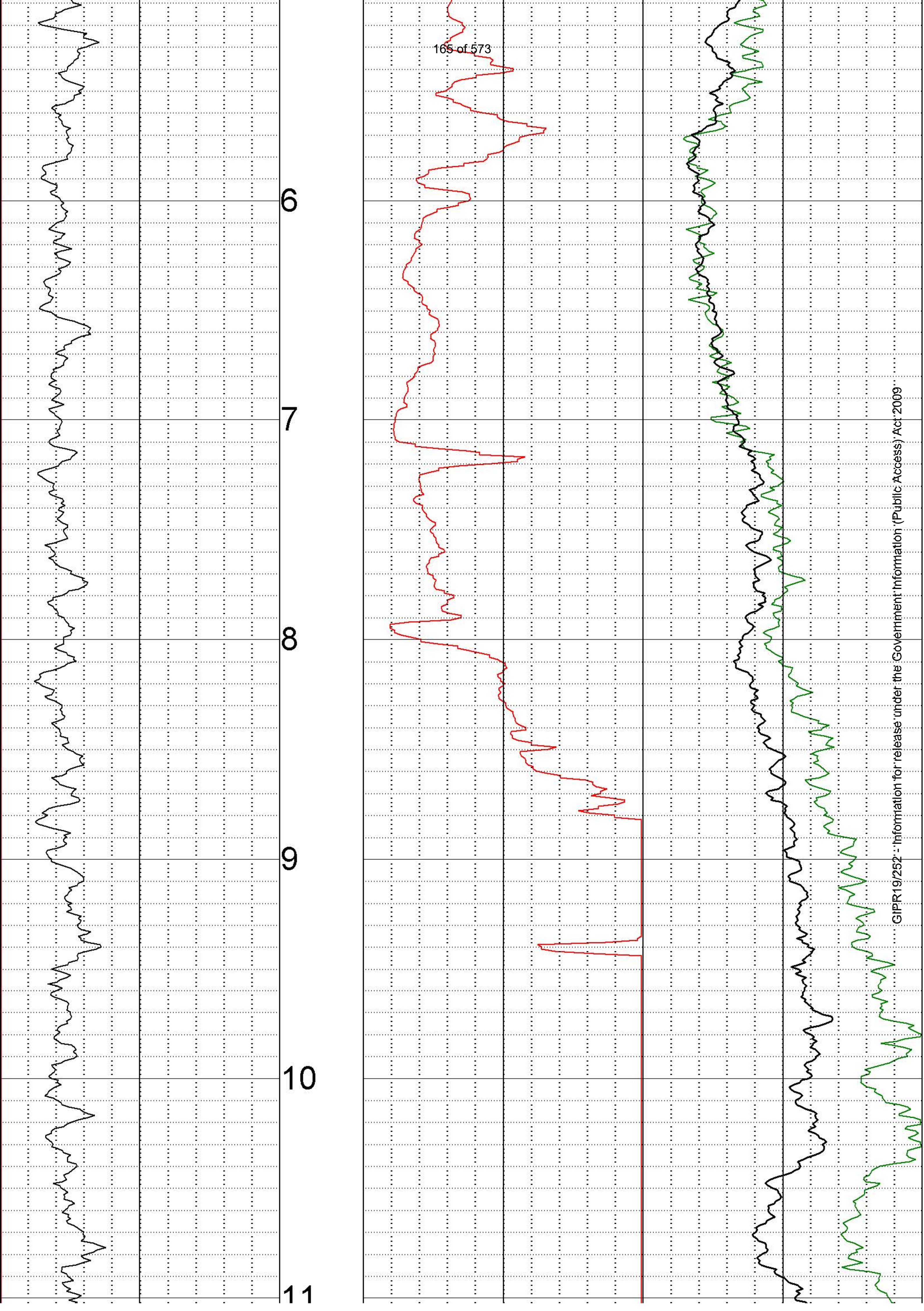
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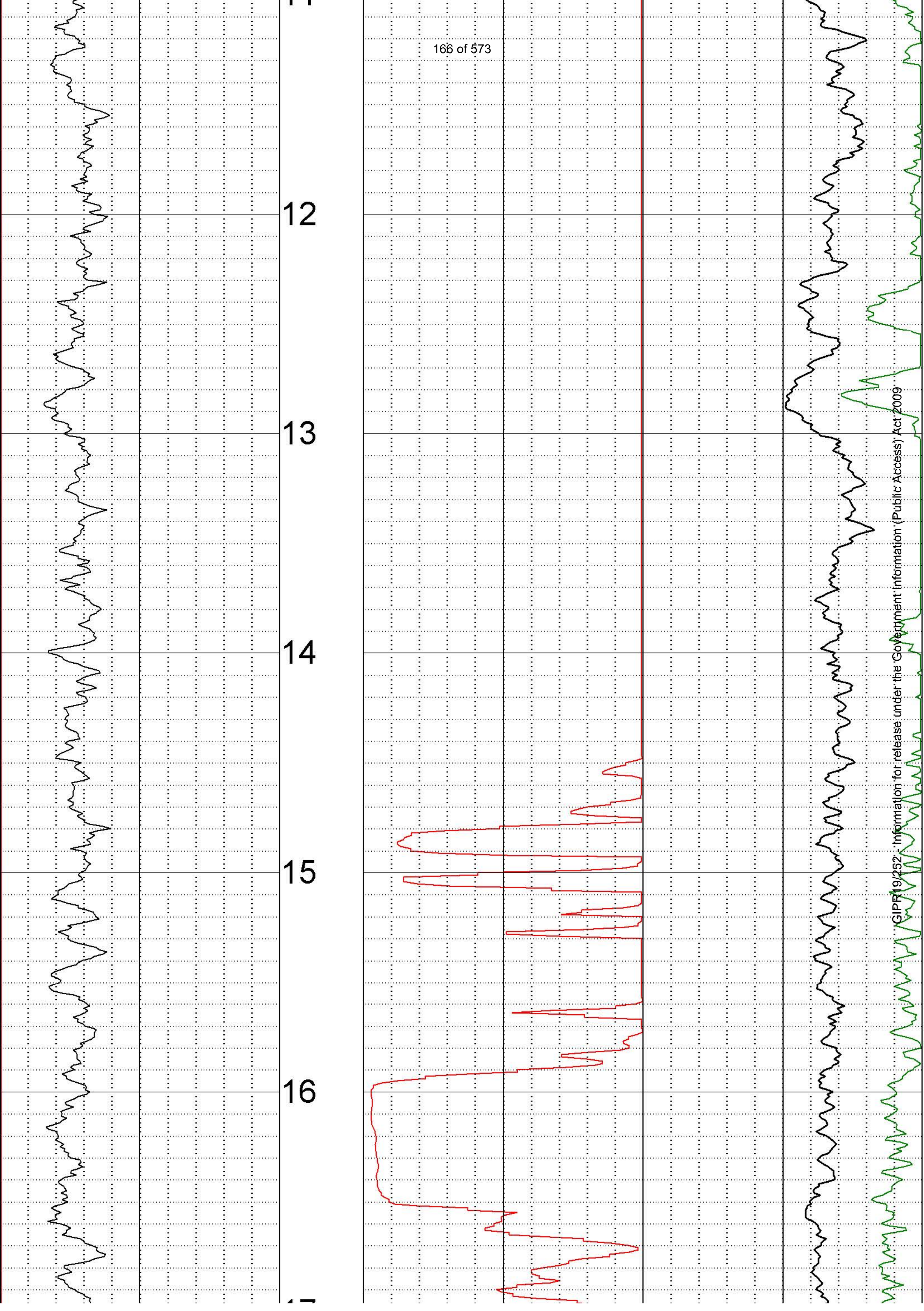
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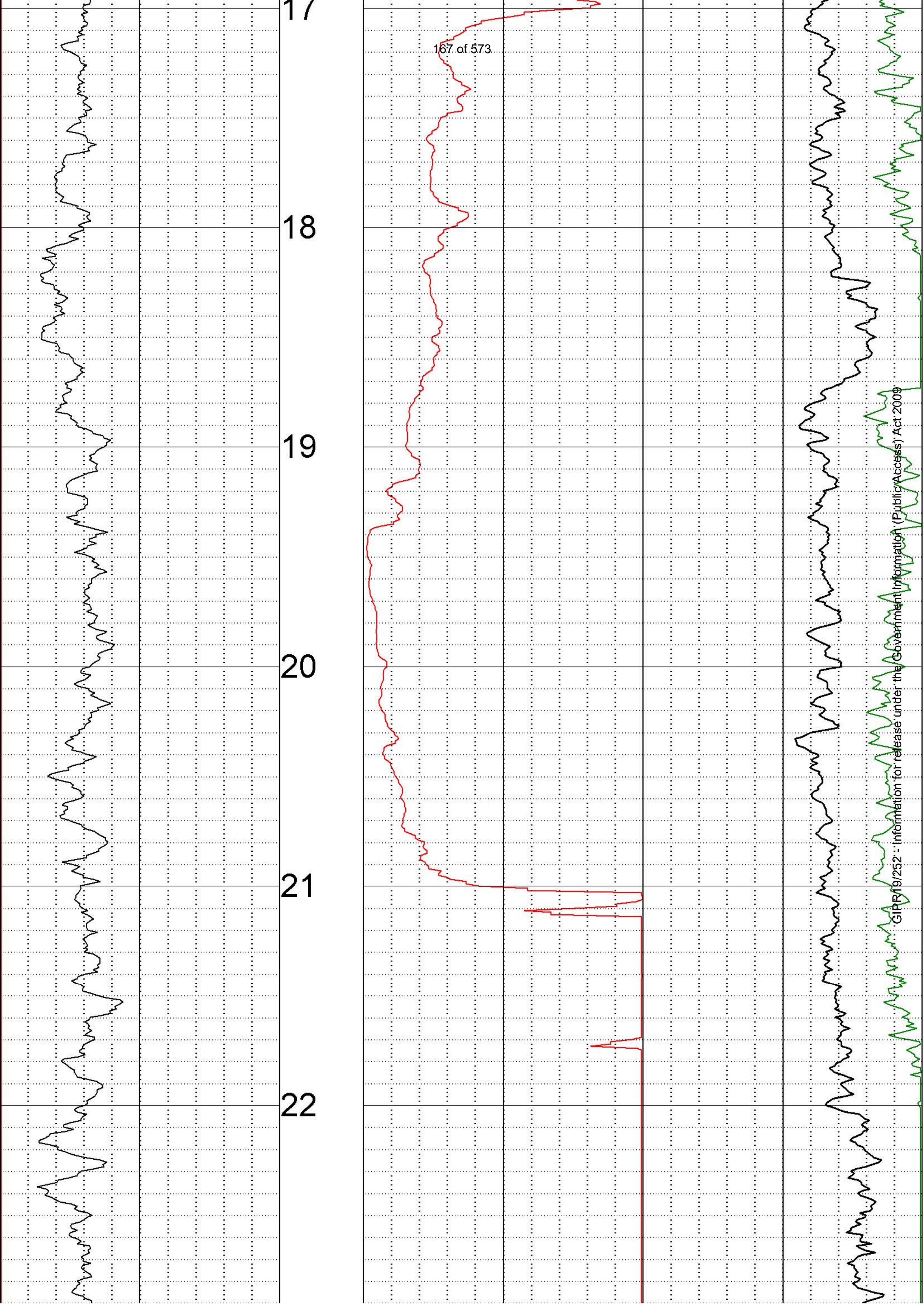
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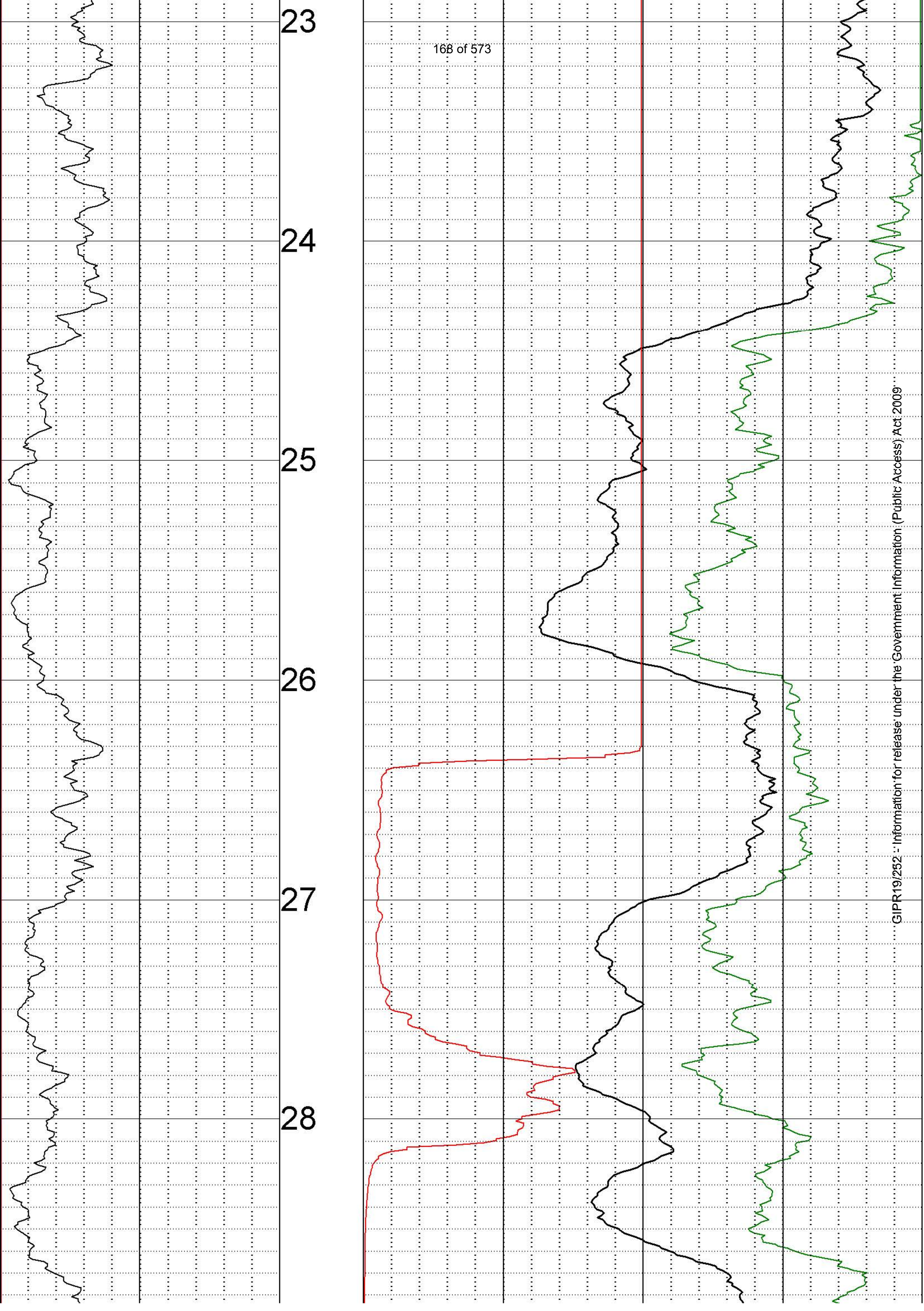
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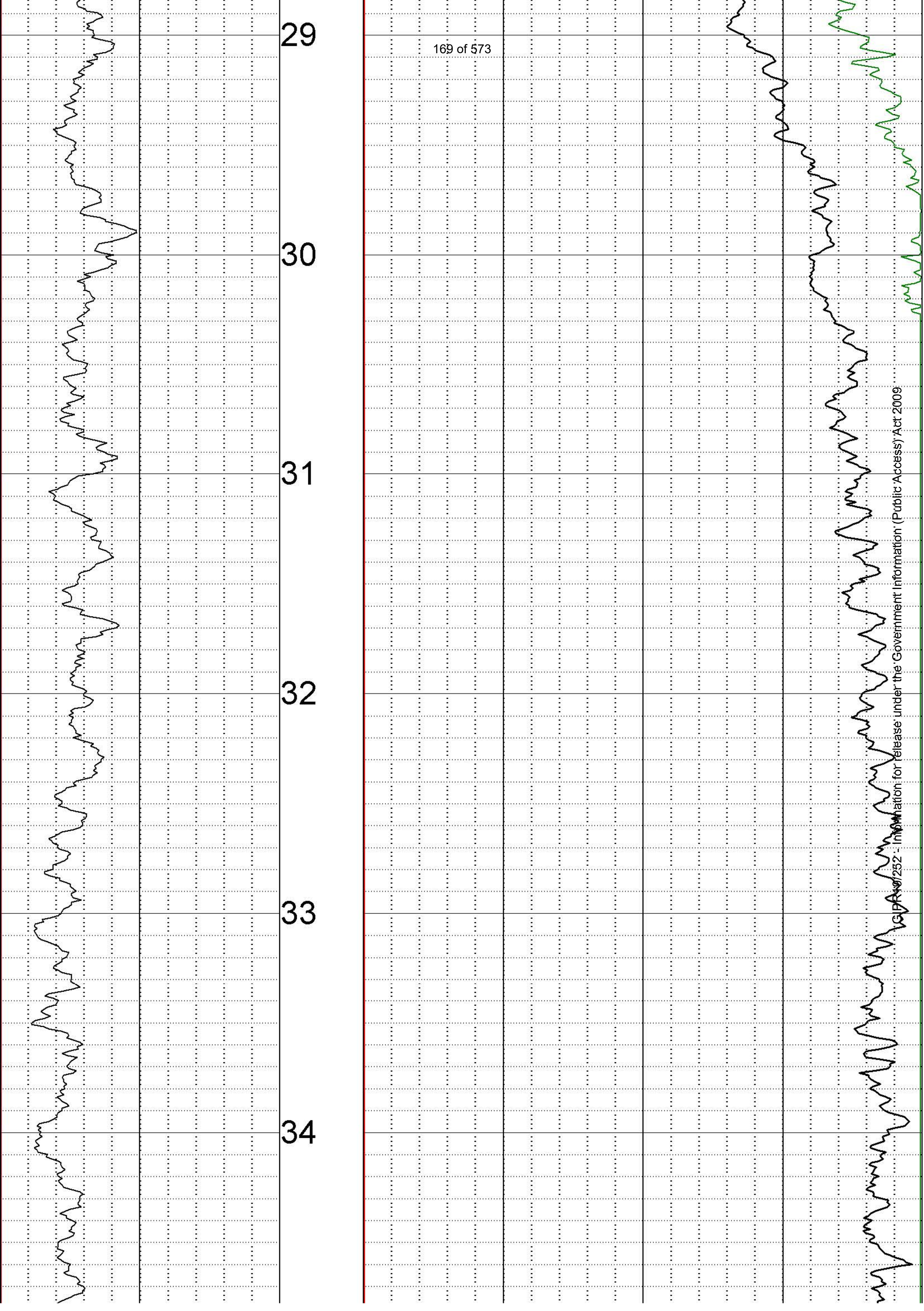
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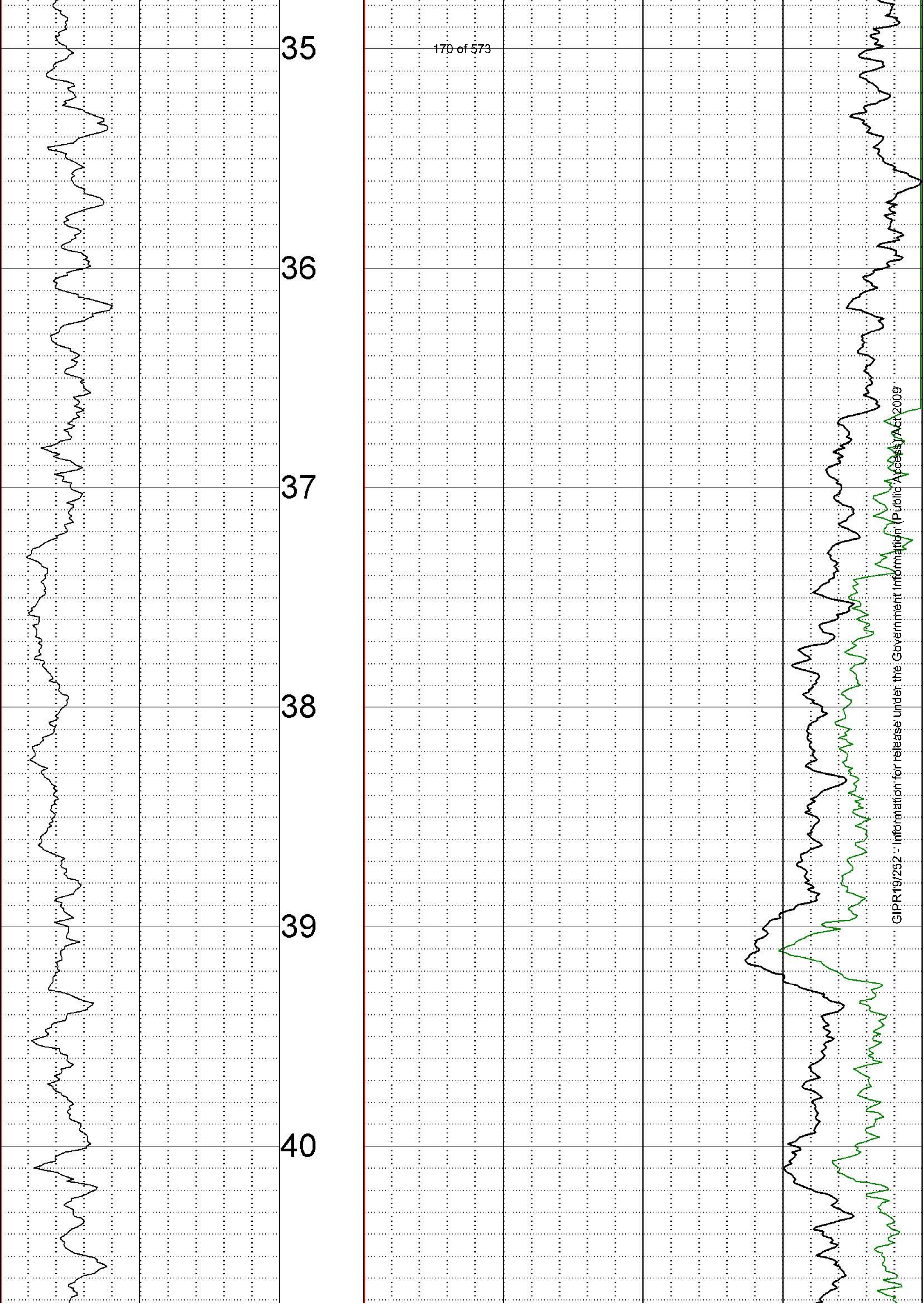
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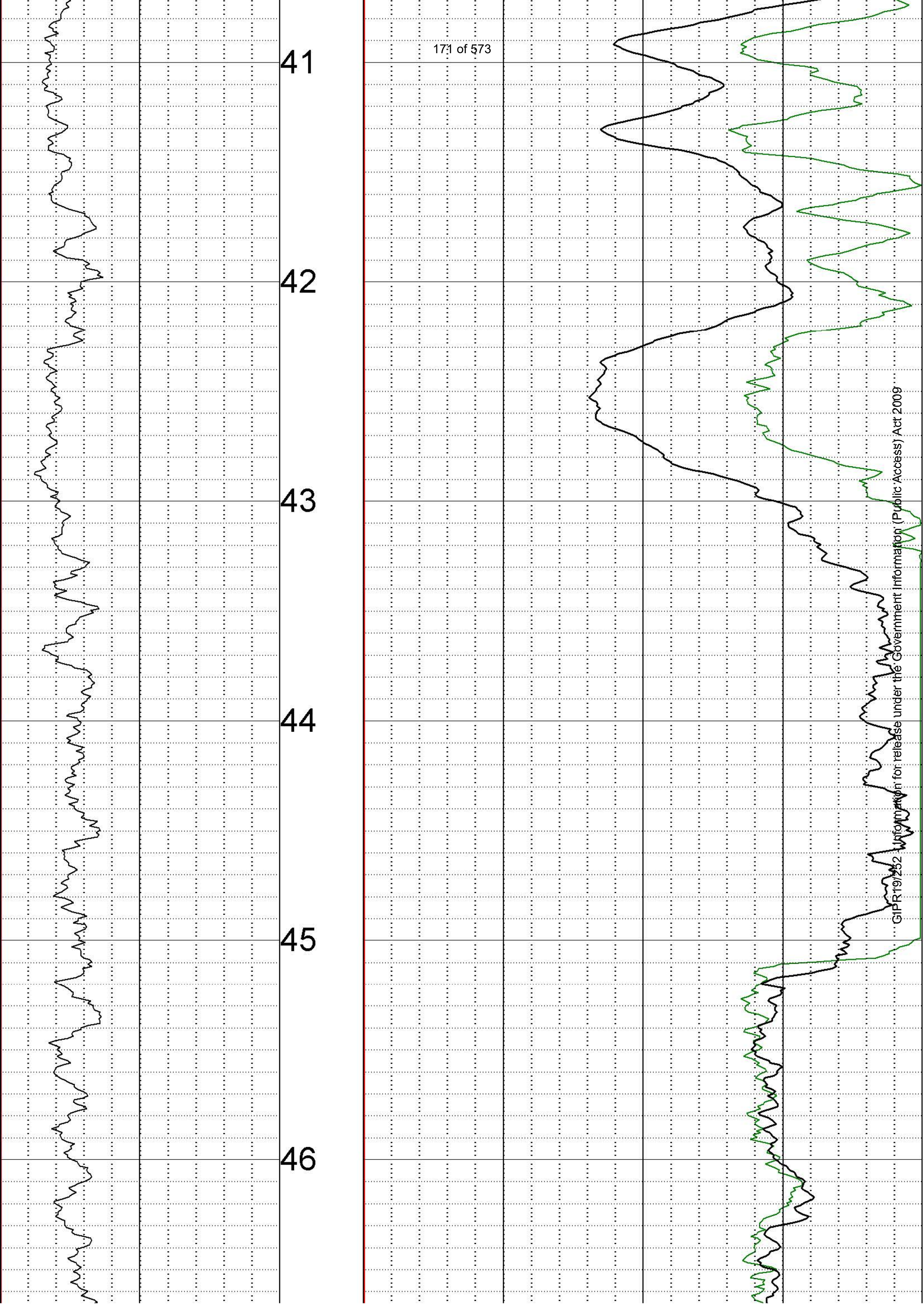
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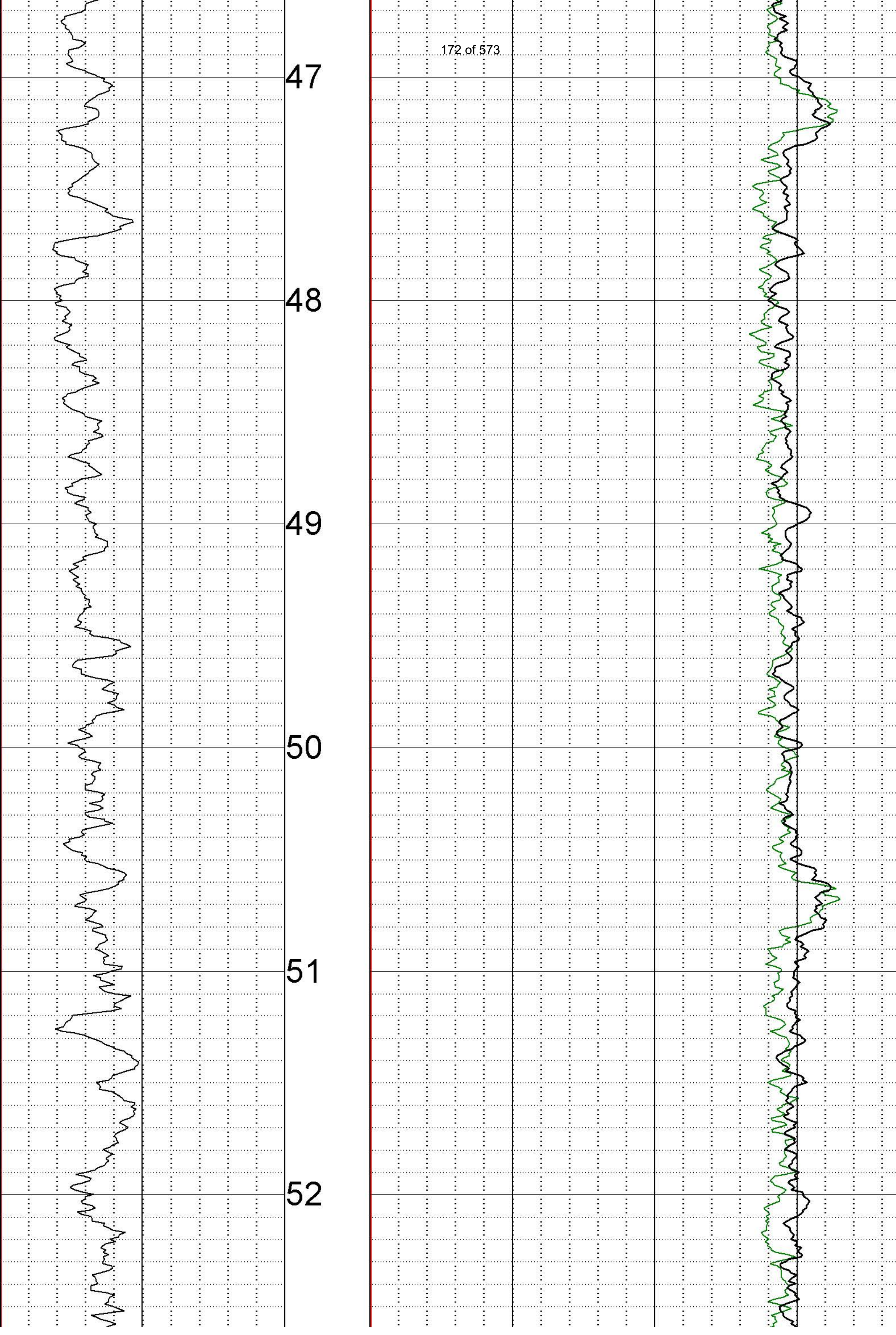

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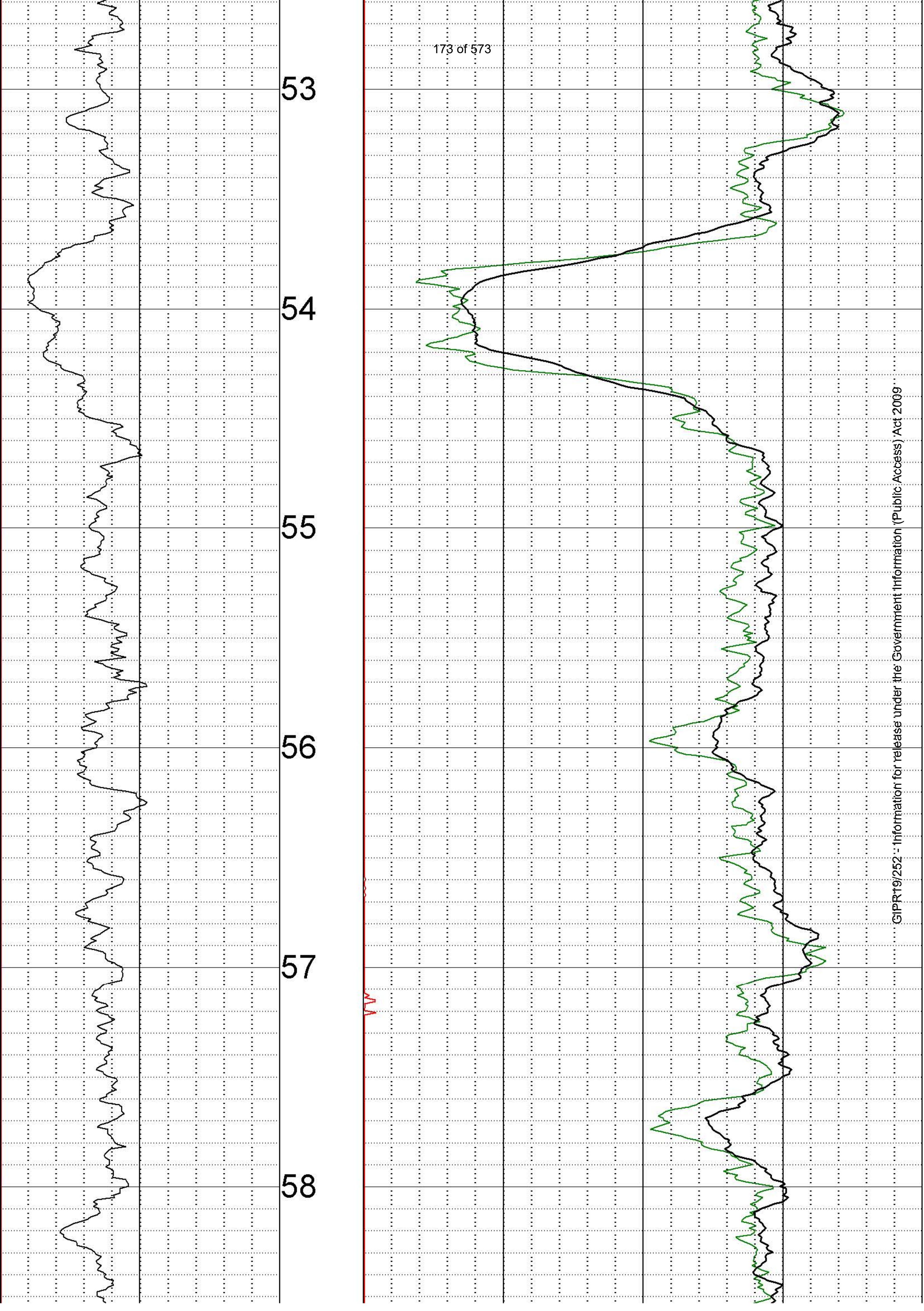
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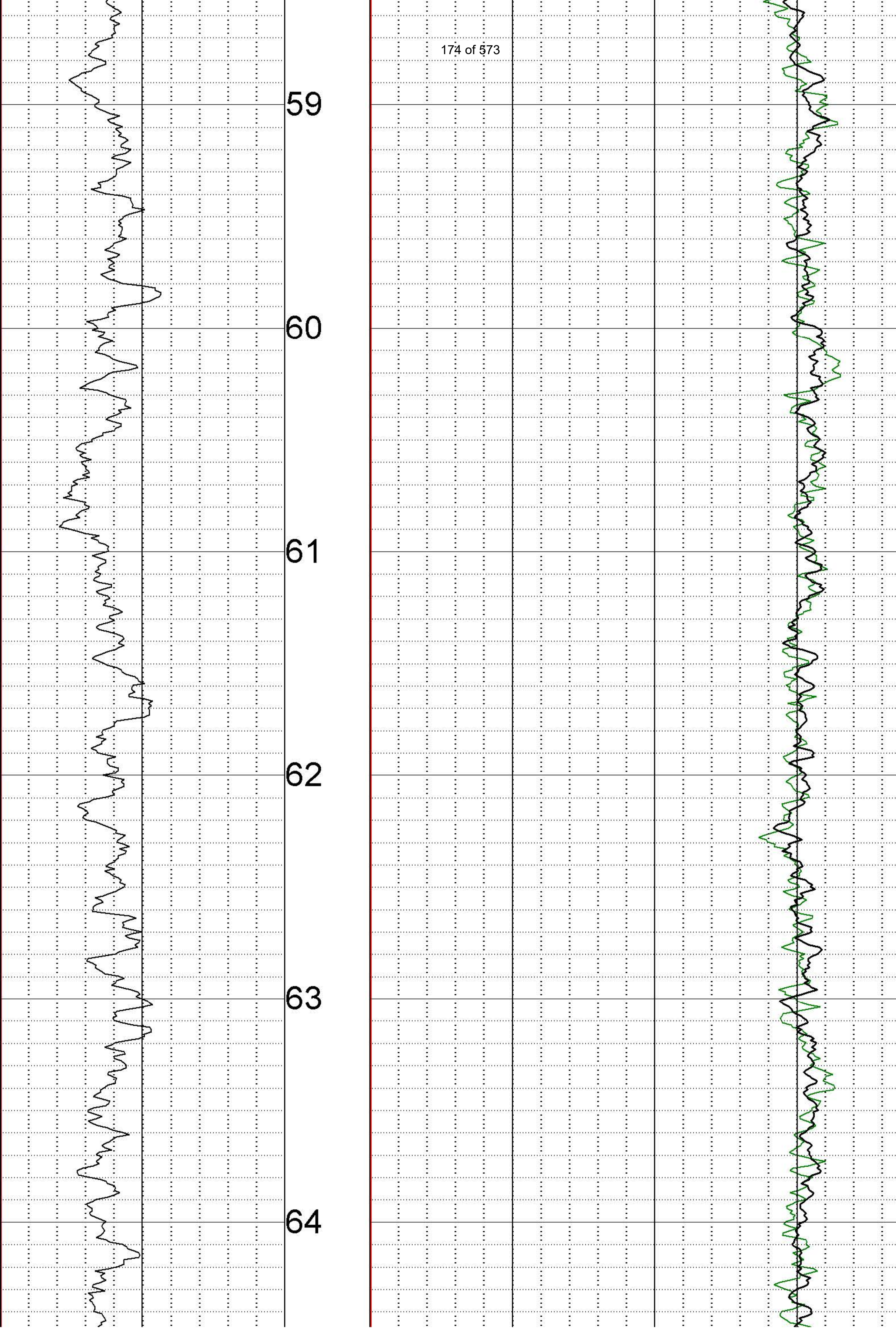
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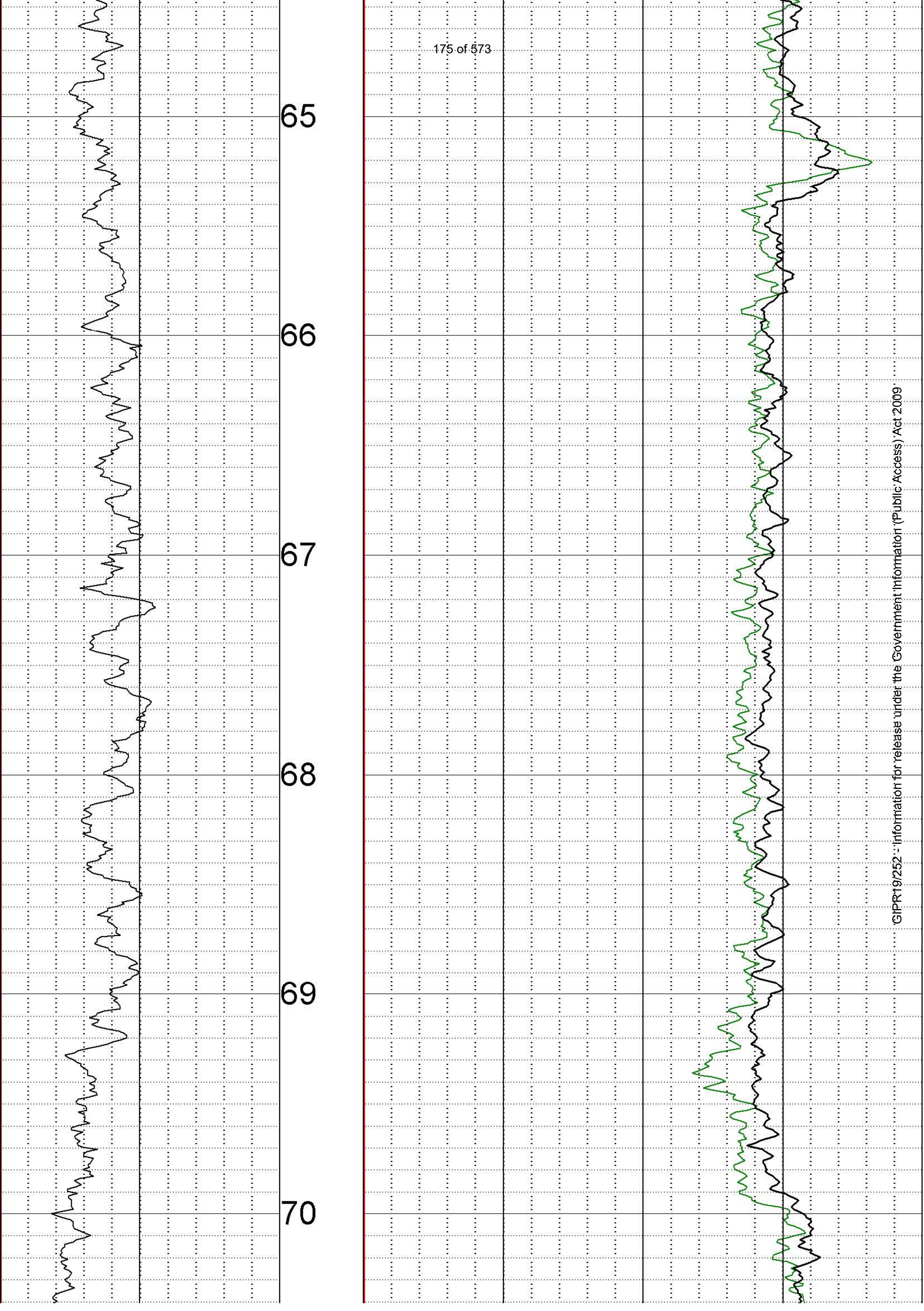
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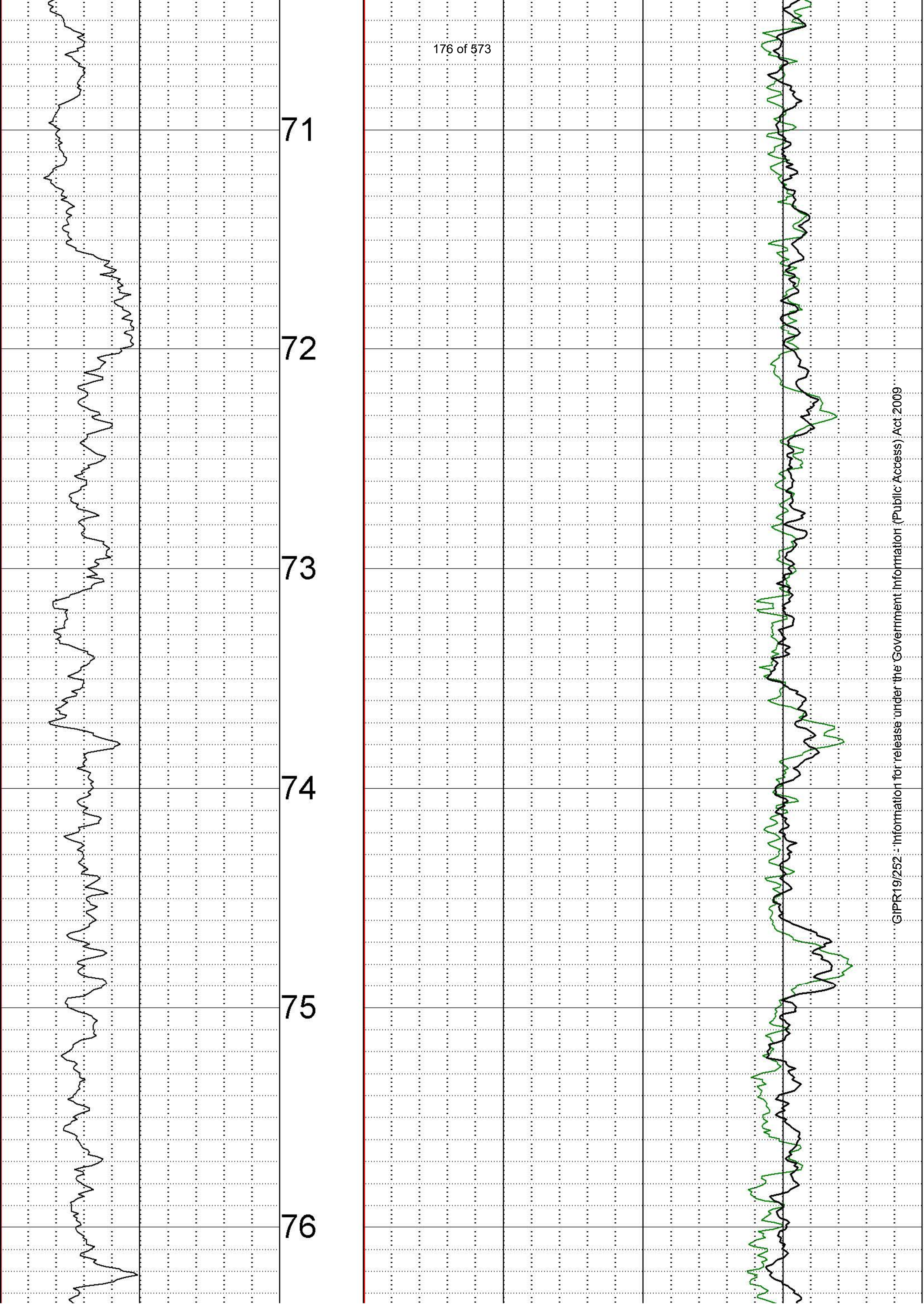
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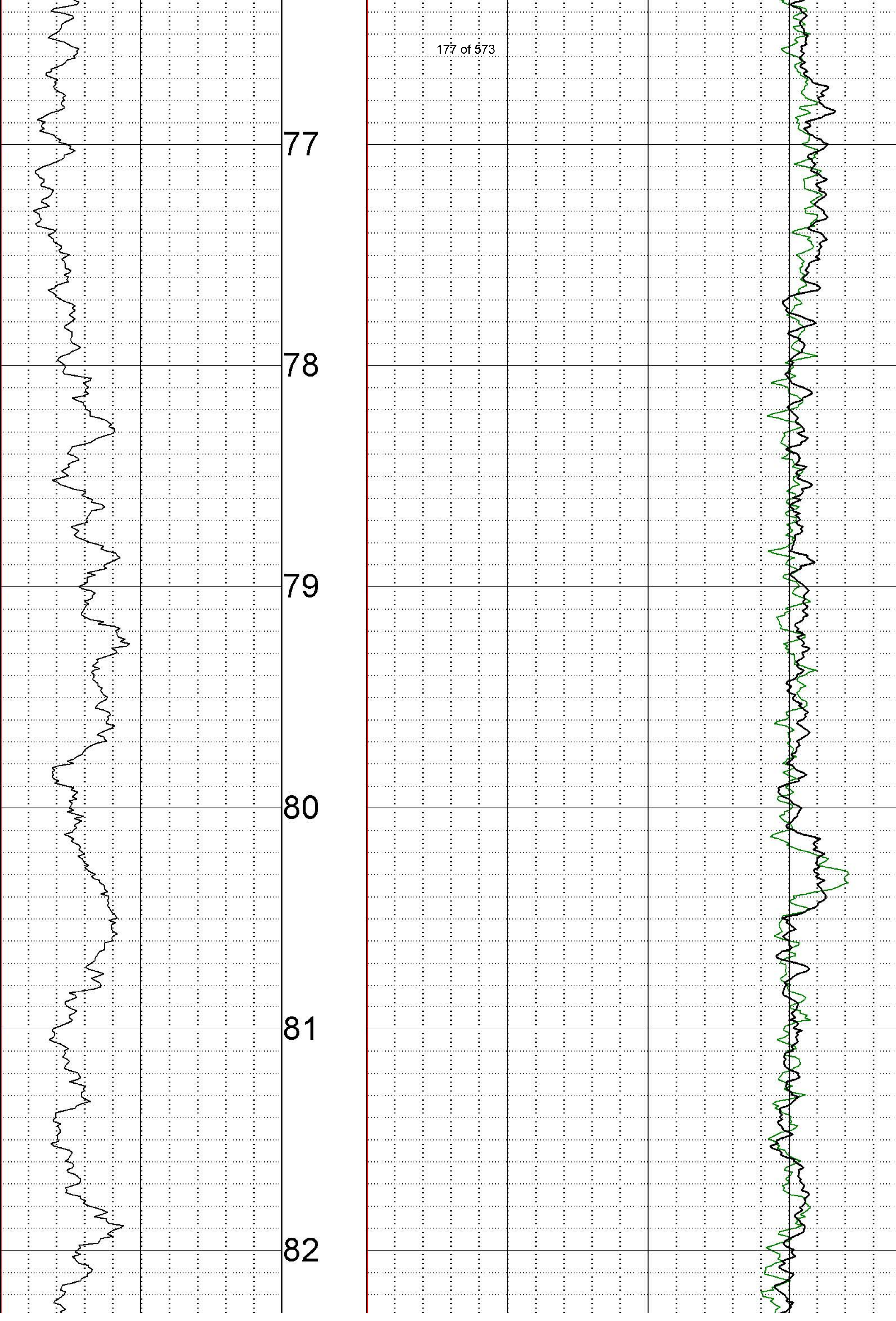
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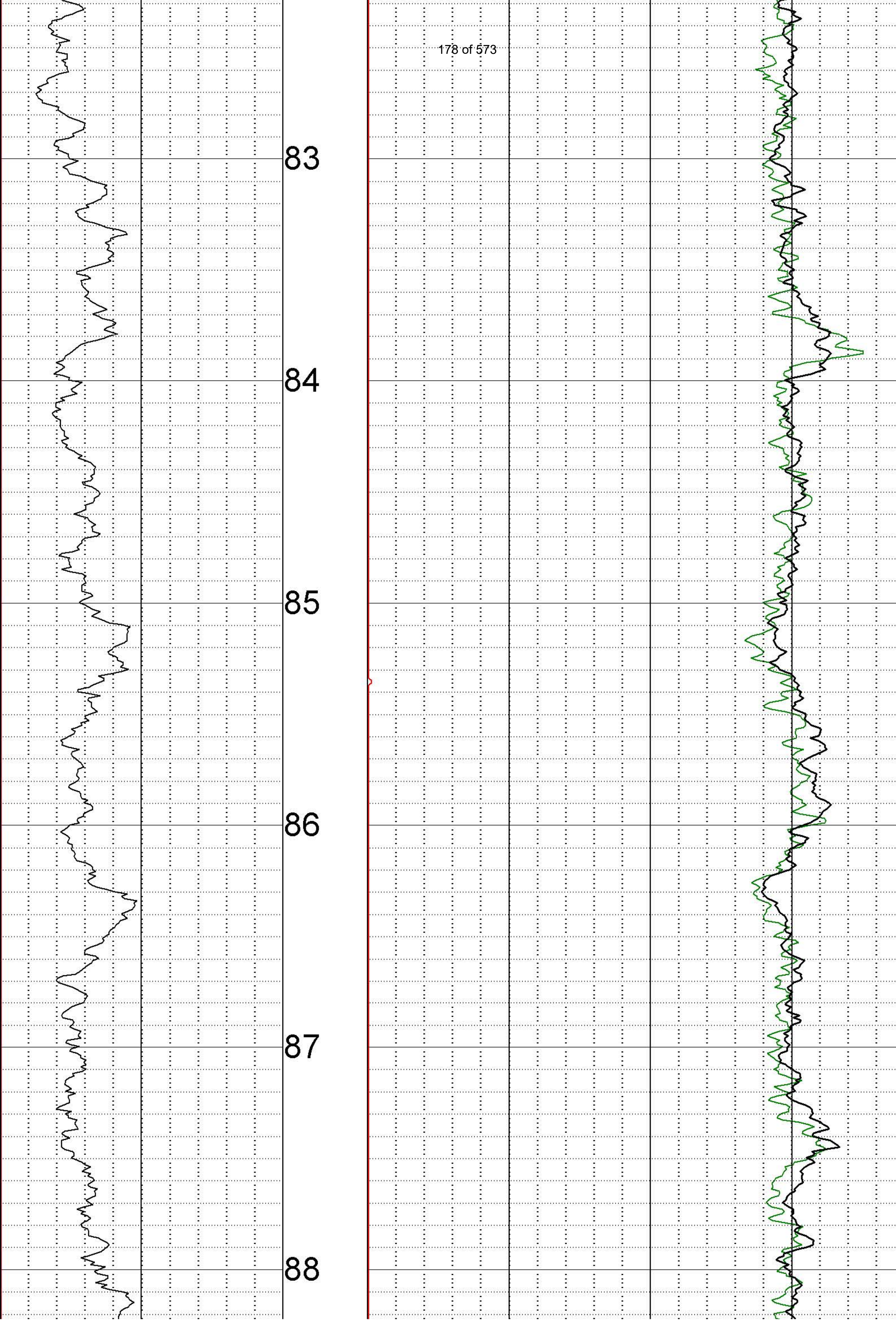
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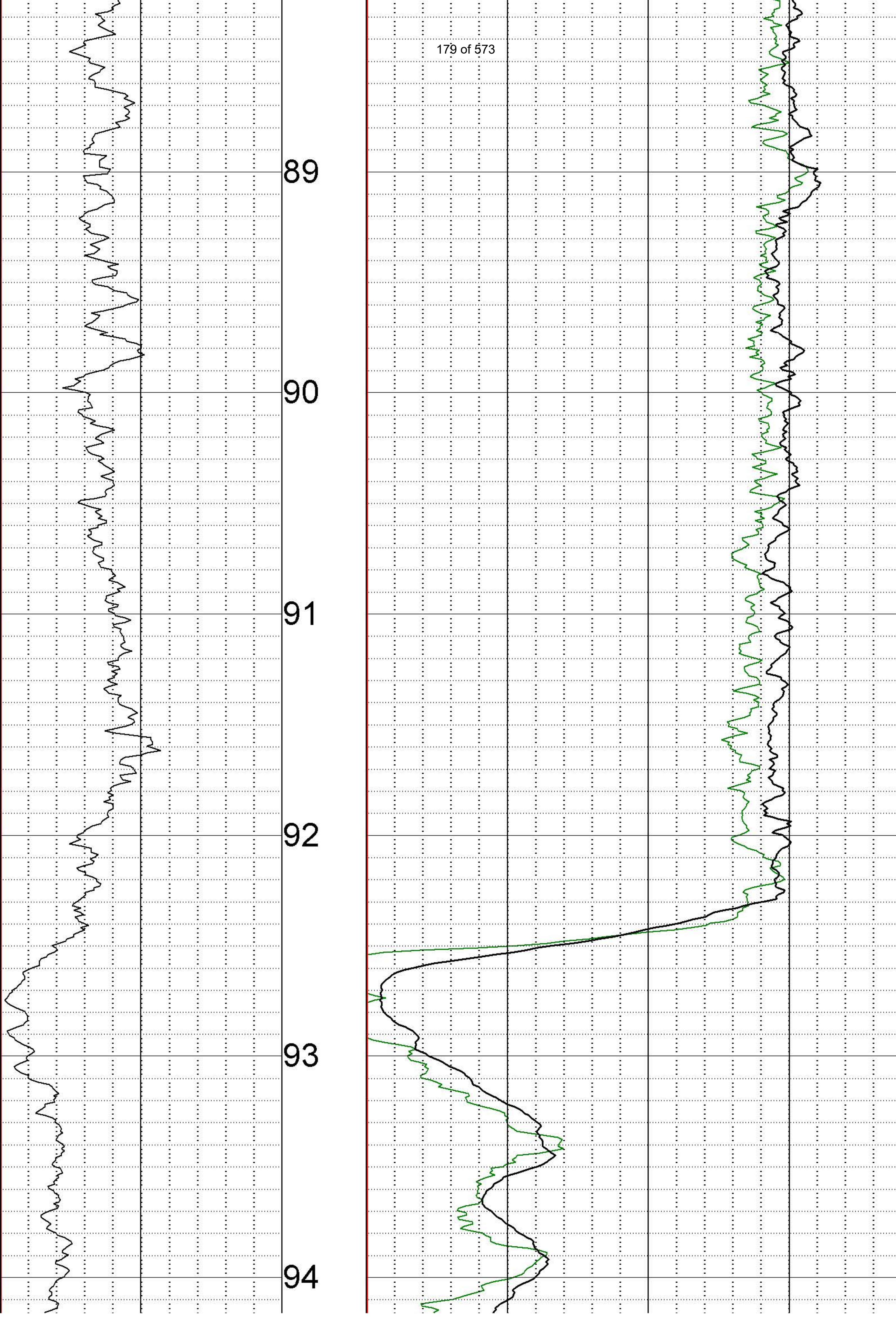
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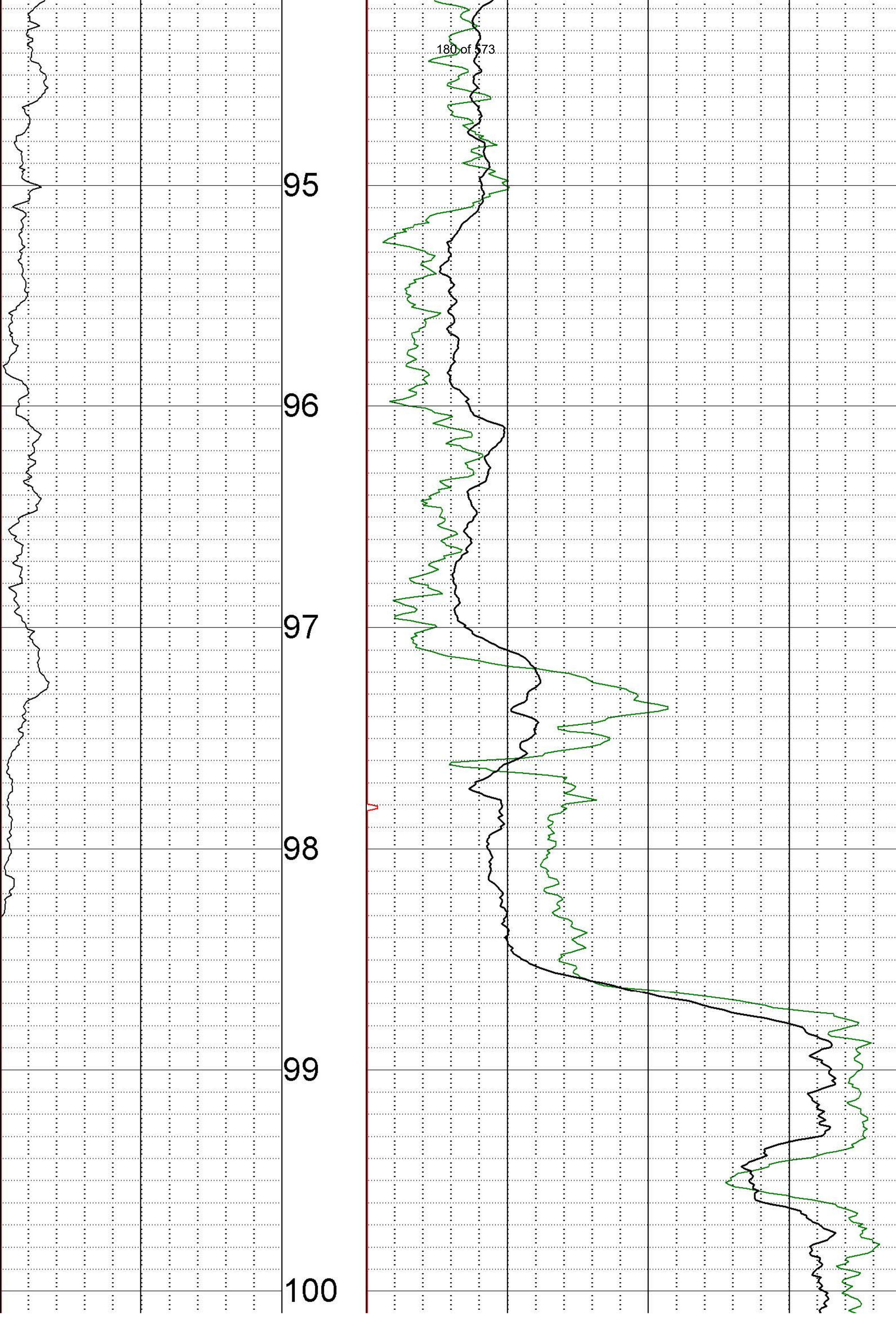
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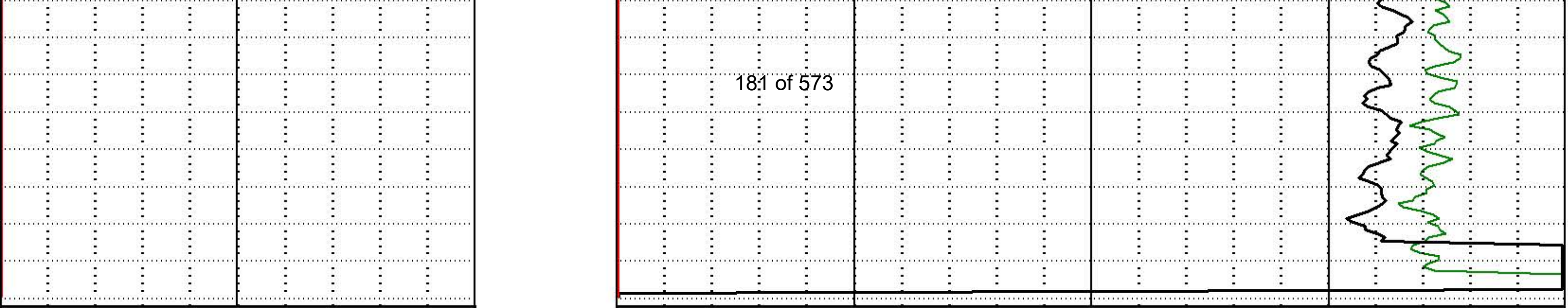

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0	API-GR	300	101	1	G/CC	3
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8	CM	18		1	G/CC	3
	CALIPER				DEN(LS)	
				0	OHM-M	2000
			METERS		RES(SG)	

Coffey Geotechnics

Borehole BH02A

ACOUSTIC TELEVIEWER PETROPHYSICAL REPORT

Groundsearch Australia Pty. Limited

3 October 2018

DISCLAIMER

The data used in this report were obtained using equipment manufactured by the Century Geophysical Corporation. The interpretations given in this report are based on judgement and experience of Groundsearch Australia's personnel. They are provided for Coffey Geotechnics sole use in accordance with a specified brief. As such, the interpretation outcomes do not necessarily address all aspects of ground conditions and behaviour on the subject site. The responsibility of Groundsearch Australia is solely to Coffey Geotechnics and it is not intended that any third party rely upon this report. This report shall not be reproduced either wholly or in part without the written permission of Groundsearch Australia Pty. Limited.

For and on behalf of Groundsearch Australia Pty. Limited

John Lea BSc (Hons) FAusIMM
Principal Geologist
Managing Director

Executive summary

The data contained in this report were obtained from one 9.6 cm diameter, vertical, cored borehole that was drilled as a component of the 2018 geotechnical exploration programme for Coffey Geotechnics at the NBN site Newcastle NSW.

Century Geophysical Corporation downhole 9804 acoustic televiewer and 9329 density tools were run to collect data in the field on 21 September 2018. This report is for data from 16.50 to 101.64 mbgl. The 9239 density tool was run inside steel casing and data were corrected for the steel. Therefore, there are no caliper or resistivity data.

The 305 identified features are interpreted as the SWL bedding, fractures and one washout. The bedding to fractures ratio is 7.3:1.

The Century Display program has automatically recalculated the dip angle data to represent the borehole in the vertical position and the dip direction data is referenced to magnetic north.

Page #

List of Tables ***Page***

List of Figures ***Page***

1.0 Background technical information

The data contained in this report were obtained from one 9.6 cm diameter, vertical, cored borehole that was drilled as a component of the 2018 geotechnical exploration programme for Coffey Geotechnics at Lingard Street Newcastle NSW.

Century Geophysical Corporation downhole 9804 acoustic televiewer and 9329 density tools were run to collect data in the field on 21 September 2018. This report is for data from 16.50 to 101.64 mbgl. The 9239 density tool was run inside steel casing and data were corrected for the steel. Therefore, there are no caliper or resistivity data.

The 305 identified features are interpreted as the SWL bedding, fractures and one washout. The bedding to fractures ratio is 7.3:1.

The Century Display program has automatically recalculated the dip angle data to represent the borehole in the vertical position and the dip direction data is referenced to magnetic north.

The Century Display program has automatically recalculated the dip angle data to represent the borehole in the vertical position and the dip direction data is referenced to magnetic north.

Subsequent processing and interpretation of data were carried out by Groundsearch.

The ATV takes an oriented image of the borehole using high-resolution sound waves. This acoustic image is displays amplitude variations. This information is used to detect bedding planes, fractures, and other borehole anomalies without the need to have clear fluid filling the boreholes. The tool works only in fluid-filled boreholes.

The televiewer digitises 256 measurements around the borehole at each high-resolution sample interval. These data can be oriented to North and displayed real-time while logging using the Visual Compu-Log System.

Analysis software includes colour adjustment, fracture dip and strike determination, and classification of features. It allows information to be displayed on the graphical screen, plot, and in report format.

2.0 Interpretation methodology

It should be noted that the ATV is a bowspring-type, centralised tool and is affected by poor wallrock conditions known as rugosity.

The ATV data interpretation procedure is based on the superposition of curves on feature logs directly onto the computer screen by using a subjective, manual; two-point definition of a feature's top and base to produce a sine curve. The sides of the time and amplitude plots represent magnetic north and magnetic south is in the centre of each plot. The low side, or trough, of the sine curve defines the dip direction of the feature.

The logging program automatically records the televiewer tool slant angle and bearing and corrects for any borehole deviations. The curves are automatically given an identification number for subsequent referencing in a report file.

There are possibly more bedding planes and structural fractures appearing in the televiewer logs that have not been included in this report due to their poor graphic definition or the inability to resolve their geometry by superposing a sine curve using the program's two point method.

This report contains a;

- Text summary of the interpreted features
- Circular representation of interpreted features
- Logs that show geological features with their subjective, numbered interpretation curves shown at 1:20 scale. The logs are in standard format whereby the optical image of the borehole wall is "flattened" onto the plot. The logs have the following additional features to enhance geological interpretations of the strata;
    - Amplitude image differentials
    - Time image differentials that indicate higher strength zones in **GREEN** and lower strength zones in **RED**
    - Tadpoles that represent feature dip and dip direction
    - Open fractures in **RED**
    - Partially open fractures in **MAGENTA**
    - Discontinuous fractures in **DARK BLUE**
  - Natural gamma
  - Slant (dip angle)
  - Slant angle bearing
  - Long and short space density
- Table containing feature curve ID, top, base, dip angle, dip azimuth, feature description and the generalised rock type that hosts the feature
- Graphical representations of the interpreted features

3.0 Borehole BH02Ainterpretation

The 305 identified features are interpreted as the SWL bedding, fractures and one washout. The bedding to fractures ratio is 7.3:1.

A description of each interpreted feature is presented in Table 1 and the log is presented in Appendix 1.

Table 1 Interpreted features report for BH02A

FEATURE ID	DIP (DEG)	AZIMUTH (DEG)	MIDPOINT (MBGL)	TOP (M)	BASE (M)	TYPE OF FEATURE	GENERALISED ROCK TYPE
1			17.05	17.05	17.05	SWL	Overburden
2	1	274	17.29	17.29	17.30	Bedding plane	Overburden
3	1	348	17.59	17.59	17.59	Bedding plane	Overburden
4	3	279	17.70	17.70	17.70	Bedding plane	Overburden
5	6	309	18.23	18.23	18.23	Bedding plane	Overburden
6	1	273	18.55	18.55	18.55	Bedding plane	Overburden
7	6	338	19.54	19.54	19.55	Bedding plane	Overburden
8	1	342	19.67	19.67	19.67	Bedding plane	Overburden
9	9	338	19.71	19.71	19.72	Bedding plane	Overburden
10	9	323	19.74	19.74	19.75	Bedding plane	Overburden
11	12	332	21.10	21.09	21.11	Bedding plane	Overburden
12	8	303	21.20	21.20	21.21	Bedding plane	Overburden
13	9	272	21.93	21.92	21.93	Bedding plane	Overburden
14	21	83	22.31	22.29	22.33	Bedding plane	Overburden
15	24	66	22.34	22.32	22.36	Bedding plane	Overburden
16	17	40	22.84	22.82	22.85	Bedding plane	Overburden
17	17	57	22.87	22.86	22.88	Bedding plane	Overburden
18	4	307	23.60	23.60	23.60	Bedding plane	Overburden
19	7	142	24.19	24.18	24.19	Bedding plane	Overburden
20	5	52	24.86	24.86	24.87	Bedding plane	Overburden
21	9	273	25.14	25.13	25.15	Bedding plane	Overburden
22	6	223	25.28	25.27	25.28	Bedding plane	Overburden
23	5	316	25.34	25.34	25.35	Bedding plane	Overburden
24	10	295	25.42	25.41	25.43	Bedding plane	Overburden
25	5	292	25.51	25.50	25.51	Bedding plane	Overburden
26	4	269	25.58	25.57	25.58	Bedding plane	Overburden
27	4	280	25.62	25.61	25.62	Bedding plane	Overburden
28	1	268	26.08	26.08	26.08	Bedding plane	Overburden
29	6	265	26.13	26.13	26.14	Top of coal unit	COAL SEAM
30	8	219	26.24	26.24	26.25	Bedding plane	COAL SEAM
31	4	269	26.31	26.31	26.31	Bedding plane	COAL SEAM
32	5	297	26.33	26.33	26.33	Bedding plane	COAL SEAM
33	5	294	26.35	26.34	26.35	Bedding plane	COAL SEAM
34	82	86	26.45	26.11	26.78	Fracture plane - partially open	COAL SEAM
35	4	232	26.55	26.55	26.55	Bedding plane	COAL SEAM
36	5	230	26.72	26.72	26.73	Bedding plane	COAL SEAM
37	2	326	26.82	26.82	26.83	Bedding plane	COAL SEAM
38	4	248	26.99	26.99	27.00	Bedding plane	COAL SEAM

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39	83	220	27.00	26.56	27.43	Fracture plane - partially open	COAL SEAM
40	4	243	27.15	27.15	27.15	Bedding plane	COAL SEAM
41	2	330	27.16	27.16	27.16	Bedding plane	COAL SEAM
42	16	277	27.25	27.24	27.26	Bedding plane	COAL SEAM
43	4	231	27.69	27.68	27.69	Base of coal unit	COAL SEAM
44	17	228	27.98	27.97	28.00	Bedding plane	Interburden
45	6	284	28.07	28.06	28.07	Bedding plane	Interburden
46	3	277	28.22	28.22	28.22	Bedding plane	Interburden
47	4	272	28.30	28.29	28.30	Bedding plane	Interburden
48	1	295	28.52	28.52	28.52	Bedding plane	Interburden
49	7	271	28.61	28.60	28.61	Top of coal unit	COAL SEAM
50	3	283	28.75	28.74	28.75	Bedding plane	COAL SEAM
51	3	30	29.04	29.03	29.04	Bedding plane	COAL SEAM
52	6	30	29.07	29.07	29.08	Bedding plane	COAL SEAM
53	15	234	29.32	29.31	29.34	Base of coal unit	COAL SEAM
54	5	60	29.50	29.50	29.50	Bedding plane	Interburden
55	6	271	29.67	29.67	29.68	Bedding plane	Interburden
56	14	262	29.80	29.79	29.81	Top of coal unit	COAL SEAM
57	9	207	30.30	30.29	30.31	Bedding plane	COAL SEAM
58	6	201	30.32	30.31	30.33	Base of coal unit	COAL SEAM
59	6	299	30.49	30.48	30.49	Bedding plane	Interburden
60	8	298	30.56	30.55	30.56	Bedding plane	Interburden
61	5	242	30.61	30.60	30.61	Bedding plane	Interburden
62	7	235	31.23	31.23	31.24	Bedding plane	Interburden
63	1	11	31.33	31.33	31.33	Bedding plane	Interburden
64	2	47	31.45	31.45	31.45	Top of washout	Interburden
65	14	45	31.72	31.71	31.73	Base of washout	Interburden
66	9	45	31.83	31.82	31.83	Bedding plane	Interburden
67	4	267	32.06	32.06	32.07	Bedding plane	Interburden
68	7	56	32.43	32.43	32.44	Bedding plane	Interburden
69	2	49	32.48	32.48	32.48	Bedding plane	Interburden
70	4	37	32.54	32.54	32.55	Bedding plane	Interburden
71	5	70	32.59	32.59	32.60	Bedding plane	Interburden
72	2	328	32.64	32.64	32.64	Bedding plane	Interburden
73	3	91	32.99	32.99	33.00	Bedding plane	Interburden
74	5	65	33.11	33.10	33.11	Bedding plane	Interburden
75	16	33	33.15	33.14	33.16	Bedding plane	Interburden
76	12	354	33.21	33.20	33.22	Bedding plane	Interburden
77	24	115	33.53	33.51	33.55	Fracture plane - partially open	Interburden
78	13	348	33.60	33.59	33.61	Fracture plane - open	Interburden
79	3	360	33.73	33.73	33.73	Bedding plane	Interburden
80	5	333	33.80	33.80	33.81	Bedding plane	Interburden
81	25	281	33.85	33.82	33.87	Fracture plane - partially open	Interburden
82	12	84	33.97	33.96	33.98	Bedding plane	Interburden
83	17	78	34.13	34.12	34.15	Bedding plane	Interburden
84	19	109	34.17	34.15	34.19	Bedding plane	Interburden
85	13	38	35.81	35.80	35.82	Bedding plane	Interburden
86	5	319	36.64	36.64	36.65	Bedding plane	Interburden
87	2	331	36.80	36.80	36.80	Bedding plane	Interburden
88	1	21	36.99	36.99	36.99	Bedding plane	Interburden

89	4	284	37.23	37.23	37.23	Bedding plane	Interburden
90	2	231	37.28	37.27	37.28	Bedding plane	Interburden
91	5	217	37.29	37.29	37.30	Bedding plane	Interburden
92	1	21	37.53	37.53	37.53	Bedding plane	Interburden
93	3	308	37.76	37.76	37.76	Bedding plane	Interburden
94	7	324	38.05	38.04	38.05	Bedding plane	Interburden
95	7	319	38.64	38.63	38.64	Bedding plane	Interburden
96	7	137	39.25	39.24	39.25	Bedding plane	Interburden
97	2	265	42.72	42.72	42.72	Bedding plane	Interburden
98	69	129	43.06	42.93	43.19	Fracture plane - partially open	Interburden
99	59	144	43.48	43.40	43.57	Fracture plane - partially open	Interburden
100	6	294	43.85	43.84	43.85	Top of coal unit	COAL SEAM
101	72	78	43.89	43.75	44.04	Fracture plane - partially open	COAL SEAM
102	72	91	43.96	43.82	44.10	Fracture plane - partially open	COAL SEAM
103	7	357	44.02	44.01	44.02	Bedding plane	COAL SEAM
104	10	349	44.05	44.04	44.06	Bedding plane	COAL SEAM
105	3	290	44.42	44.41	44.42	Bedding plane	COAL SEAM
106	3	41	44.43	44.43	44.44	Bedding plane	COAL SEAM
107	6	279	44.92	44.92	44.93	Base of coal unit	COAL SEAM
108	17	296	45.13	45.12	45.15	Bedding plane	Interburden
109	10	271	45.25	45.24	45.26	Bedding plane	Interburden
110	13	22	47.92	47.91	47.93	Bedding plane	Interburden
111	5	71	48.25	48.25	48.25	Bedding plane	Interburden
112	2	331	49.76	49.76	49.76	Bedding plane	Interburden
113	11	257	49.85	49.84	49.86	Bedding plane	Interburden
114	4	99	51.32	51.31	51.32	Bedding plane	Interburden
115	75	175	53.27	53.06	53.49	Fracture plane - partially open	Interburden
116	70	240	54.00	53.86	54.15	Fracture plane - partially open	Interburden
117	75	241	54.19	53.99	54.39	Fracture plane - partially open	Interburden
118	19	335	54.58	54.56	54.60	Bedding plane	Interburden
119	77	232	54.98	54.75	55.20	Fracture plane - partially open	Interburden
120	76	232	55.02	54.83	55.21	Fracture plane - partially open	Interburden
121	5	286	55.26	55.26	55.26	Bedding plane	Interburden
122	4	263	55.30	55.29	55.30	Bedding plane	Interburden
123	12	313	55.53	55.52	55.54	Top of coal unit	COAL SEAM
124	6	263	55.59	55.58	55.59	Bedding plane	COAL SEAM
125	4	329	55.64	55.64	55.65	Bedding plane	COAL SEAM
126	3	272	55.70	55.70	55.70	Bedding plane	COAL SEAM
127	4	321	55.93	55.93	55.94	Bedding plane	COAL SEAM
128	7	325	56.09	56.08	56.09	Base of coal unit	COAL SEAM
129	79	233	56.46	56.19	56.73	Fracture plane - open	Interburden
130	71	241	56.69	56.55	56.83	Fracture plane - partially open	Interburden
131	71	242	56.77	56.64	56.91	Fracture plane - partially open	Interburden
132	74	226	56.91	56.73	57.08	Fracture plane - partially open	Interburden
133	74	228	57.01	56.84	57.18	Fracture plane - partially open	Interburden
134	76	223	57.15	56.93	57.37	Fracture plane - partially open	Interburden
135	10	59	57.40	57.39	57.40	Bedding plane	Interburden
136	14	52	57.56	57.54	57.57	Bedding plane	Interburden
137	9	20	57.58	57.57	57.58	Bedding plane	Interburden

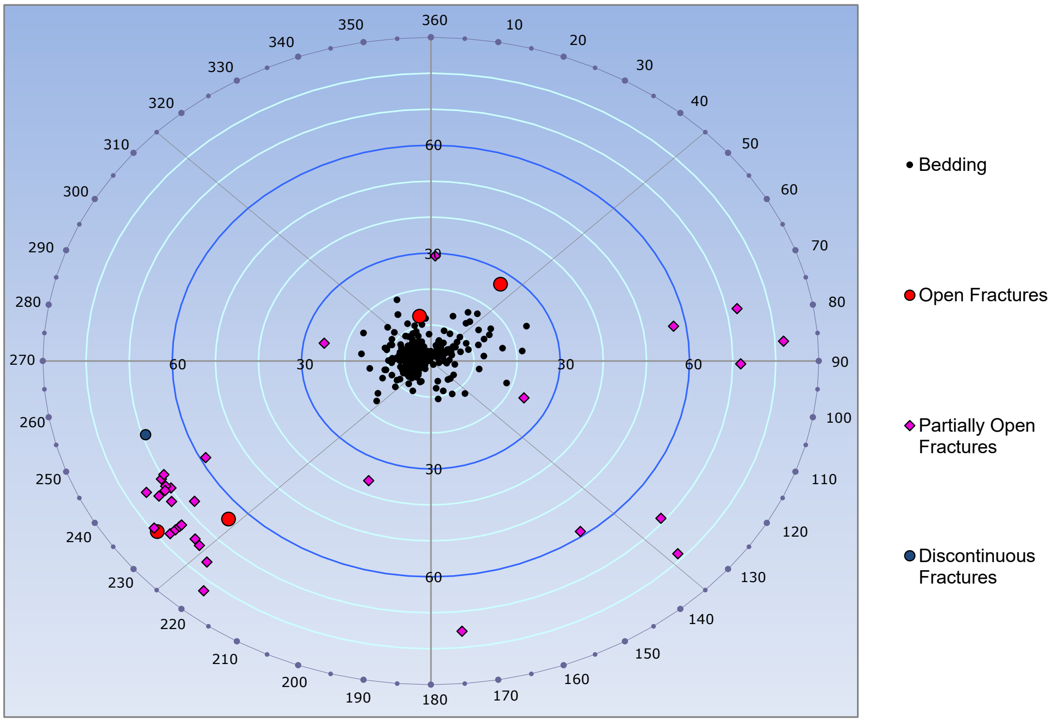
138	8	276	57.62	57.61	57.63	Bedding plane	Interburden
139	79	234	58.08	57.82	58.34	Fracture plane - partially open	Interburden
140	10	296	58.63	58.63	58.64	Bedding plane	Interburden
141	2	105	58.72	58.72	58.73	Bedding plane	Interburden
142	2	348	58.87	58.87	58.87	Bedding plane	Interburden
143	7	295	58.99	58.98	58.99	Bedding plane	Interburden
144	1	271	59.08	59.08	59.08	Bedding plane	Interburden
145	7	70	59.12	59.12	59.13	Bedding plane	Interburden
146	5	58	59.16	59.15	59.16	Bedding plane	Interburden
147	12	139	59.27	59.26	59.29	Bedding plane	Interburden
148	10	152	59.30	59.29	59.31	Bedding plane	Interburden
149	6	259	59.34	59.33	59.34	Bedding plane	Interburden
150	36	203	59.39	59.35	59.43	Fracture plane - partially open	Interburden
151	27	37	59.55	59.53	59.58	Fracture plane - open	Interburden
152	14	40	59.58	59.57	59.60	Bedding plane	Interburden
153	1	345	59.69	59.69	59.69	Bedding plane	Interburden
154	7	53	59.74	59.73	59.74	Bedding plane	Interburden
155	6	203	60.65	60.65	60.66	Bedding plane	Interburden
156	8	171	60.67	60.66	60.68	Bedding plane	Interburden
157	11	171	60.73	60.72	60.74	Bedding plane	Interburden
158	1	355	60.99	60.99	60.99	Bedding plane	Interburden
159	4	25	61.15	61.15	61.16	Bedding plane	Interburden
160	5	51	61.78	61.78	61.79	Bedding plane	Interburden
161	8	49	61.80	61.80	61.81	Bedding plane	Interburden
162	9	31	61.83	61.82	61.83	Bedding plane	Interburden
163	3	58	61.96	61.96	61.96	Bedding plane	Interburden
164	1	354	62.12	62.12	62.12	Bedding plane	Interburden
165	1	352	62.87	62.87	62.87	Bedding plane	Interburden
166	4	87	63.04	63.04	63.04	Bedding plane	Interburden
167	6	21	63.16	63.16	63.16	Bedding plane	Interburden
168	2	295	63.19	63.19	63.20	Bedding plane	Interburden
169	3	326	63.26	63.26	63.26	Bedding plane	Interburden
170	5	290	63.32	63.32	63.32	Bedding plane	Interburden
171	9	70	63.48	63.47	63.48	Bedding plane	Interburden
172	7	126	63.73	63.72	63.74	Bedding plane	Interburden
173	11	101	63.75	63.74	63.76	Bedding plane	Interburden
174	7	276	63.80	63.79	63.81	Bedding plane	Interburden
175	11	229	63.86	63.85	63.87	Bedding plane	Interburden
176	9	275	64.05	64.04	64.05	Bedding plane	Interburden
177	9	331	64.88	64.88	64.89	Bedding plane	Interburden
178	6	100	65.24	65.23	65.24	Bedding plane	Interburden
179	6	223	65.51	65.50	65.51	Bedding plane	Interburden
180	3	276	65.87	65.87	65.87	Bedding plane	Interburden
181	5	307	66.03	66.02	66.03	Bedding plane	Interburden
182	5	296	66.42	66.41	66.42	Bedding plane	Interburden
183	5	305	67.49	67.48	67.49	Bedding plane	Interburden
184	3	344	67.69	67.69	67.69	Bedding plane	Interburden
185	2	51	69.17	69.17	69.17	Bedding plane	Interburden
186	7	308	69.90	69.89	69.90	Bedding plane	Interburden

187	6	327	69.97	69.97	69.97	Bedding plane	Interburden
188	4	338	69.98	69.98	69.99	Bedding plane	Interburden
189	2	7	70.10	70.10	70.10	Bedding plane	Interburden
190	2	8	70.23	70.23	70.23	Bedding plane	Interburden
191	5	31	70.74	70.74	70.74	Bedding plane	Interburden
192	8	289	71.69	71.68	71.70	Bedding plane	Interburden
193	6	328	71.94	71.94	71.94	Bedding plane	Interburden
194	2	9	72.10	72.10	72.10	Bedding plane	Interburden
195	9	161	72.57	72.56	72.58	Bedding plane	Interburden
196	78	133	72.85	72.58	73.11	Fracture plane - partially open	Interburden
197	4	326	73.21	73.21	73.21	Bedding plane	Interburden
198	5	312	75.38	75.37	75.38	Bedding plane	Interburden
199	4	325	75.45	75.45	75.45	Bedding plane	Interburden
200	4	317	76.29	76.29	76.29	Bedding plane	Interburden
201	6	233	76.38	76.38	76.39	Bedding plane	Interburden
202	4	310	76.52	76.52	76.53	Bedding plane	Interburden
203	4	272	76.56	76.55	76.56	Bedding plane	Interburden
204	7	270	76.67	76.66	76.68	Bedding plane	Interburden
205	2	312	76.77	76.77	76.77	Bedding plane	Interburden
206	3	210	77.55	77.55	77.56	Bedding plane	Interburden
207	6	320	77.76	77.75	77.76	Bedding plane	Interburden
208	70	243	78.15	78.01	78.29	Fracture plane - partially open	Interburden
209	57	80	78.22	78.14	78.30	Fracture plane - partially open	Interburden
210	59	243	78.39	78.31	78.47	Fracture plane - partially open	Interburden
211	71	240	78.54	78.39	78.68	Fracture plane - partially open	Interburden
212	73	239	78.64	78.47	78.81	Fracture plane - partially open	Interburden
213	15	62	79.00	78.99	79.01	Bedding plane	Interburden
214	14	64	79.18	79.17	79.20	Bedding plane	Interburden
215	12	68	80.10	80.09	80.11	Bedding plane	Interburden
216	7	295	80.29	80.28	80.29	Bedding plane	Interburden
217	6	256	80.50	80.49	80.50	Bedding plane	Interburden
218	1	298	80.56	80.56	80.56	Bedding plane	Interburden
219	5	336	81.04	81.04	81.05	Bedding plane	Interburden
220	2	300	81.25	81.24	81.25	Bedding plane	Interburden
221	4	293	81.59	81.59	81.59	Bedding plane	Interburden
222	7	250	81.75	81.75	81.76	Bedding plane	Interburden
223	4	285	81.87	81.86	81.87	Bedding plane	Interburden
224	7	239	82.28	82.28	82.29	Bedding plane	Interburden
225	6	331	82.37	82.37	82.38	Bedding plane	Interburden
226	9	236	82.98	82.97	82.99	Bedding plane	Interburden
227	10	246	83.02	83.01	83.03	Bedding plane	Interburden
228	10	339	83.10	83.09	83.11	Bedding plane	Interburden
229	7	242	84.25	84.25	84.26	Bedding plane	Interburden
230	4	58	84.37	84.36	84.37	Bedding plane	Interburden
231	6	164	84.69	84.68	84.69	Bedding plane	Interburden
232	5	282	84.82	84.81	84.82	Bedding plane	Interburden
233	2	278	84.94	84.94	84.94	Bedding plane	Interburden
234	2	325	85.11	85.11	85.11	Bedding plane	Interburden
235	4	274	85.83	85.83	85.84	Bedding plane	Interburden
236	12	247	86.12	86.11	86.13	Bedding plane	Interburden

237	7	230	86.15	86.14	86.16	Bedding plane	Interburden
238	5	67	86.81	86.81	86.82	Bedding plane	Interburden
239	7	249	87.23	87.22	87.23	Bedding plane	Interburden
240	7	337	88.72	88.71	88.72	Bedding plane	Interburden
241	9	235	88.92	88.92	88.93	Bedding plane	Interburden
242	3	279	89.37	89.37	89.37	Bedding plane	Interburden
243	3	34	89.45	89.45	89.45	Bedding plane	Interburden
244	2	60	89.62	89.62	89.63	Bedding plane	Interburden
245	69	253	89.73	89.61	89.85	Fracture plane - discontinuous	Interburden
246	6	215	89.81	89.81	89.82	Bedding plane	Interburden
247	7	283	90.01	90.00	90.01	Bedding plane	Interburden
248	1	1	90.04	90.04	90.04	Bedding plane	Interburden
249	7	283	90.24	90.24	90.25	Bedding plane	Interburden
250	7	246	90.53	90.53	90.54	Bedding plane	Interburden
251	3	295	90.66	90.66	90.66	Bedding plane	Interburden
252	64	227	90.72	90.62	90.82	Fracture plane - open	Interburden
253	3	281	90.73	90.73	90.74	Bedding plane	Interburden
254	5	296	90.93	90.92	90.93	Bedding plane	Interburden
255	3	55	91.04	91.03	91.04	Bedding plane	Interburden
256	11	304	91.35	91.34	91.35	Bedding plane	Interburden
257	5	247	91.47	91.46	91.47	Bedding plane	Interburden
258	2	347	91.70	91.70	91.70	Bedding plane	Interburden
259	3	283	91.82	91.82	91.82	Bedding plane	Interburden
260	3	281	91.93	91.93	91.93	Bedding plane	Interburden
261	2	259	92.07	92.07	92.07	Bedding plane	Interburden
262	72	237	92.15	92.02	92.29	Fracture plane - partially open	Interburden
263	2	299	92.43	92.43	92.43	Bedding plane	Interburden
264	5	284	92.59	92.58	92.59	Bedding plane	Interburden
265	74	232	92.66	92.50	92.82	Fracture plane - partially open	Interburden
266	74	232	92.78	92.62	92.93	Fracture plane - partially open	Interburden
267	5	309	93.09	93.09	93.10	Bedding plane	Interburden
268	5	299	93.22	93.21	93.22	Bedding plane	Interburden
269	7	257	93.61	93.61	93.62	Bedding plane	Interburden
270	29	2	93.67	93.64	93.70	Fracture plane - partially open	Interburden
271	5	298	93.76	93.76	93.77	Bedding plane	Interburden
272	5	277	94.06	94.06	94.06	Bedding plane	Interburden
273	5	286	94.17	94.16	94.17	Bedding plane	Interburden
274	3	21	94.21	94.21	94.22	Bedding plane	Interburden
275	2	297	94.31	94.31	94.31	Bedding plane	Interburden
276	4	221	94.34	94.34	94.35	Bedding plane	Interburden
277	67	235	94.36	94.24	94.47	Fracture plane - partially open	Interburden
278	3	230	94.36	94.36	94.36	Bedding plane	Interburden
279	4	17	94.47	94.47	94.48	Bedding plane	Interburden
280	5	297	94.62	94.61	94.62	Bedding plane	Interburden
281	15	329	94.70	94.69	94.71	Bedding plane	Interburden
282	14	313	94.80	94.79	94.81	Top of coal unit	COAL SEAM
283	6	323	95.20	95.19	95.20	Bedding plane	COAL SEAM
284	15	329	95.34	95.33	95.35	Bedding plane	COAL SEAM
285	5	15	95.37	95.37	95.38	Bedding plane	COAL SEAM
286	6	18	95.41	95.40	95.41	Bedding plane	COAL SEAM

FEATURE ID	DIP (DEG)	AZIMUTH (DEG)	MIDPOINT (MBGL)	TOP (M)	BASE (M)	TYPE OF FEATURE	GENERALISED ROCK TYPE
287	6	18	95.71	95.70	95.71	Bedding plane	COAL SEAM
288	2	34	95.73	95.73	95.73	Bedding plane	COAL SEAM
289	2	289	97.38	97.38	97.38	Bedding plane	COAL SEAM
290	11	287	97.97	97.97	97.98	Bedding plane	COAL SEAM
291	0	311	98.09	98.09	98.09	Bedding plane	COAL SEAM
292	0	290	98.12	98.12	98.12	Bedding plane	COAL SEAM
293	9	320	98.19	98.18	98.20	Bedding plane	COAL SEAM
294	3	278	98.52	98.51	98.52	Bedding plane	COAL SEAM
295	6	271	98.53	98.53	98.53	Bedding plane	COAL SEAM
296	2	40	99.01	99.01	99.01	Bedding plane	COAL SEAM
297	4	25	99.14	99.14	99.15	Bedding plane	COAL SEAM
298	3	70	99.20	99.20	99.20	Bedding plane	COAL SEAM
299	6	312	99.31	99.30	99.31	Bedding plane	COAL SEAM
300	11	257	100.41	100.40	100.42	Base of coal unit	COAL SEAM
301	7	281	100.67	100.67	100.67	Bedding plane	Interburden
302	9	267	100.72	100.71	100.72	Bedding plane	Interburden
303	6	244	100.76	100.76	100.76	Bedding plane	Interburden
304	11	289	101.22	101.21	101.23	Bedding plane	Interburden
305	1	151	101.32	101.31	101.32	Bedding plane	Interburden

Figure 1 BH02A circular plan representation of interpreted features



The 266 identified sedimentary features are predominantly bedding planes that appear to range in dip from flat-lying to 24^0. Figures 2 and 3 show the distribution of the planes' dip angles and dip direction with depth.

Table 2 details the variation in the dip angle and dip direction data. Figure 4 shows the dip direction data in a rose diagram with the bedding planes' dip angle and dip direction data shown as histograms in Figures 5 and 6.

The 36 fractures are identified as open (11%), partially open (86%) and discontinuous (3%). The fracture dip angles range from 13 to 83^0.

Table 3 details the variation in the fractures' dip angle and dip direction data. Figure 7 shows the dip direction data in a rose diagram with the fractures' plane dip angle and dip direction data as histograms in Figures 8 and 9.

Figure 2 BH02A feature dip angle data distribution

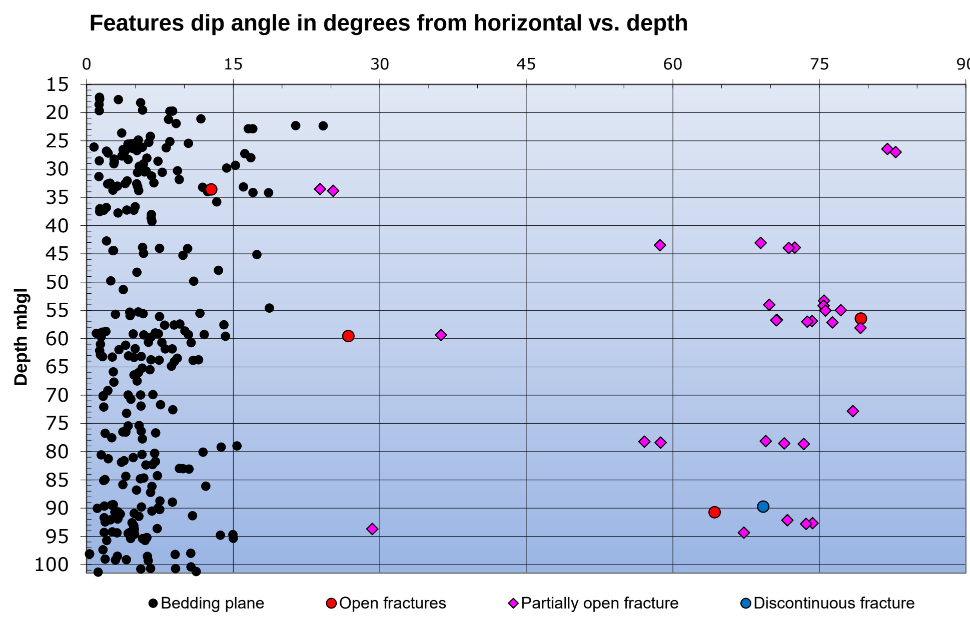


Figure 3 BH02A feature dip direction data distribution

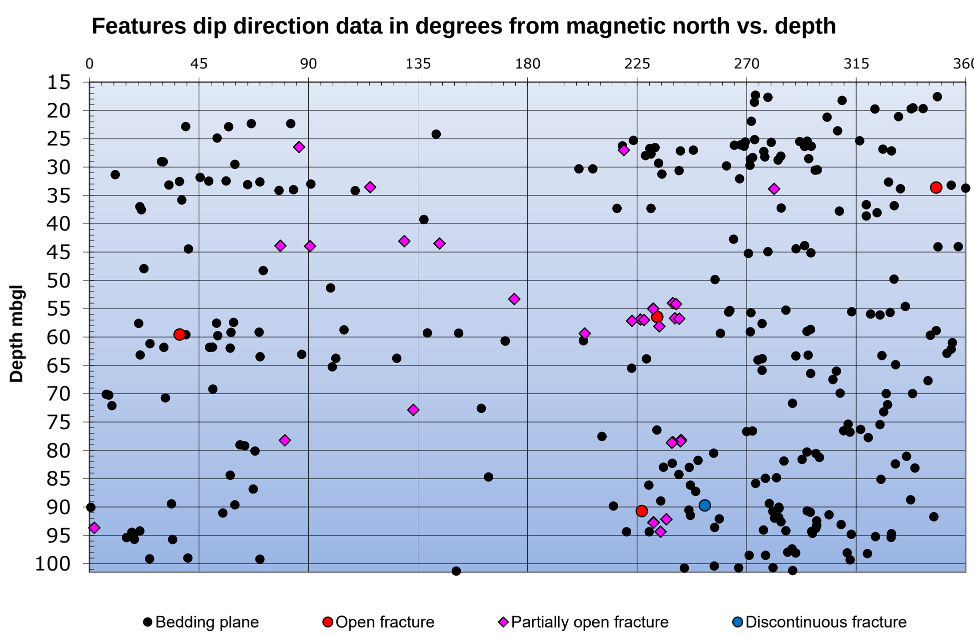


Table 2 BH02A bedding histogram data

Dip Distribution			Orientation Distribution		
	Total: 266			Total: 266	
Dip Range	**Count**	**%**	**Bearing Range**	**Count**	**%**
0 to 10	224	84.2	0 to 10	4	1.5
10 to 20	40	15.0	10 to 20	5	1.9
20 to 30	2	0.8	20 to 30	9	3.4
30 to 40	0	0.0	30 to 40	10	3.8
40 to 50	0	0.0	40 to 50	5	1.9
50 to 60	0	0.0	50 to 60	14	5.3
60 to 70	0	0.0	60 to 70	8	3.0
70 to 80	0	0.0	70 to 80	4	1.5
80 to 90	0	0.0	80 to 90	3	1.1
			90 to 100	3	1.1
			100 to 110	3	1.1
			110 to 120	0	0.0
			120 to 130	1	0.4
			130 to 140	2	0.8
			140 to 150	1	0.4
			150 to 160	2	0.8
			160 to 170	2	0.8
			170 to 180	2	0.8
			180 to 190	0	0.0
			190 to 200	0	0.0
			200 to 210	3	1.1
			210 to 220	4	1.5
			220 to 230	7	2.6
			230 to 240	10	3.8
			240 to 250	11	4.1
			250 to 260	6	2.3
			260 to 270	11	4.1
			270 to 280	25	9.4
			280 to 290	19	7.1
			290 to 300	27	10.2
			300 to 310	10	3.8
			310 to 320	12	4.5
			320 to 330	17	6.4
			330 to 340	13	4.9
			340 to 350	7	2.6
			350 to 360	6	2.3

Figure 5 BH02A bedding dip angles histogram

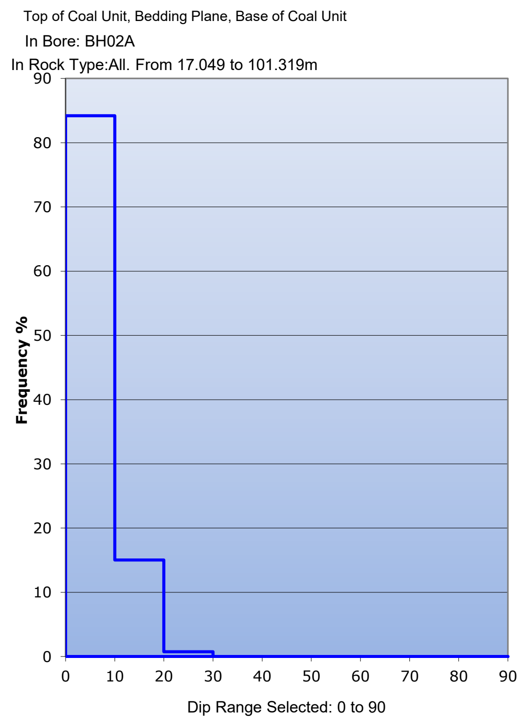


Figure 4 BH02A bedding dip direction data rose diagram

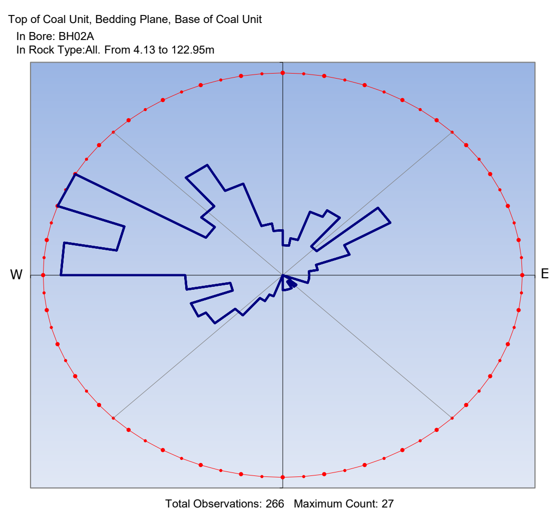


Figure 6 BH02A bedding dip directions histogram

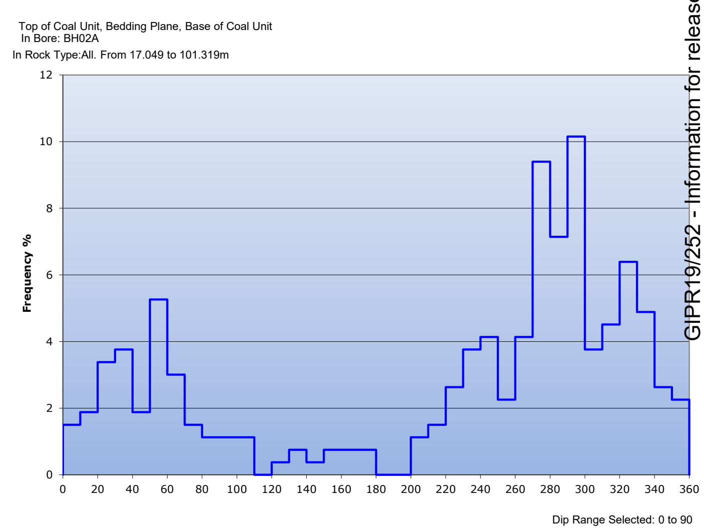


Table 3 BH02A fractures histogram data

Dip Distribution
Total: 36

Dip Range	Count	%
0 to 10	0	0.0
10 to 20	1	2.8
20 to 30	4	11.1
30 to 40	1	2.8
40 to 50	0	0.0
50 to 60	3	8.3
60 to 70	6	16.7
70 to 80	19	52.8
80 to 90	2	5.6

Orientation Distribution
Total: 36

Bearing Range	Count	%
0 to 10	1	2.8
10 to 20	0	0.0
20 to 30	0	0.0
30 to 40	1	2.8
40 to 50	0	0.0
50 to 60	0	0.0
60 to 70	0	0.0
70 to 80	1	2.8
80 to 90	2	5.6
90 to 100	1	2.8
100 to 110	0	0.0
110 to 120	1	2.8
120 to 130	1	2.8
130 to 140	1	2.8
140 to 150	1	2.8
150 to 160	0	0.0
160 to 170	0	0.0
170 to 180	1	2.8
180 to 190	0	0.0
190 to 200	0	0.0
200 to 210	1	2.8
210 to 220	1	2.8
220 to 230	4	11.1
230 to 240	11	30.6
240 to 250	5	13.9
250 to 260	1	2.8
260 to 270	0	0.0
270 to 280	0	0.0
280 to 290	1	2.8
290 to 300	0	0.0
300 to 310	0	0.0
310 to 320	0	0.0
320 to 330	0	0.0
330 to 340	0	0.0
340 to 350	1	2.8
350 to 360	0	0.0

Figure 8 BH02A fractures dip angles histogram

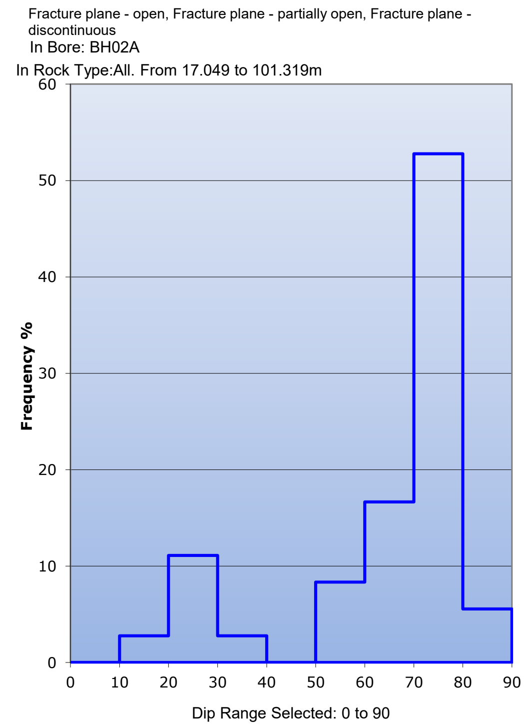


Figure 7 BH02A fractures dip direction data rose diagram

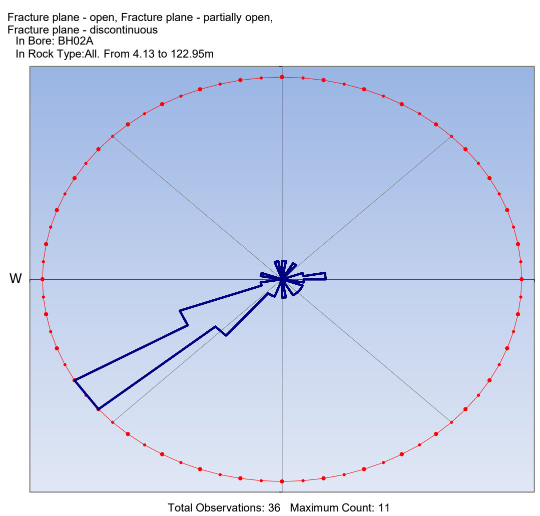
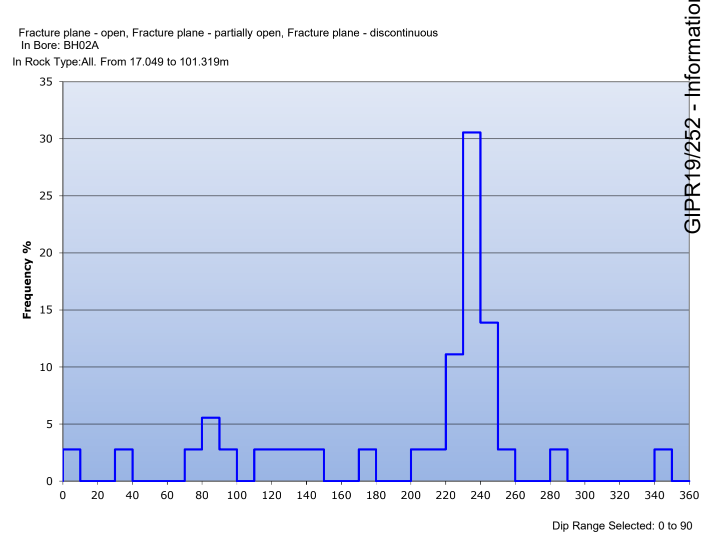


Figure 9 BH02A fractures dip directions histogram



Appendix 1

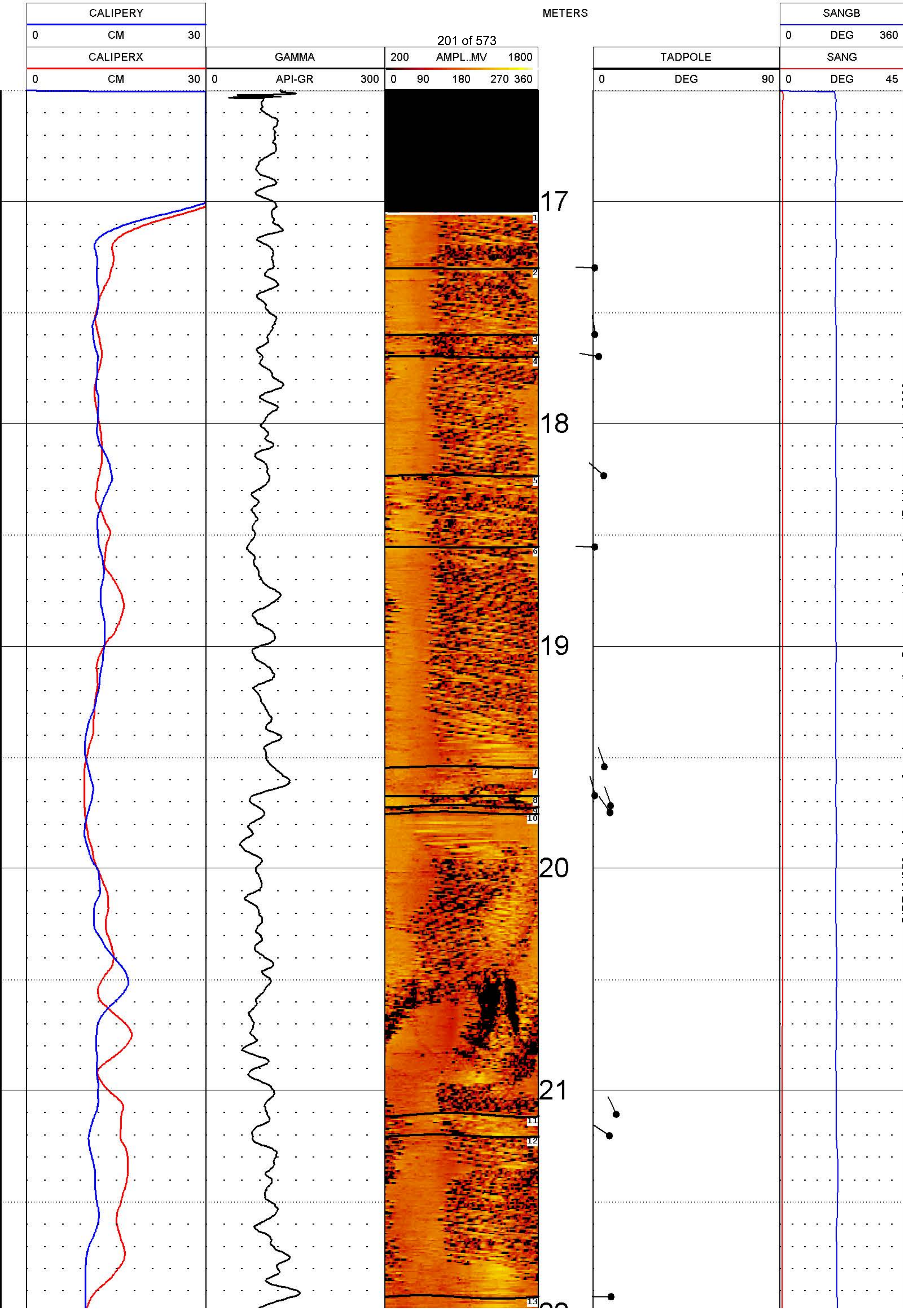
Appendix 1 *1:20 Interpretation logs – 16.50 to 101.64 mbgl*

GROUNDSEARCH AUSTRALIA

BH2A ATV 1:20

COMPANY	COFFEY GEOTECHNICS	OTHER SERVICES:	TV, ON TV, TV	UTM-E	NA
WELL	BH2A ATV 1:20			UTM-N	NA
LOCATION/FIELD	NBN				
COUNTY					
LOCATION	NSW				
SECTION	NA	TOWNSHIP	NA	RANGE	NA
DATE	09/21/18	PERMANENT DATUM			
DEPTH DRILLER	101			KB	NA
LOG BOTTOM	101.640	LOG MEASURED FROM	GL	DF	NA
LOG TOP	16.500	DRL MEASURED FROM	GL	GL	0
CASING DIAMETER	10.	LOGGING UNIT	121		
CASING TYPE	HWT	FIELD OFFICE	RUTHERFORD		
CASING THICKNESS	.5	RECORDED BY	M CRANE		
BIT SIZE	9.6	BOREHOLE FLUID	0	FILE	PROCESSED
MAGNETIC DECL.	0	RM	0	TYPE	9804A
MATRIX DENSITY	2.65	RM TEMPERATURE	0	LGDATE	09/21/18
NEUTRON MATRIX	SANDSTONE	MATRIX DELTA T	177	LGTIME	12:10
				THRESH	99999

ALL SERVICES PROVIDED SUBJECT TO STANDARD TERMS AND CONDITIONS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SANGB
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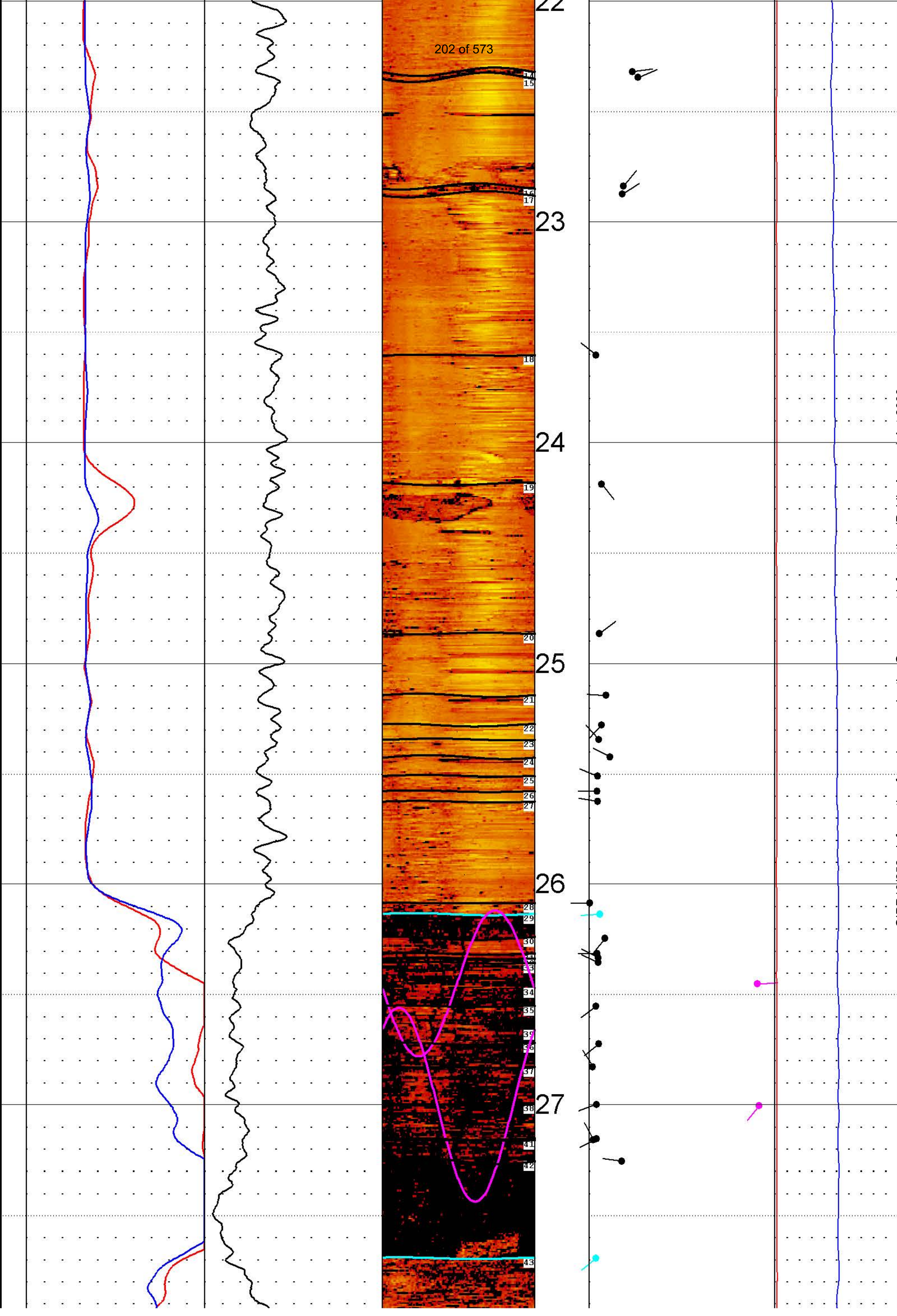
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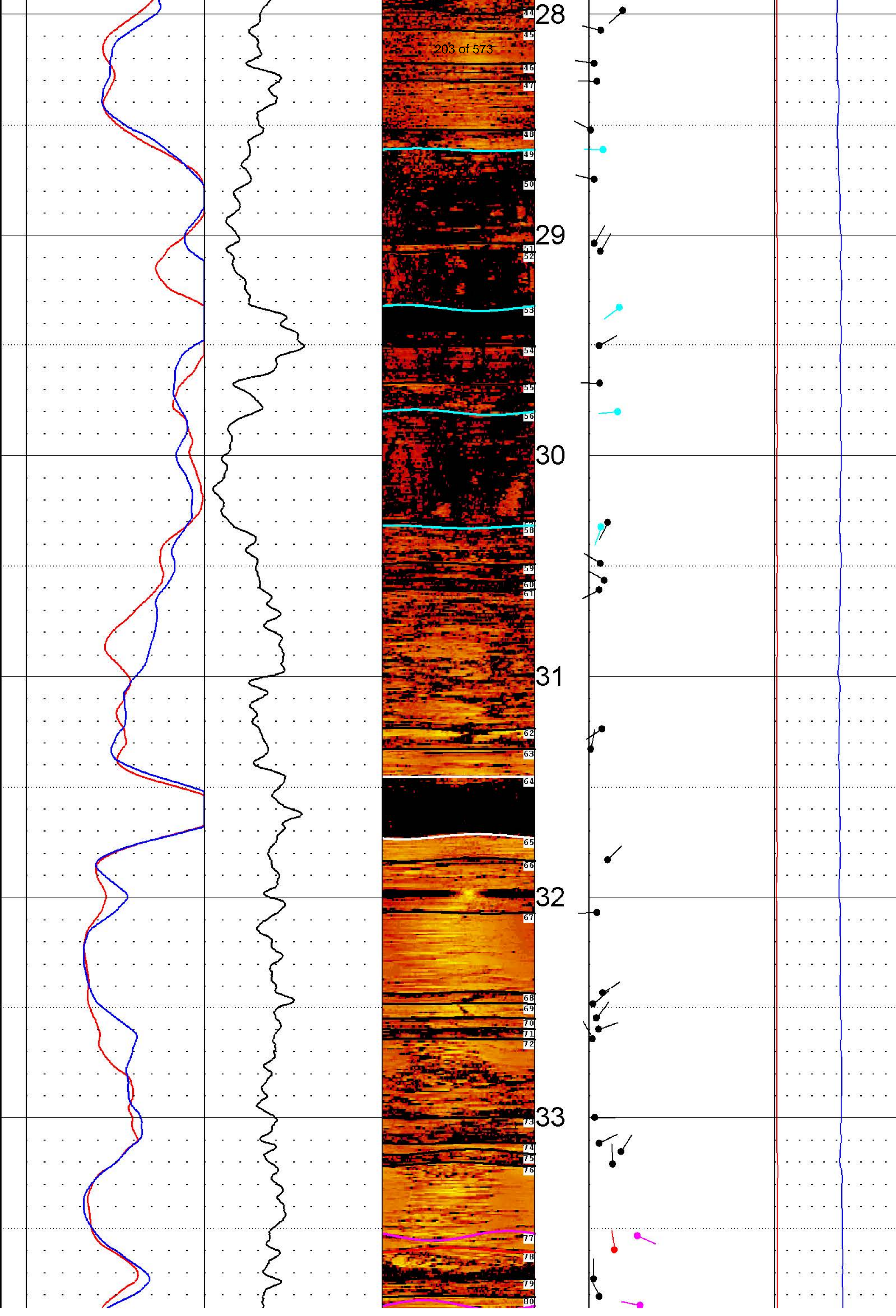
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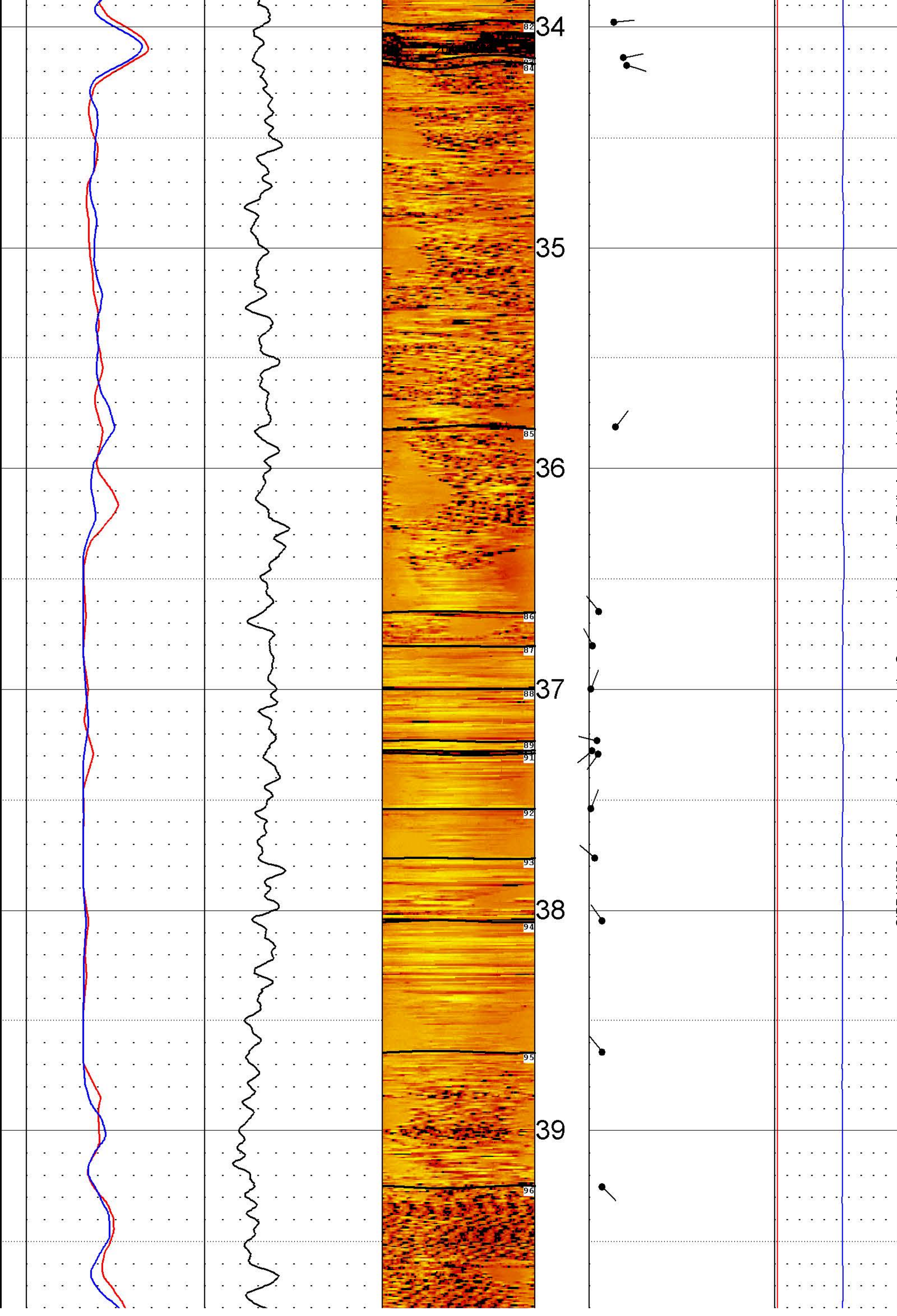
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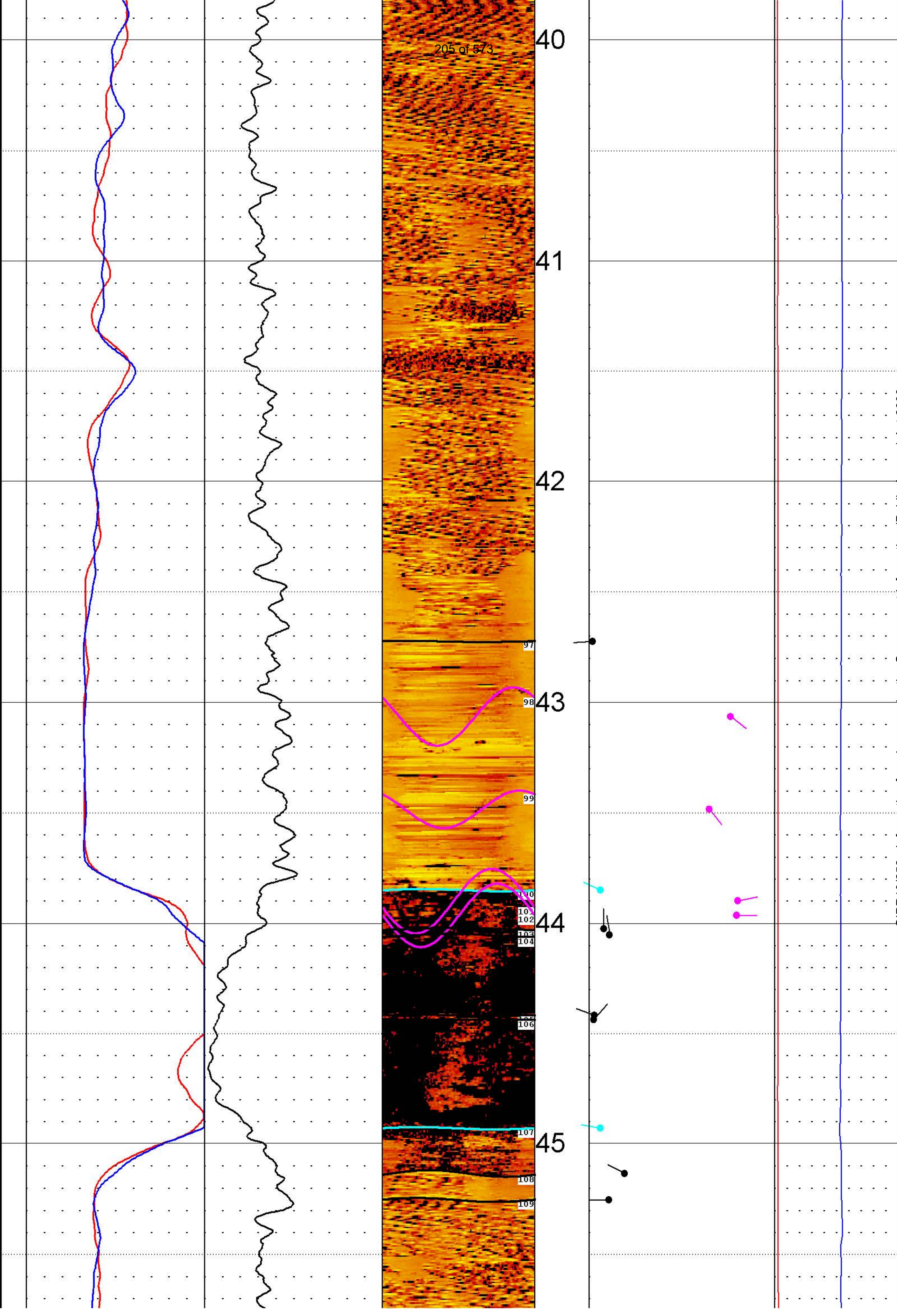

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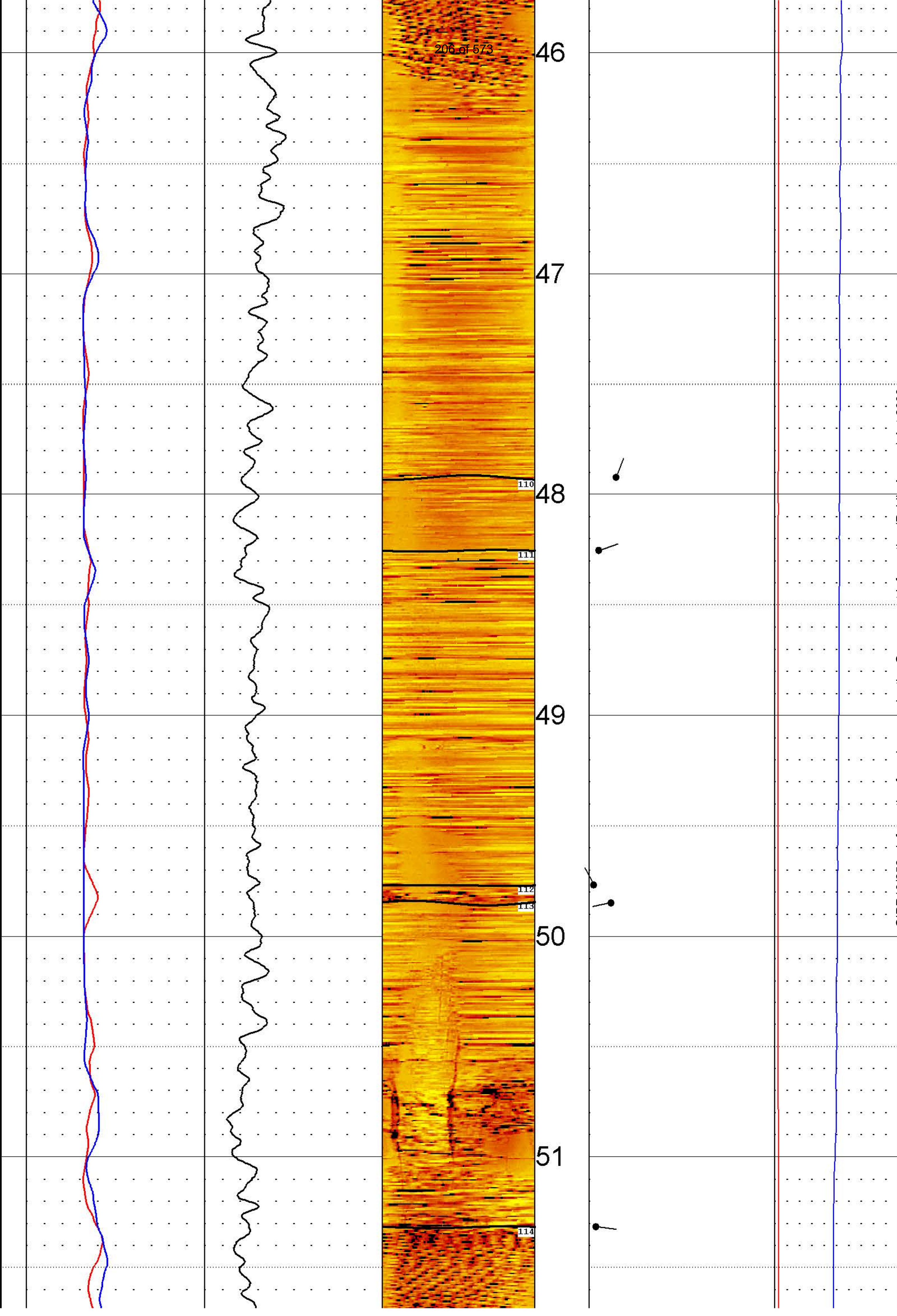
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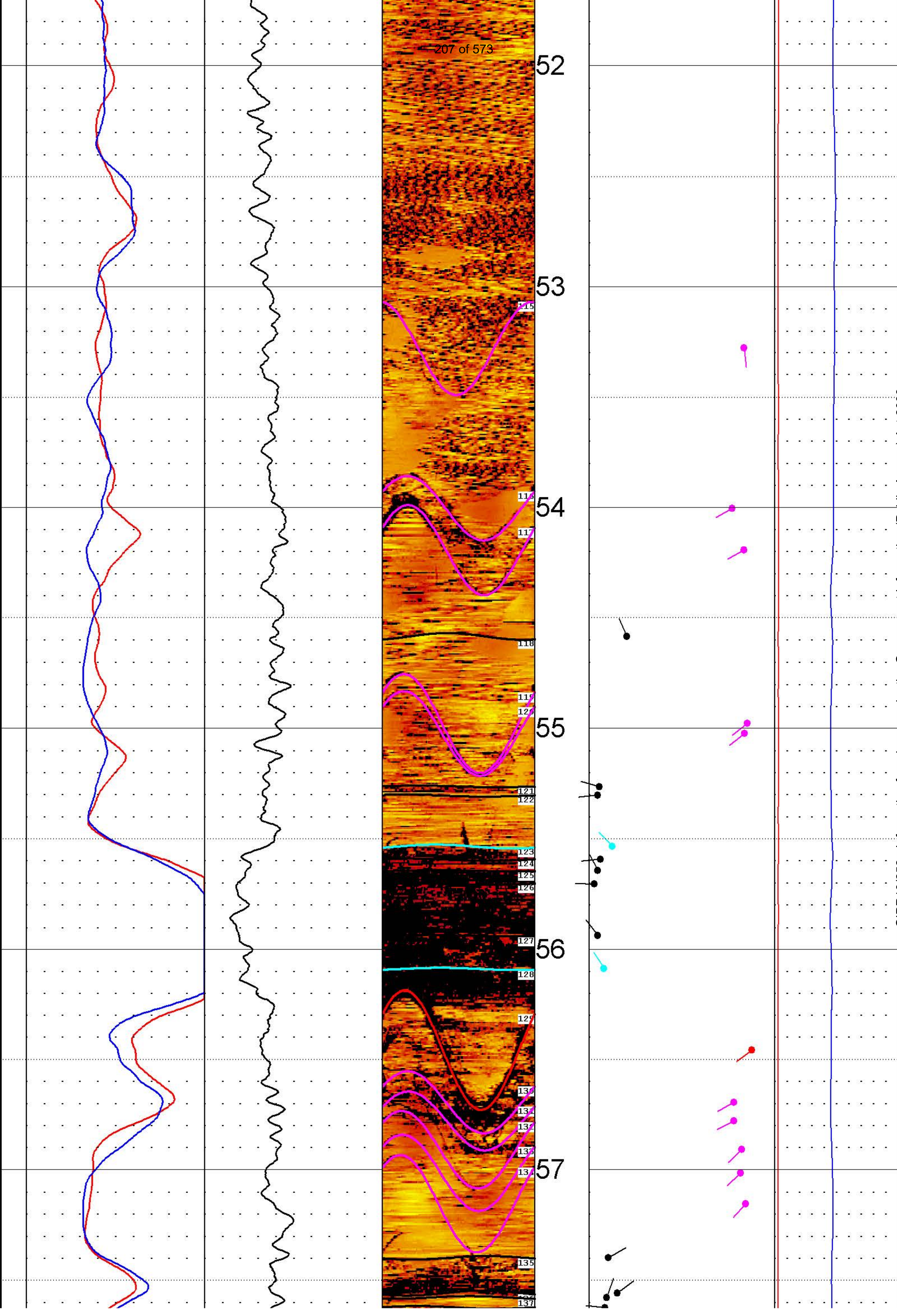

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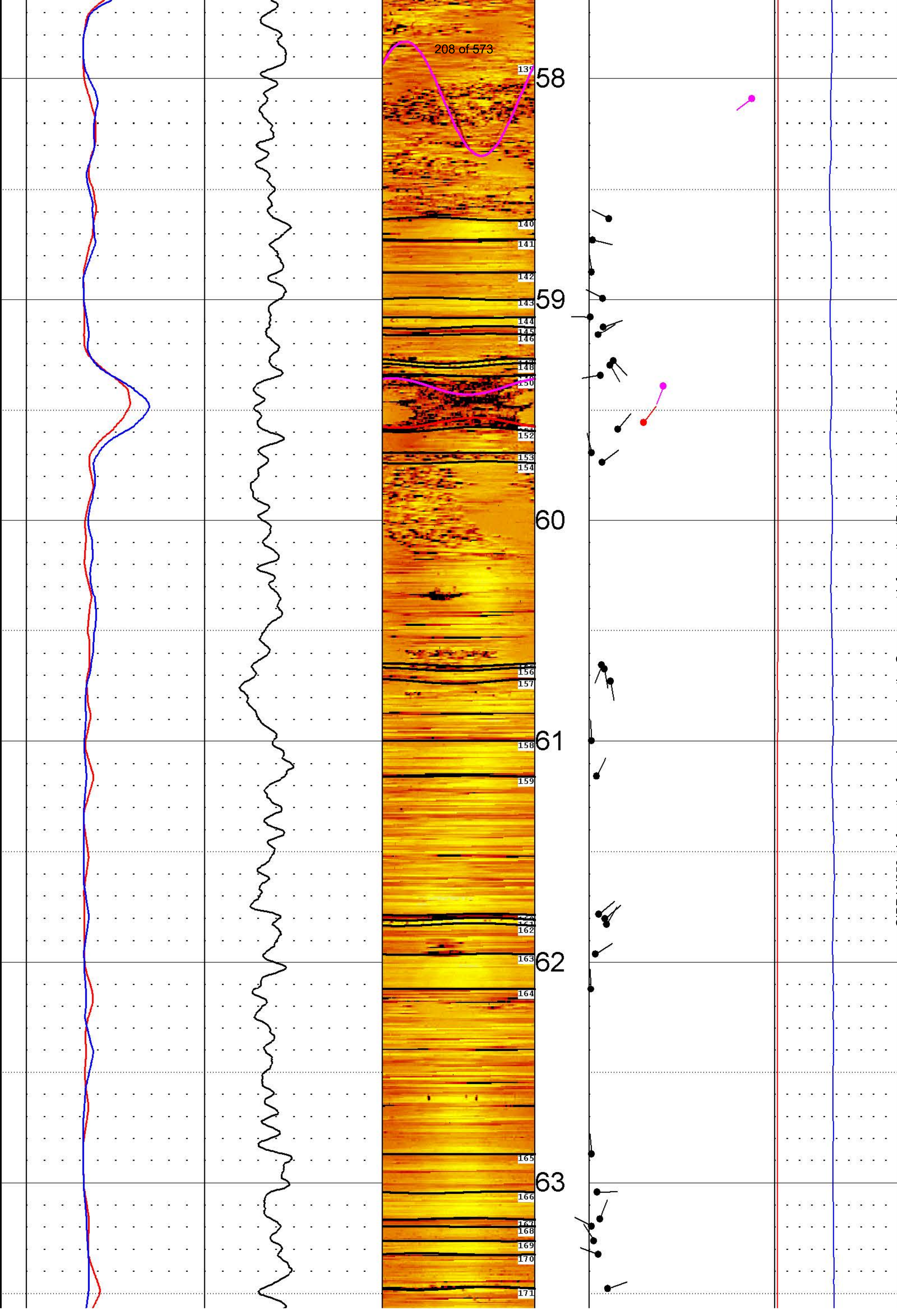

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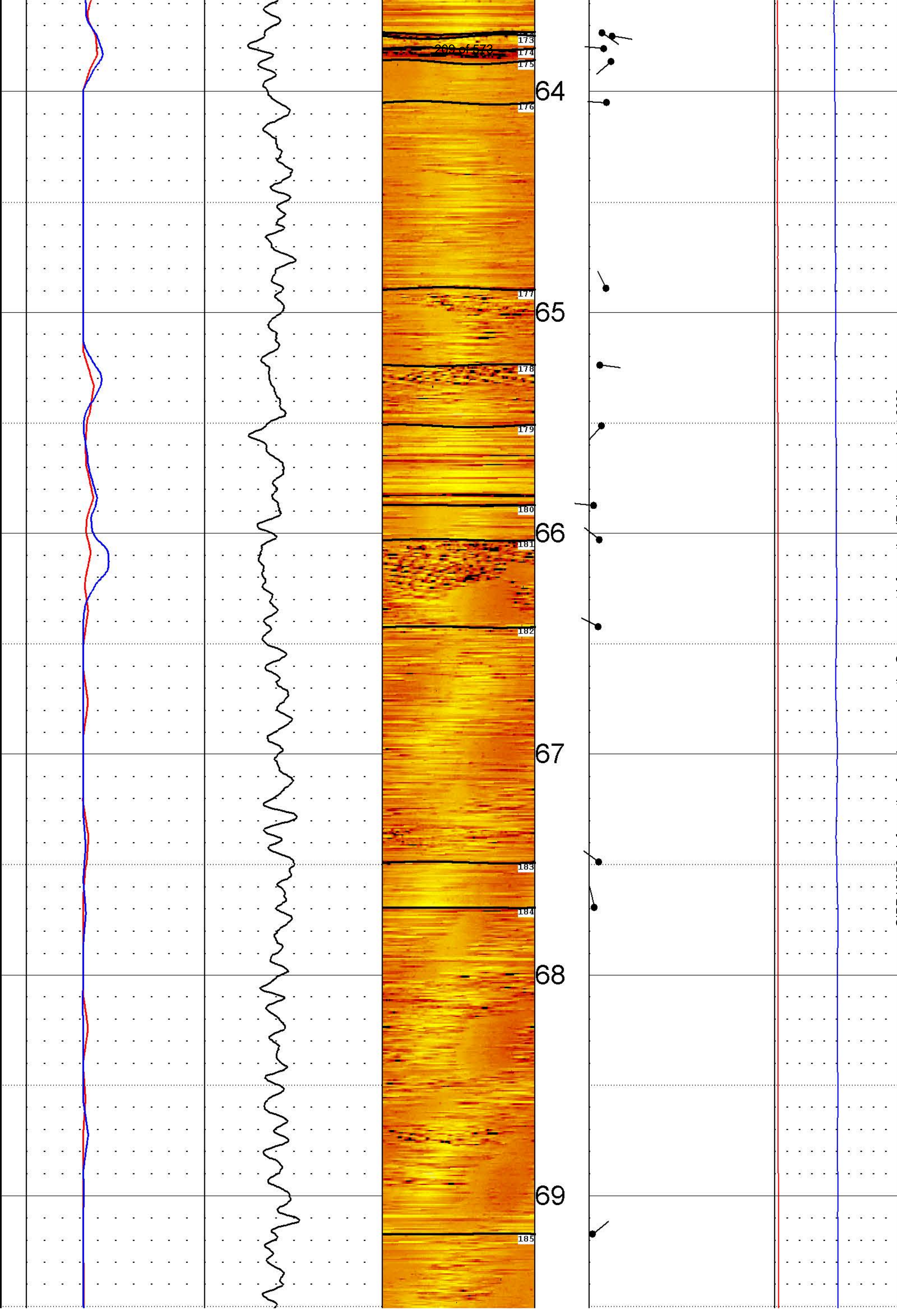
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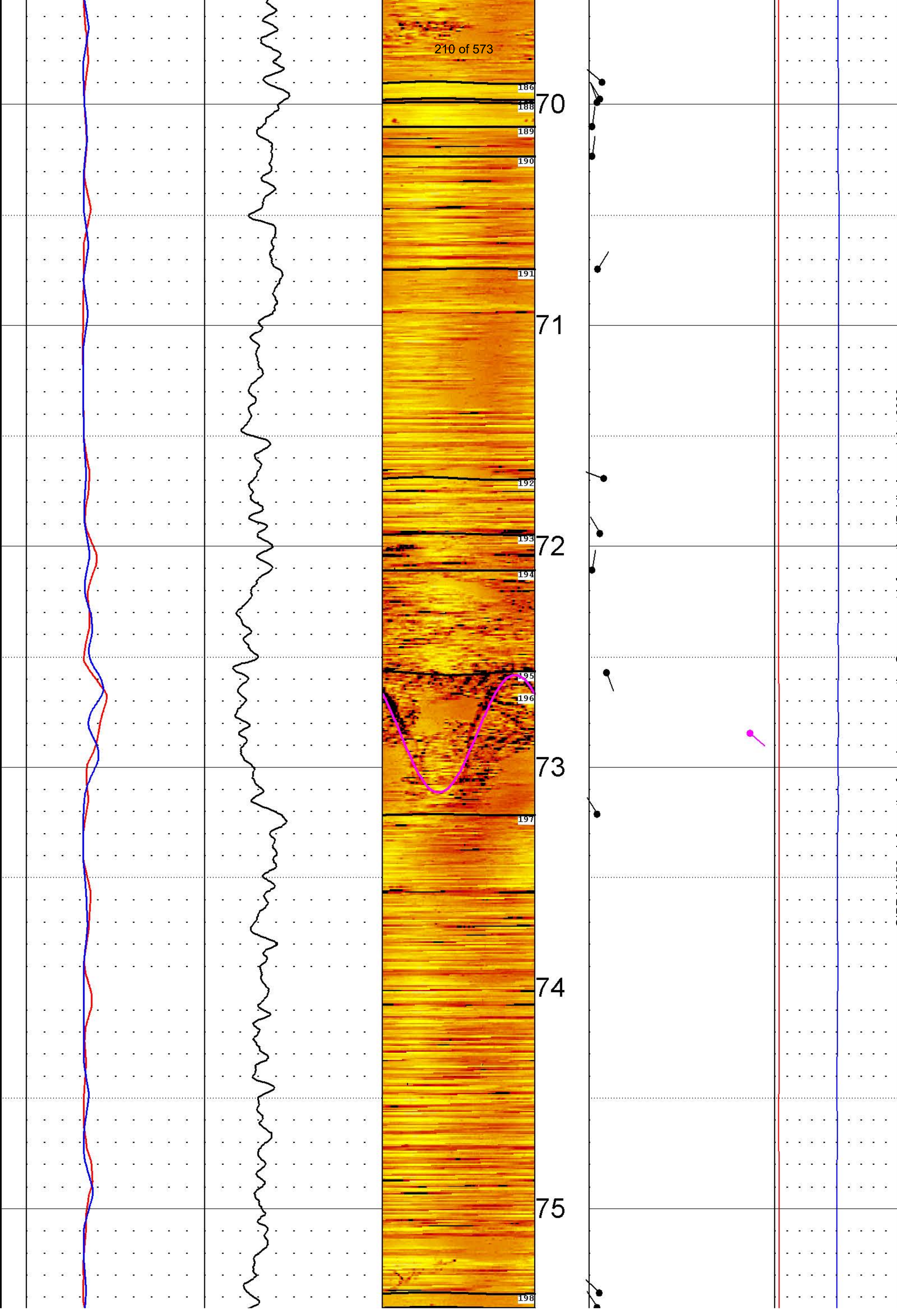
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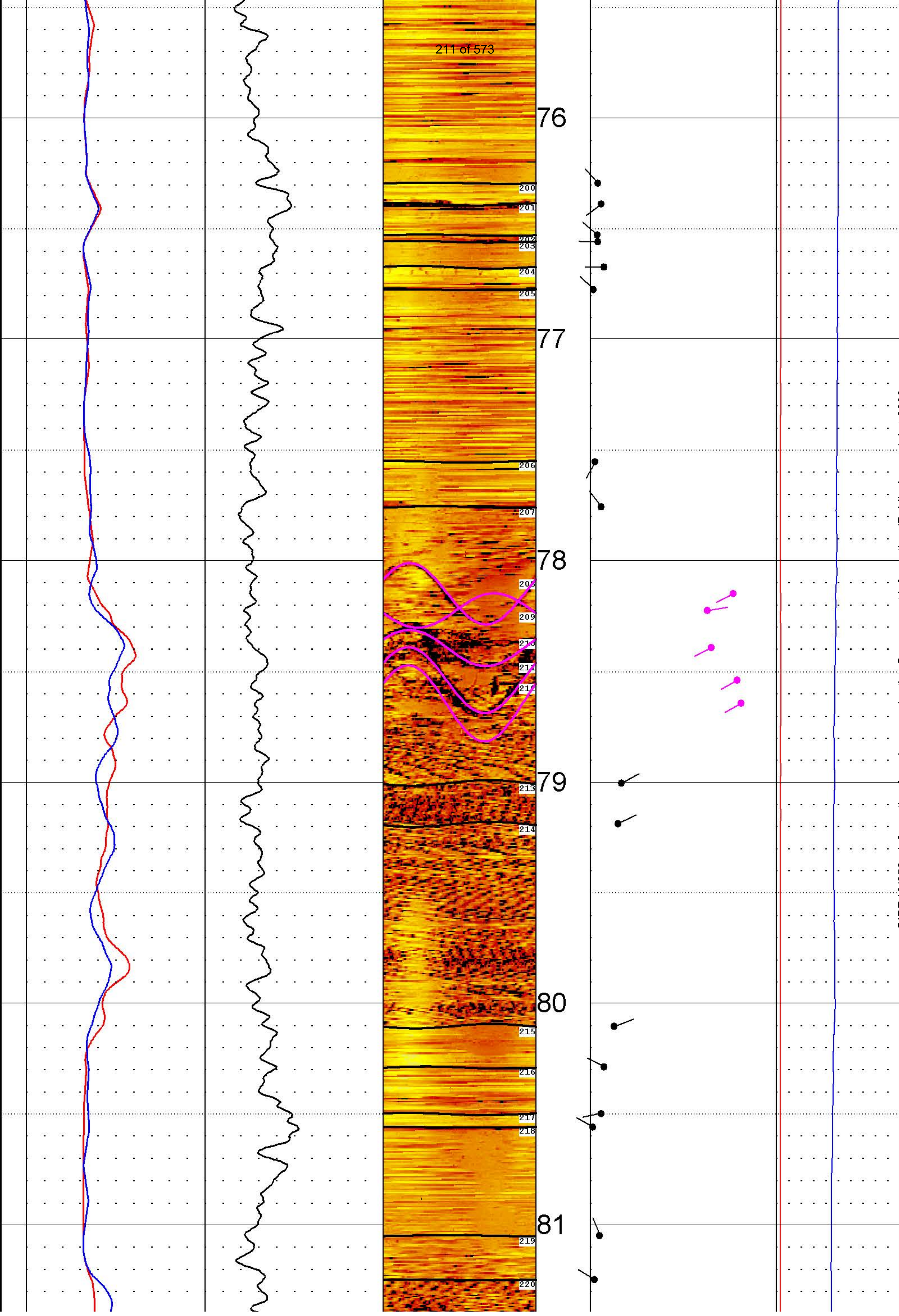
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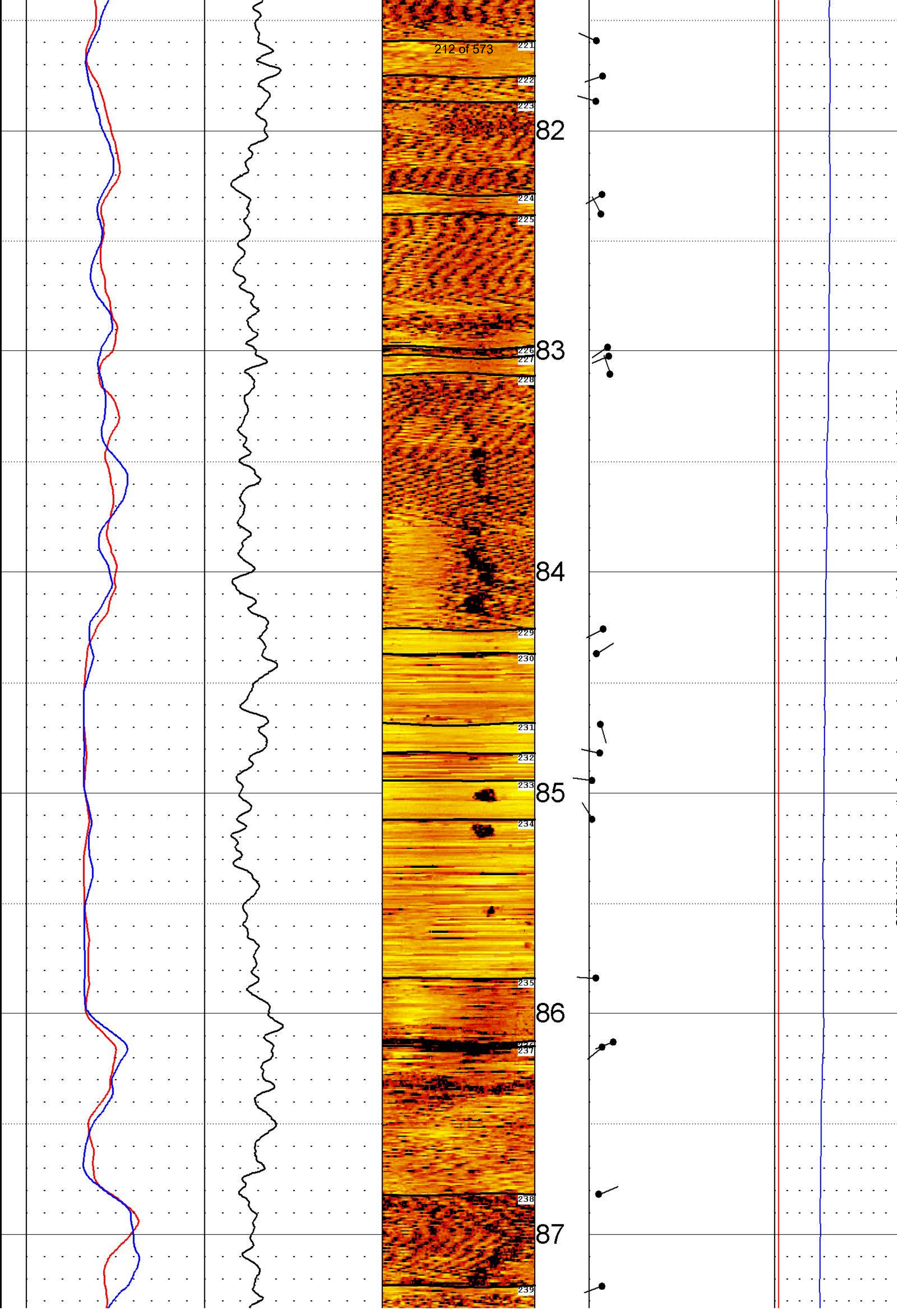
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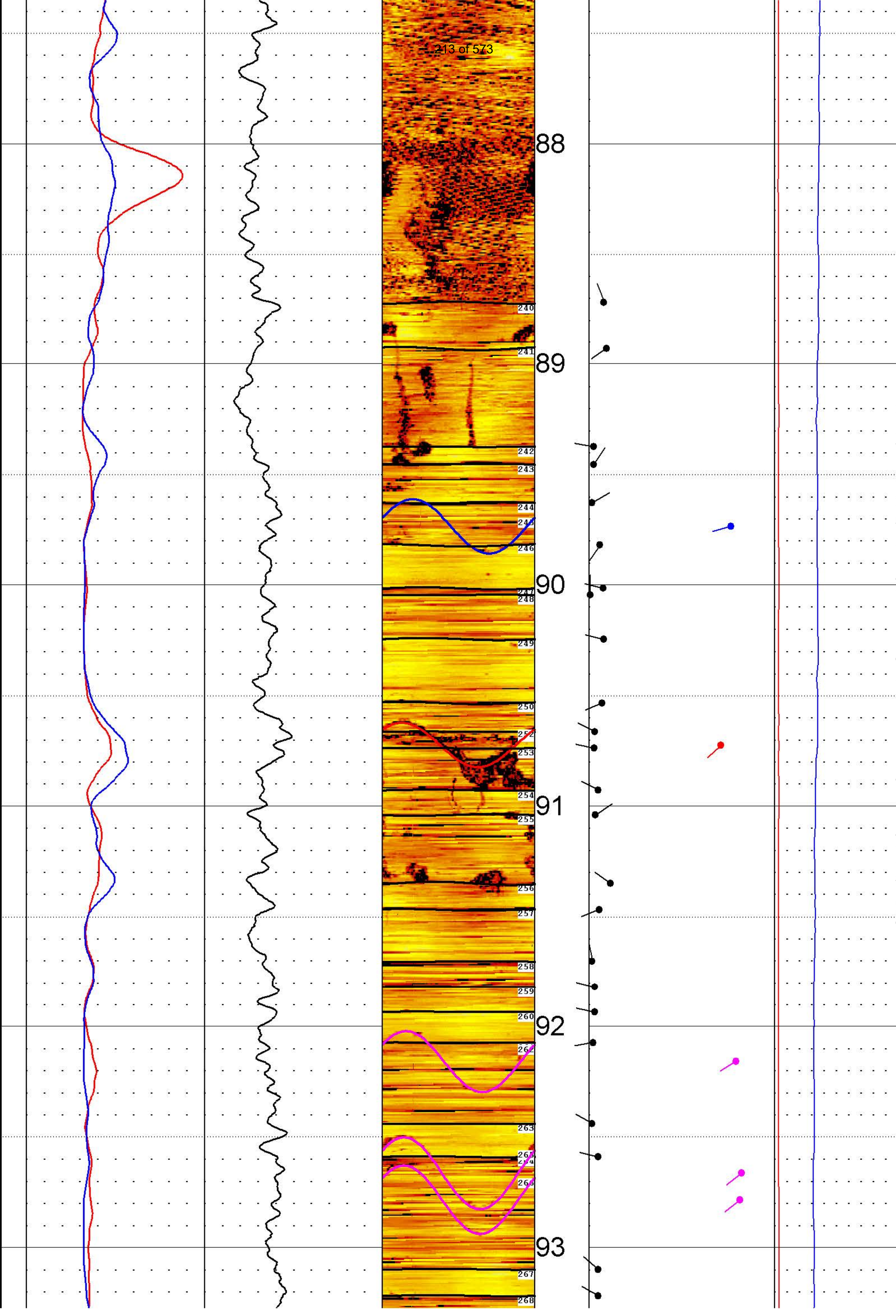
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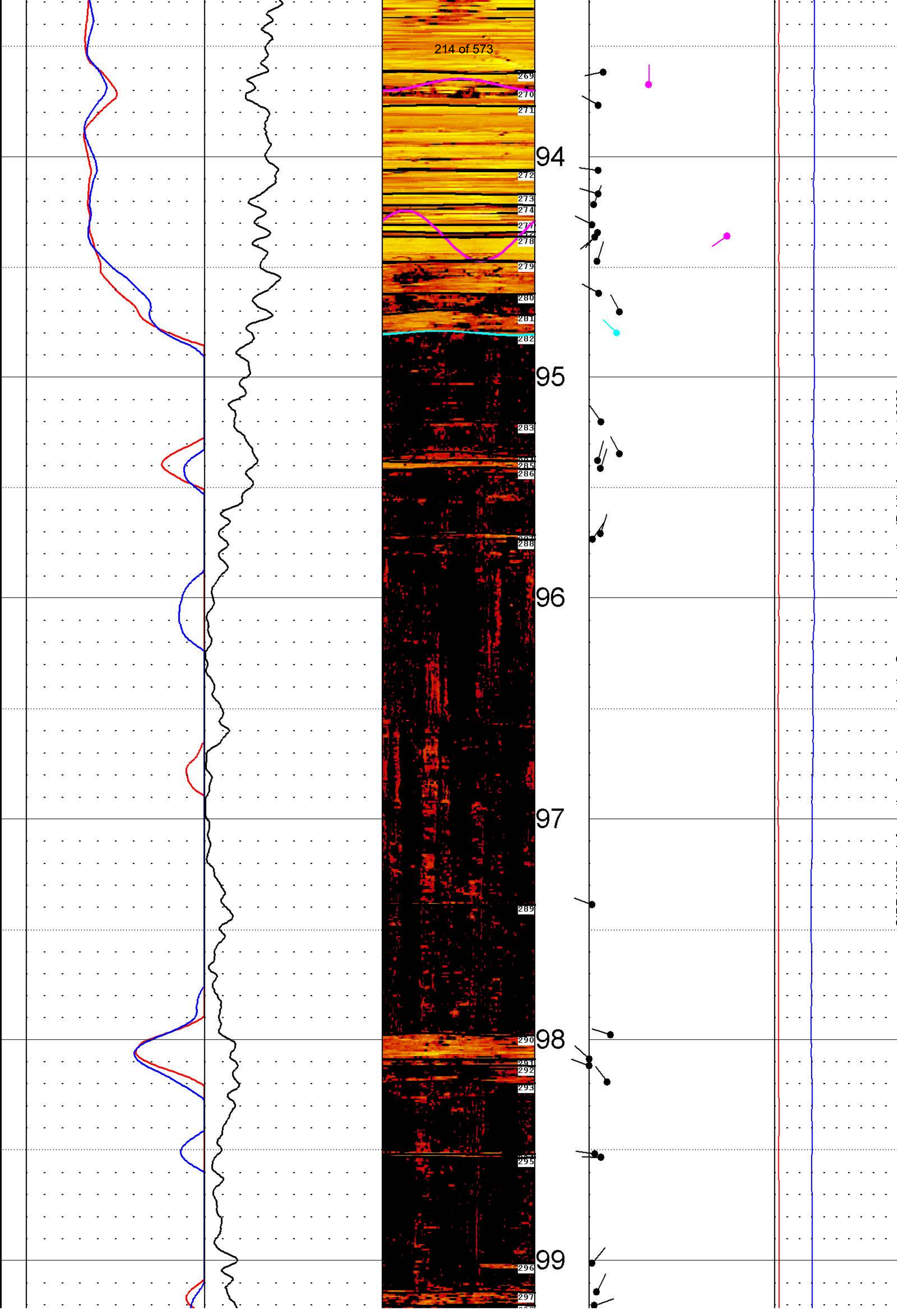
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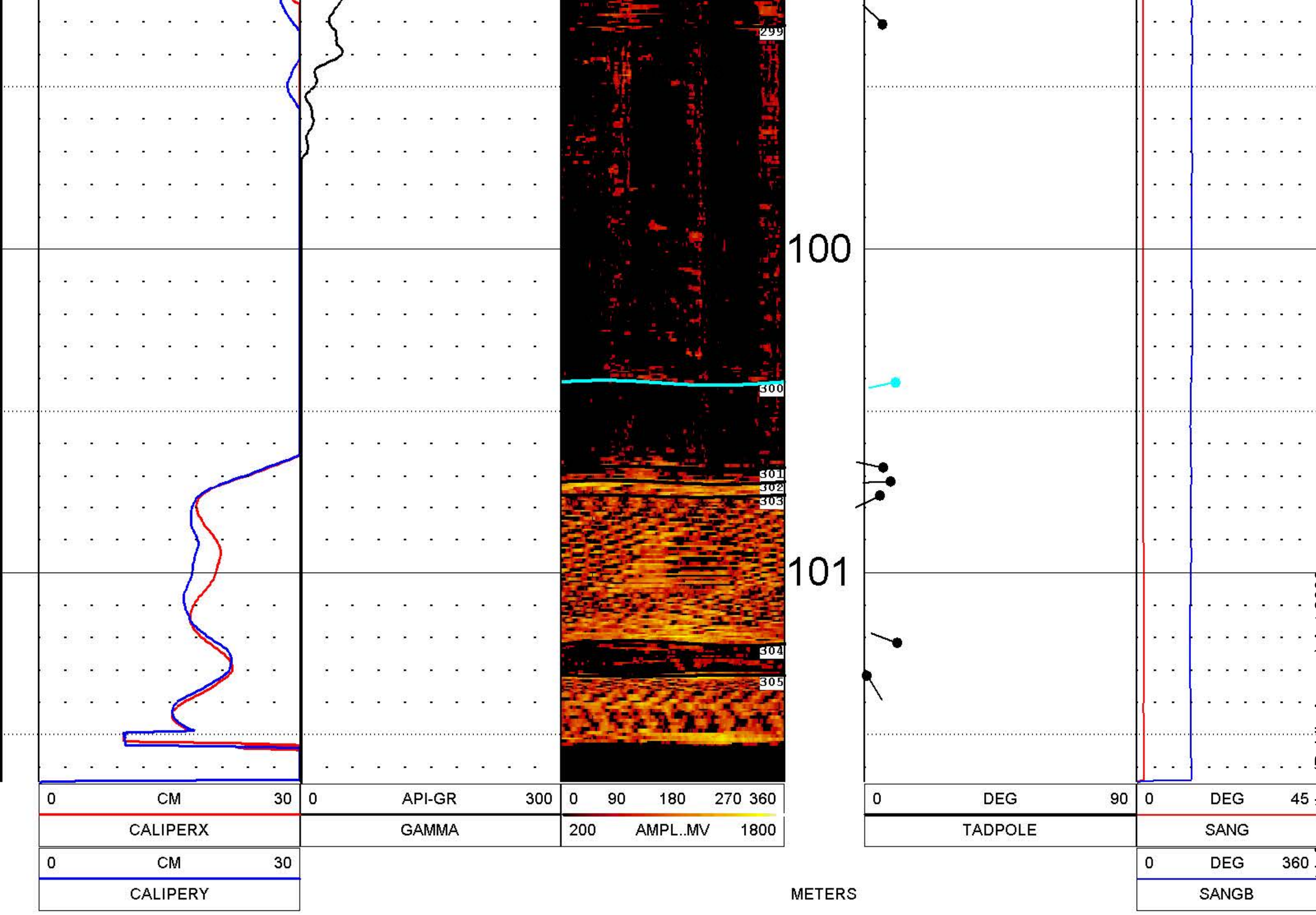
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200 AMPL..MV 1800
METERS
0 DEG 90
TADPOLE
0 DEG 45
SANG
0 DEG 360
SANGB

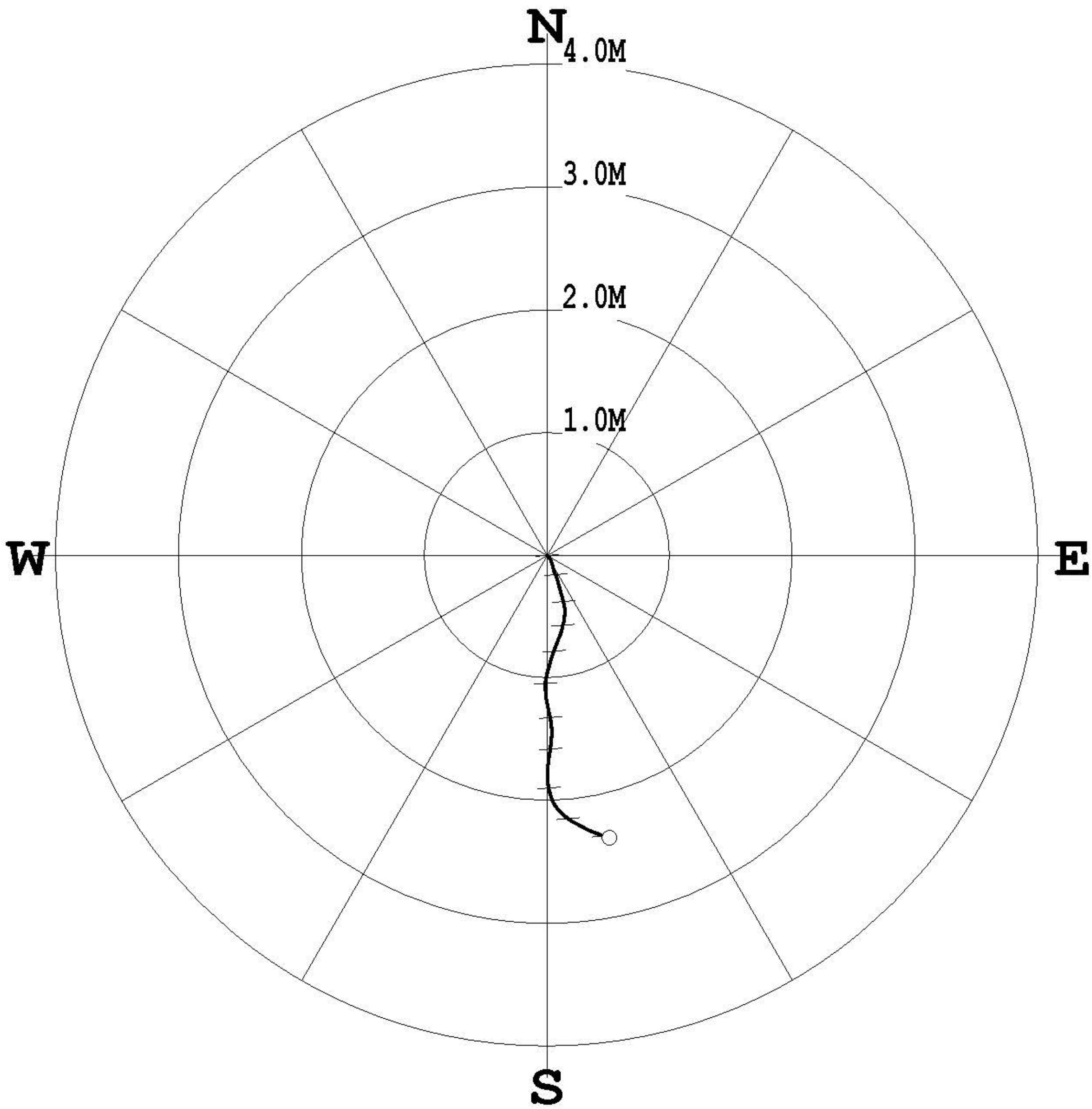
PLAN VIEW

COMPU-LOG DEVIATION

CLIENT: COFFEY
LOCATION: NBN
HOLE ID: BH2A TELEVIEWER
DATE OF LOG: 09/21/18
PROBE: 9804A 4402

MAG DECL: 0.0

SCALE: 1 M/CM
TRUE DEPTH: 101.60 M
AZIMUTH: 167.5
DISTANCE: 2.4 M
+ = 10 M INCR
○ = BOTTOM OF HOLE



* * * * * * * COMPU-LOG - VERTICAL DEVIATION * * * * * * *

CLIENT : COFFEY
FIELD OFFICE : RUTHERFORD
DATA FROM : NA
MAG. DECL. : 0.000

HOLE ID : BH2A TELEVIEW
DATE OF LOG : 09/21/18
PROBE : 9804A , 4402
DEPTH UNITS : METERS

LOG: BH2ATELEVIEWER_09-21-18_12-10_9804A_.01_-0.73_101.64_DEVI.log

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10.00	10.00	-0.16	0.07	0.2	156.2	1.4	158.0
20.00	20.00	-0.37	0.13	0.4	160.7	1.3	164.5
30.00	29.99	-0.57	0.13	0.6	167.3	1.2	196.9
40.00	39.99	-0.78	0.05	0.8	176.0	1.4	199.0
50.00	49.99	-1.04	-0.01	1.0	180.8	1.6	186.3
60.00	59.98	-1.32	0.02	1.3	178.9	1.5	171.3
70.00	69.98	-1.58	0.03	1.6	179.1	1.7	189.4
80.00	79.98	-1.89	0.01	1.9	179.6	1.8	174.4
90.00	89.97	-2.14	0.17	2.1	175.4	1.9	128.2
100.00	99.97	-2.28	0.46	2.3	168.7	2.0	111.6
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GROUNDSEARCH AUSTRALIA

BH2A DENSITYC 1:20

COMPANY	: COFFEY						
WELL	: BH2A DENSITYC 1:20						
LOCATION/FIELD	: NBN						
COUNTRY	: AUST						
LOCATION	: NSW						
SECTION	: NA	TOWNSHIP	: NA	RANGE	: NA		
DATE	: 09/21/18	PERMANENT DATUM	: -1.5				
DEPTH DRILLER	: 102			KB	: NA		
LOG BOTTOM	: 100.55	LOG MEASURED FROM:	GL	DF	: NA		
LOG TOP	: -1.28	DRL MEASURED FROM:	GL	GL	: 0		
CASING DIAMETER	: 10.	LOGGING UNIT	: 121				
CASING TYPE	: HWT	FIELD OFFICE	: RUTHERFORD				
CASING THICKNESS:	.5	RECORDED BY	: M CRANE				
BIT SIZE	: 9.60	BOREHOLE FLUID	: 0	FILE	: PROCESSED		
MAGNETIC DECL.	: 0	RM	: 0	TYPE	: 9239B		
MATRIX DENSITY	: 2.65	RM TEMPERATURE	: 0	LGDATE	: 09/21/18		
NEUTRON MATRIX	: SANDSTONE	MATRIX DELTA T	: 177	LGTIME	: 10:54:		
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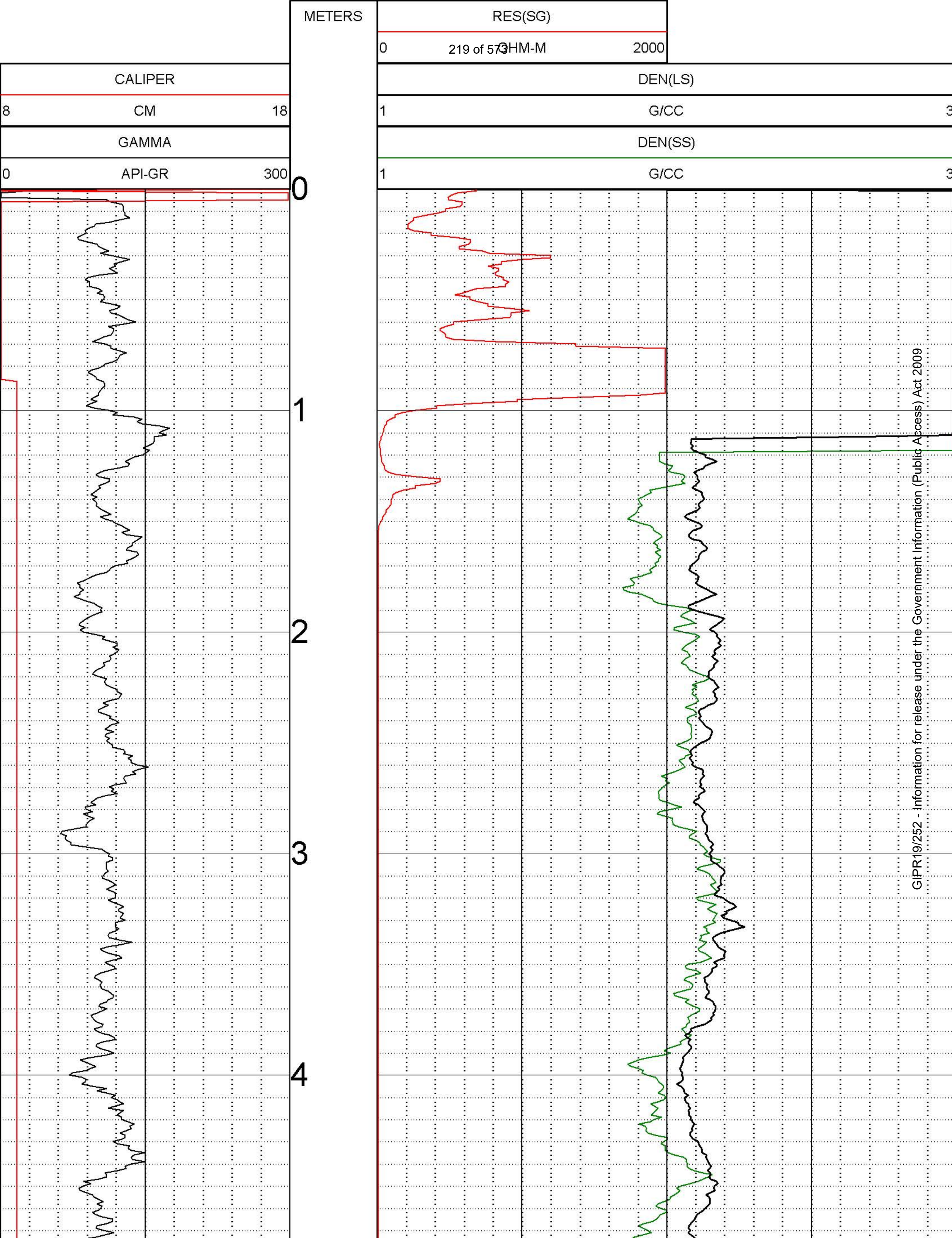
OTHER SERVICES:
DEN TV

CORRECTED FOR STEEL

ALL SERVICES PROVIDED SUBJECT TO STANDARD TERMS AND CONDITIONS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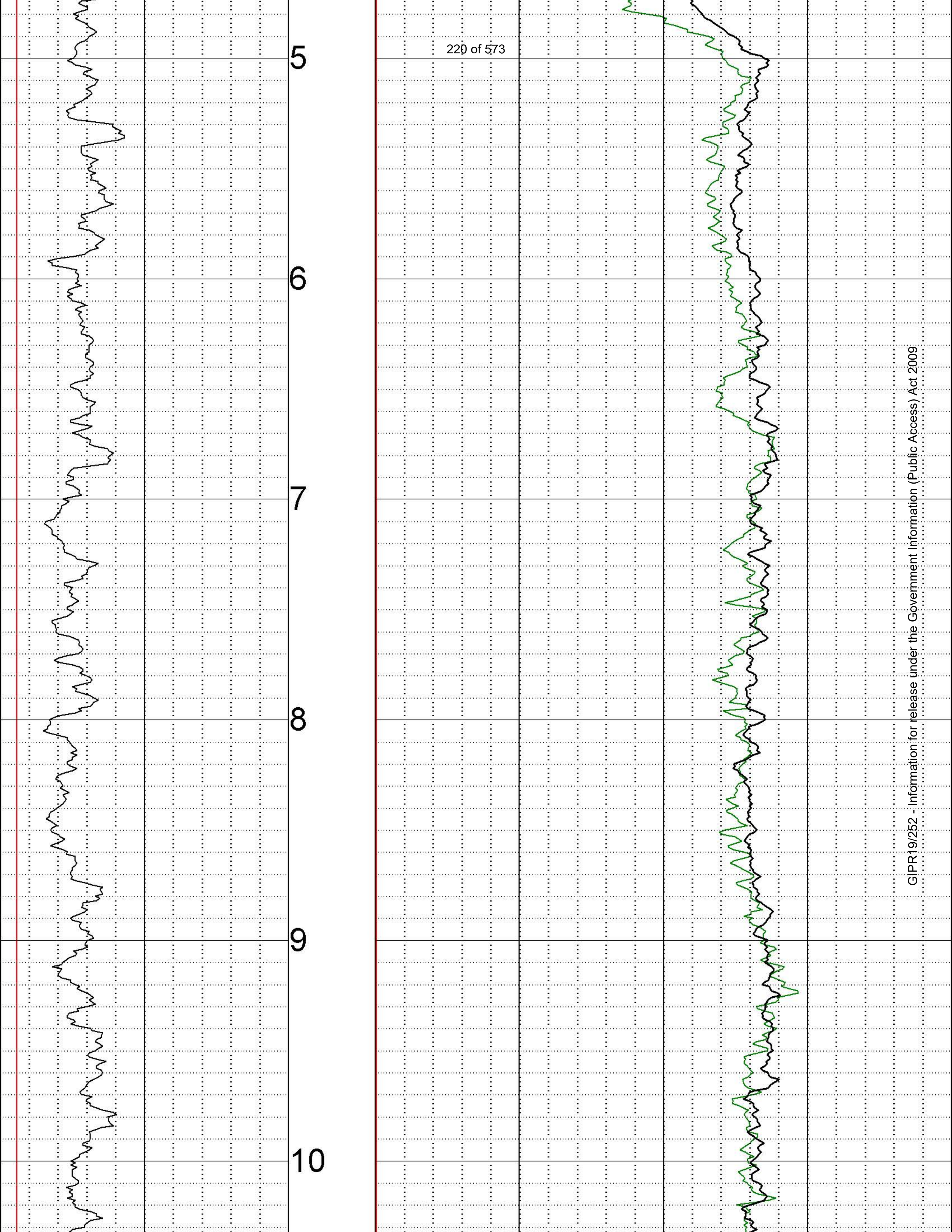
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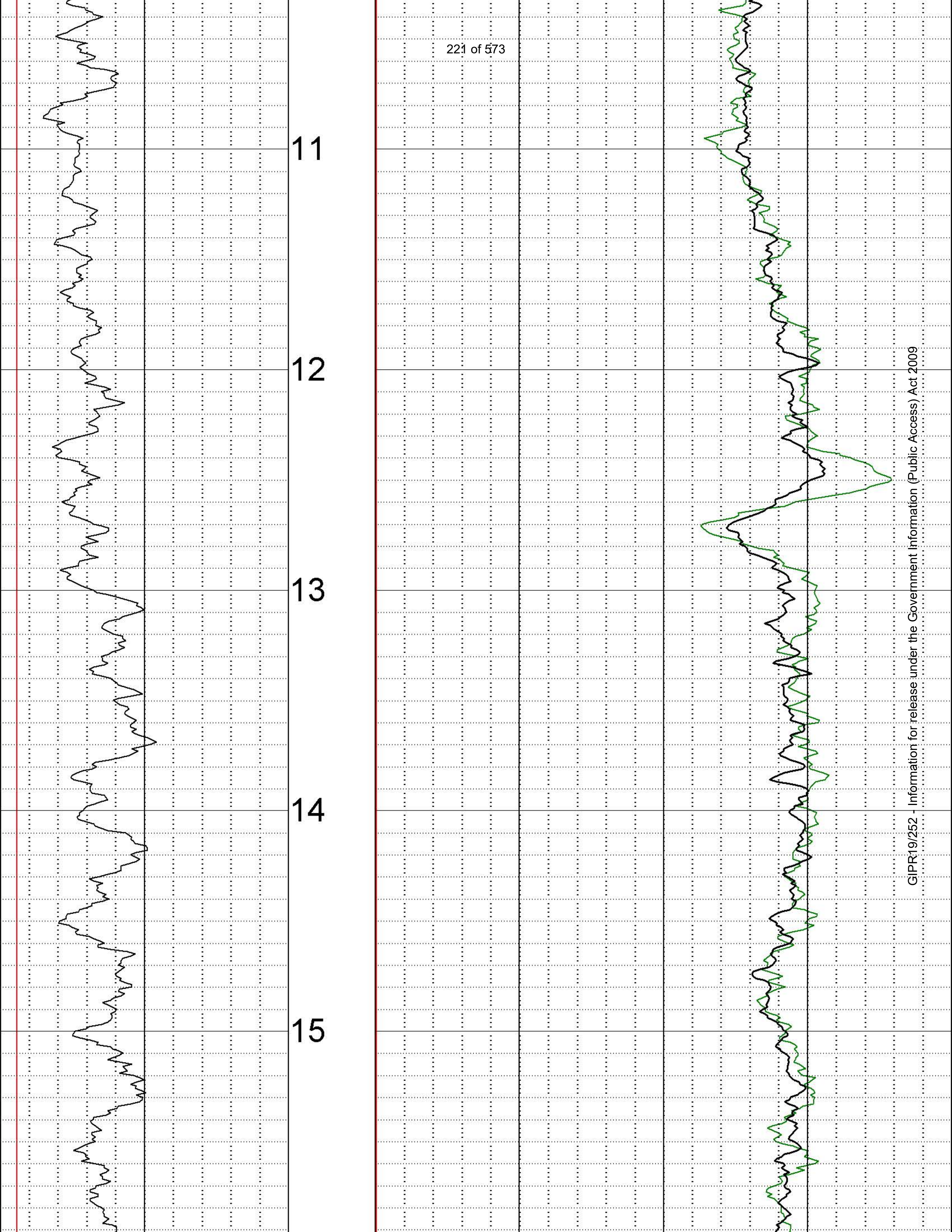
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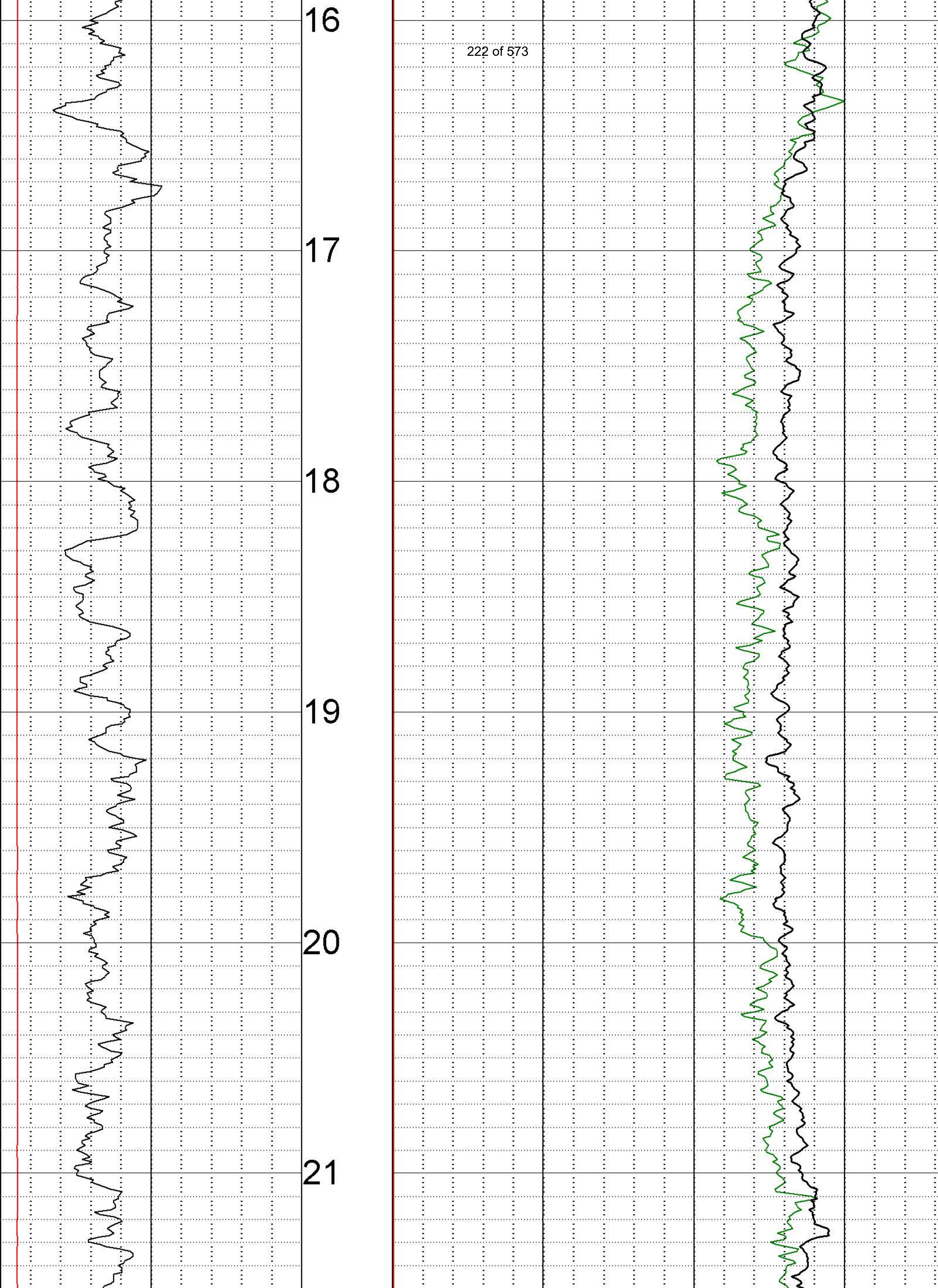
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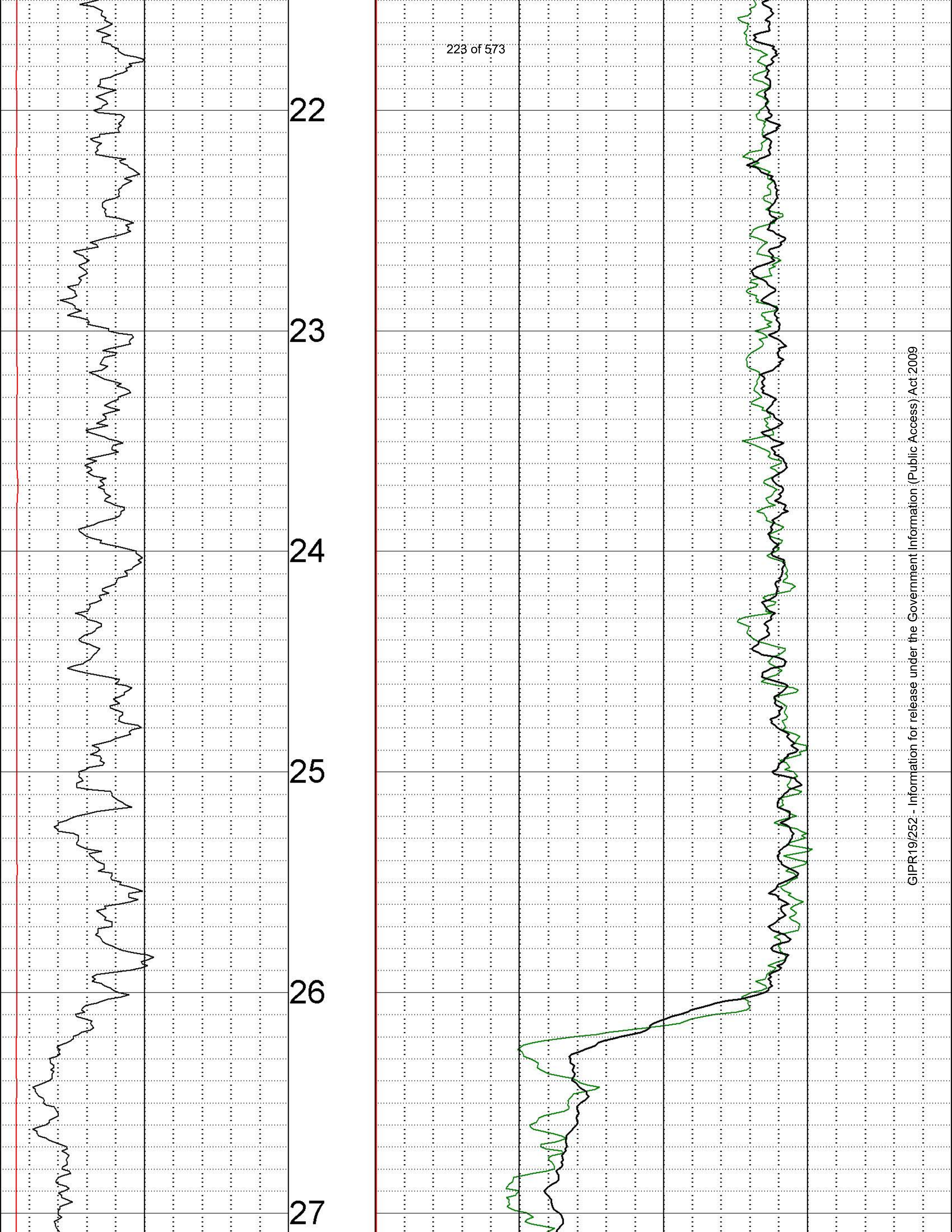
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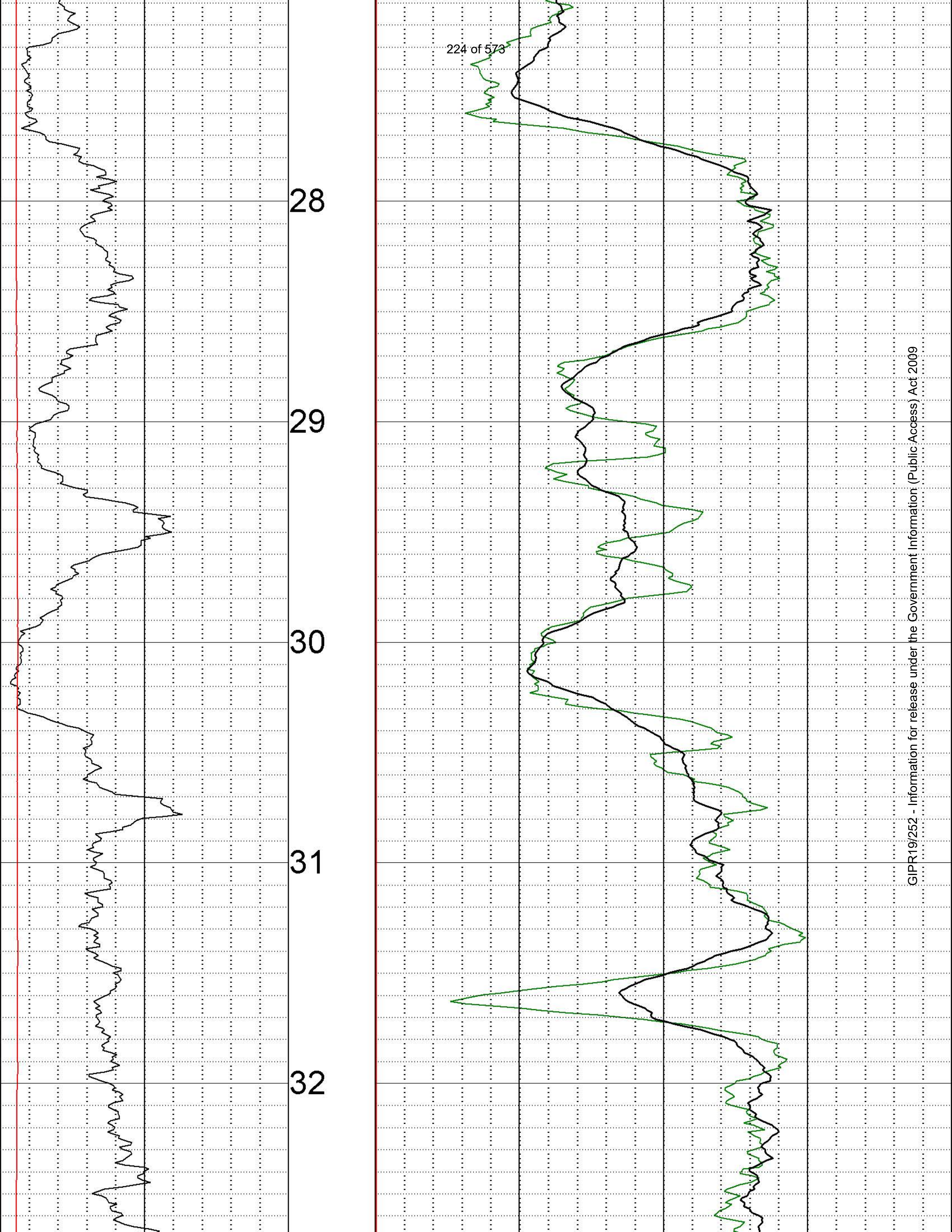
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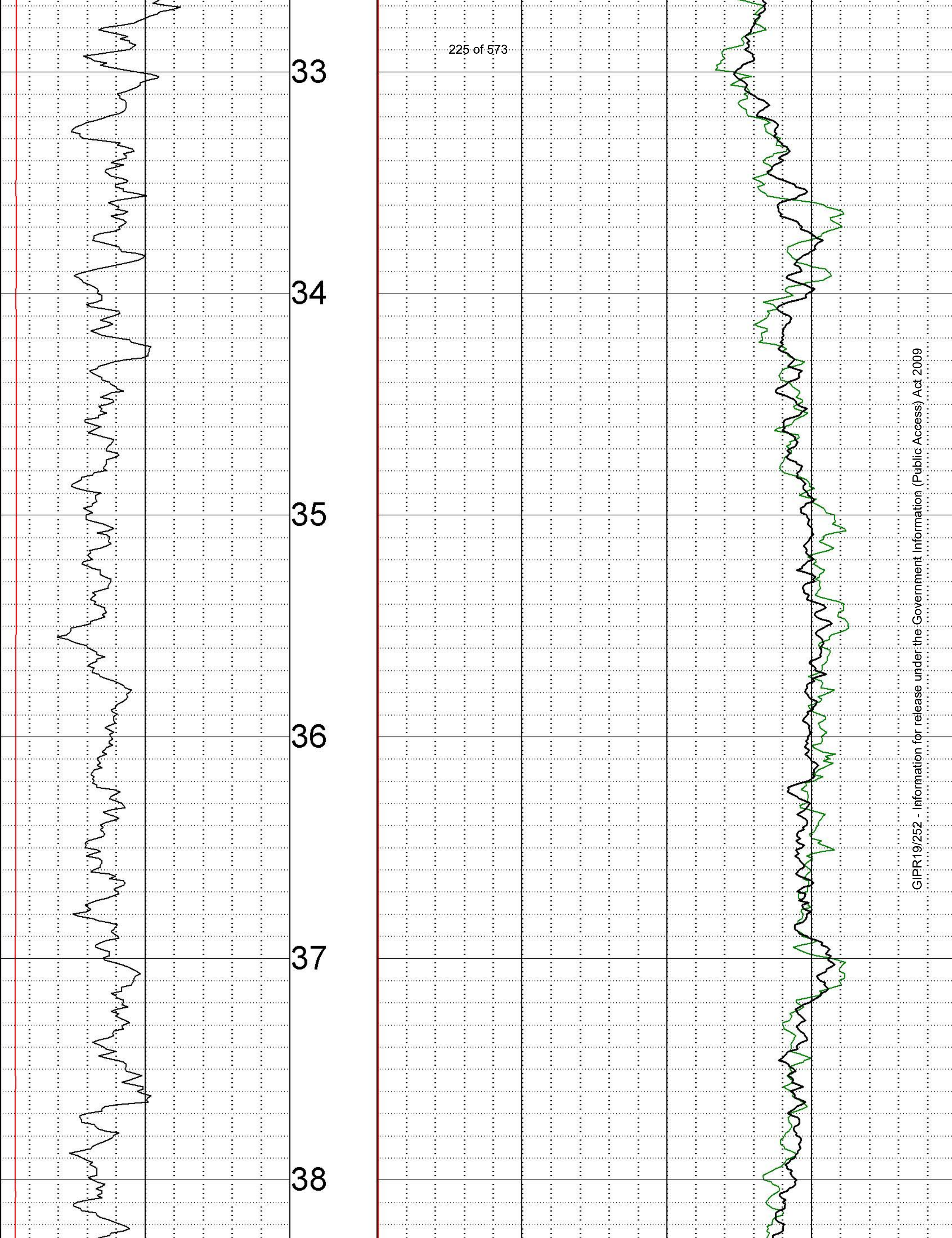
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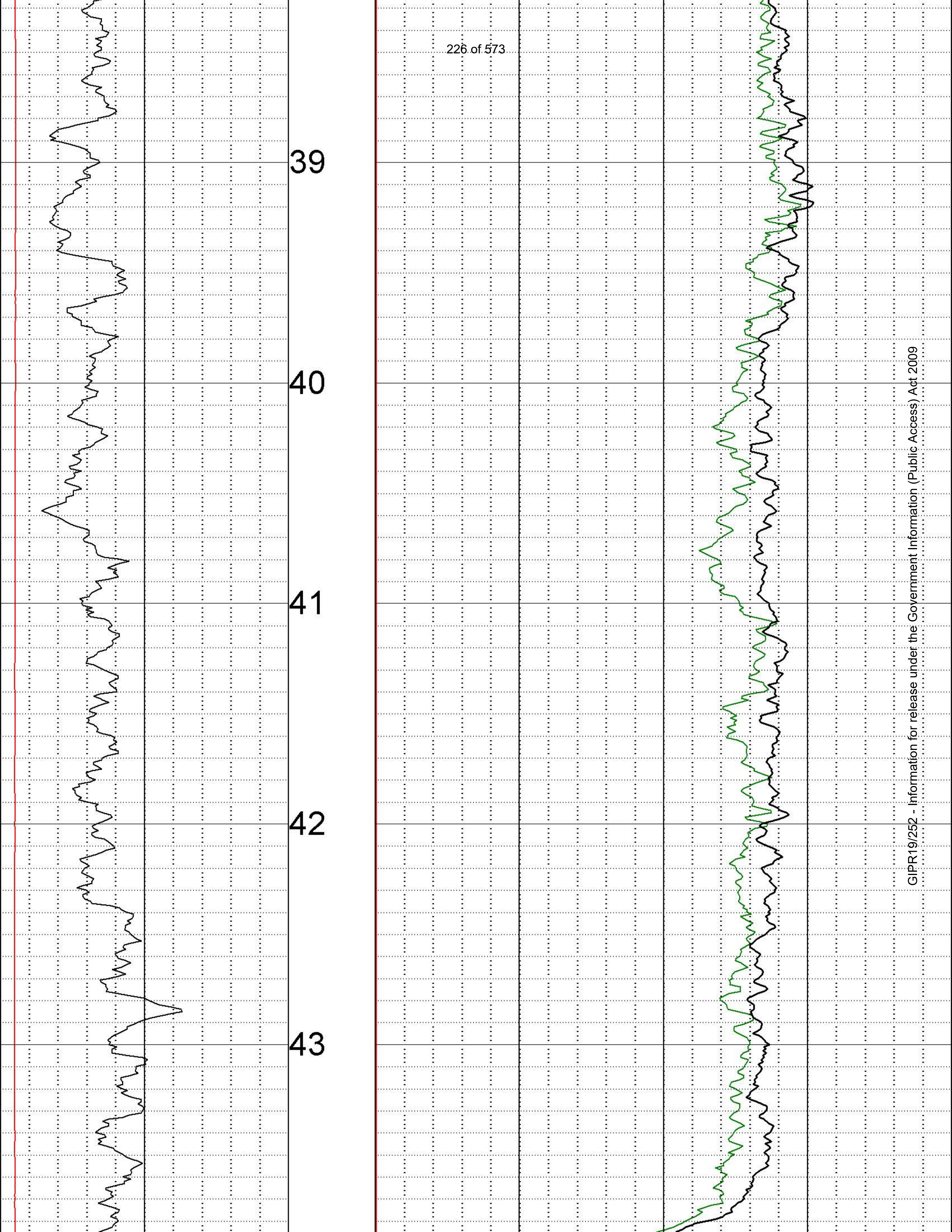
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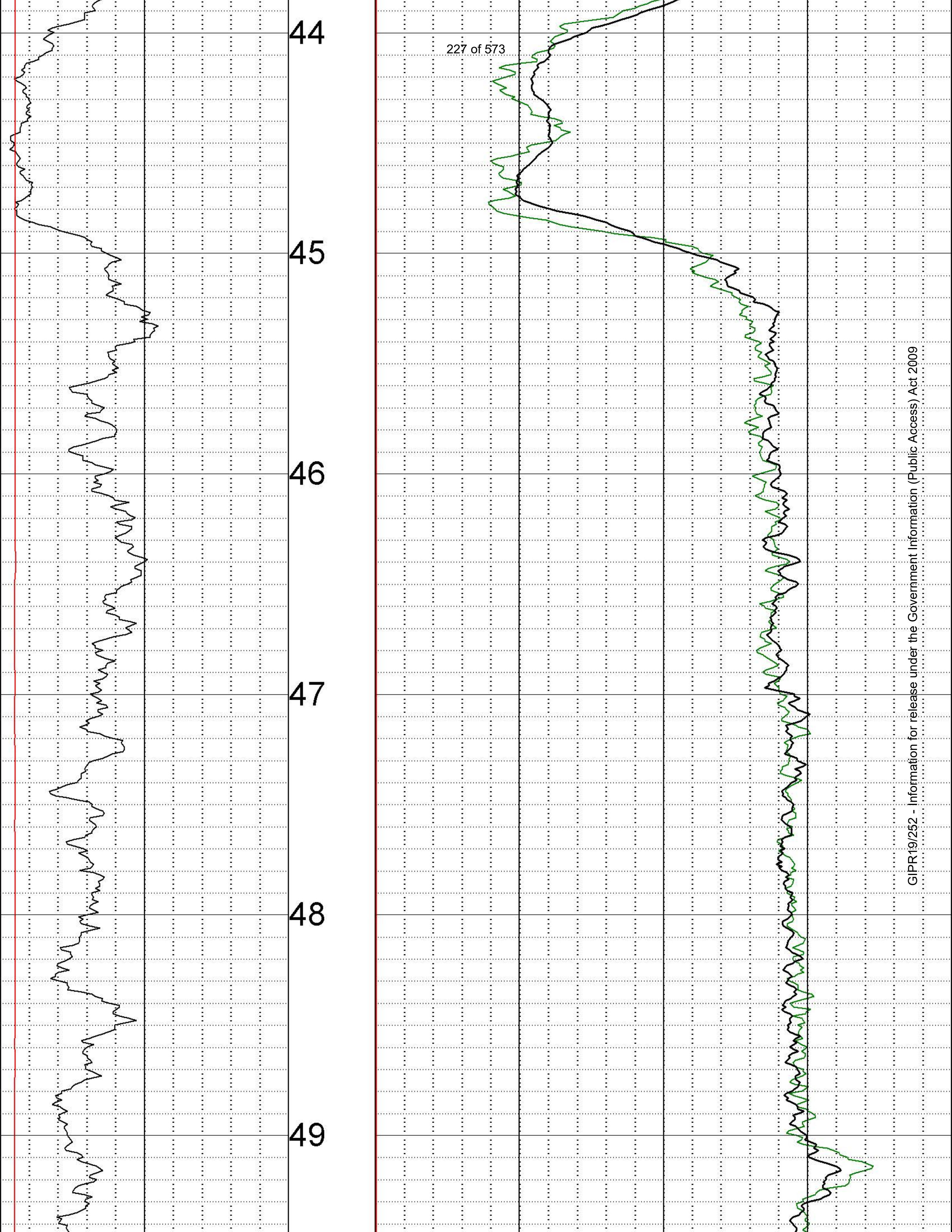
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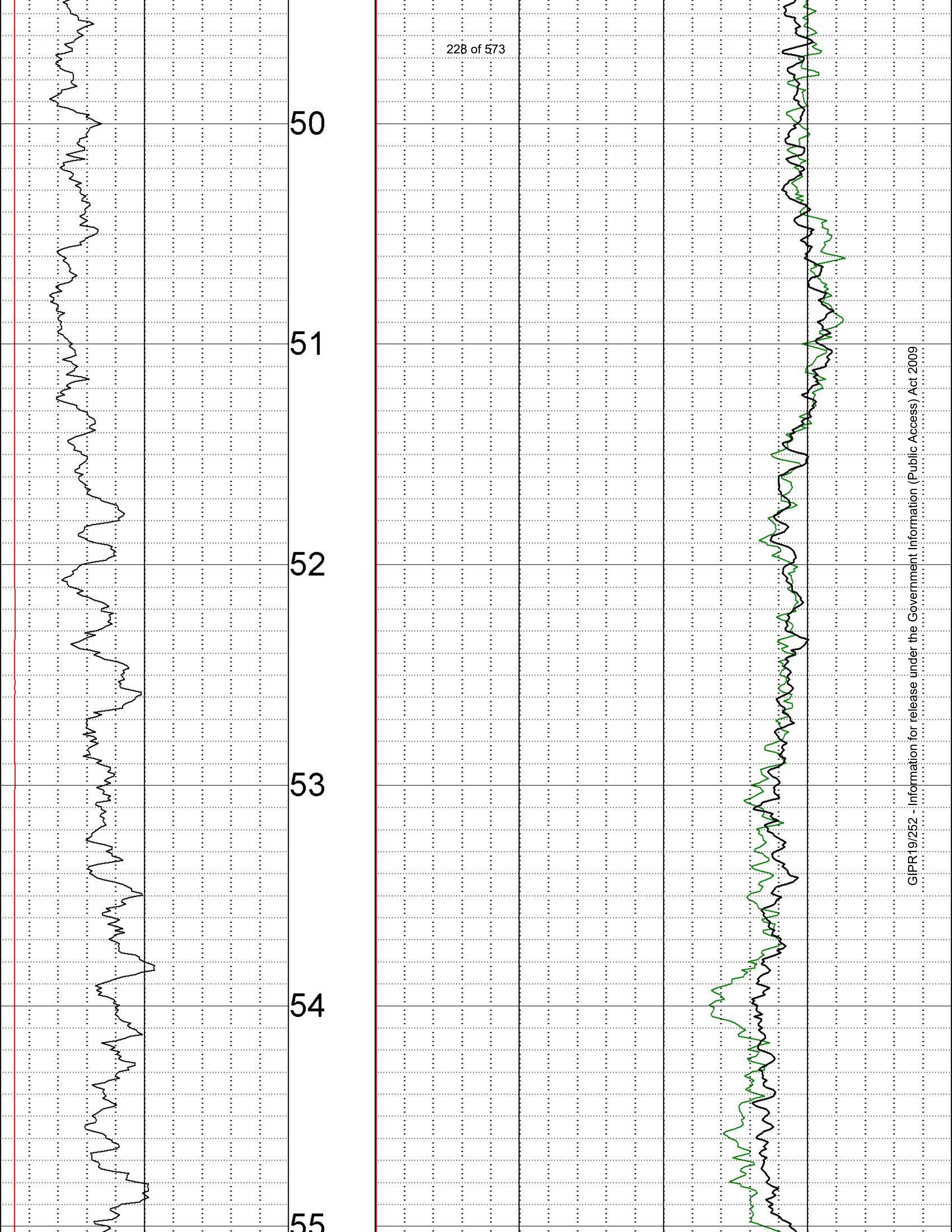
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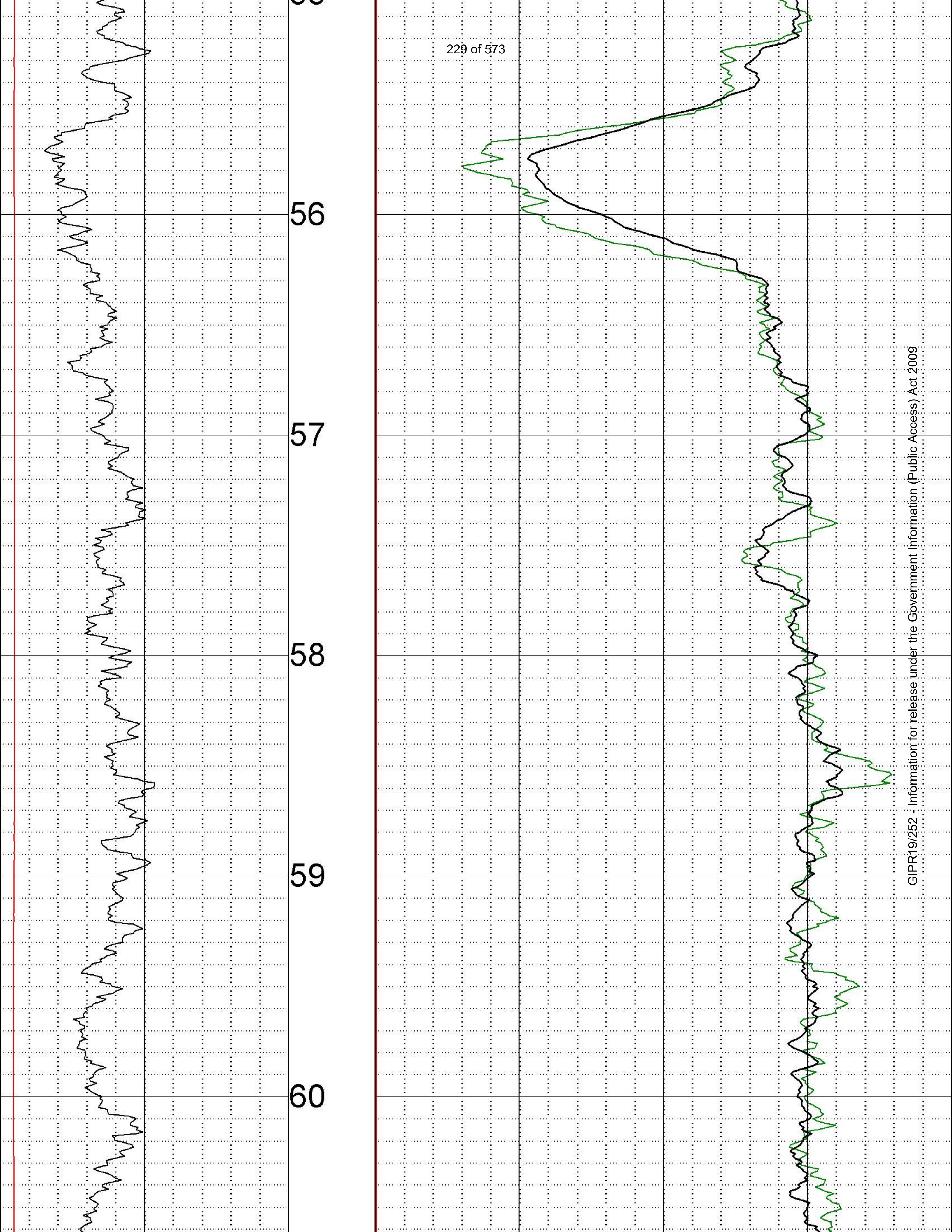
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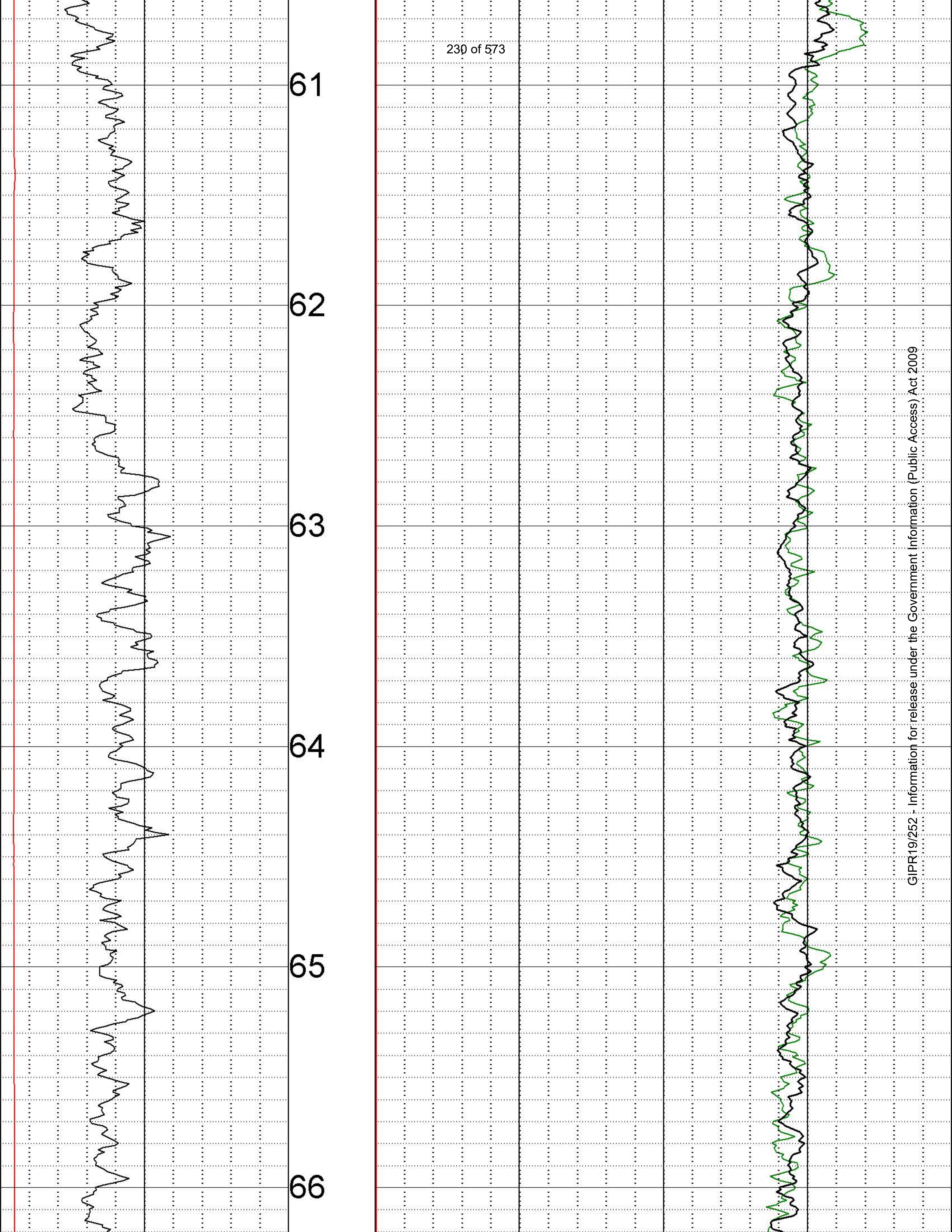
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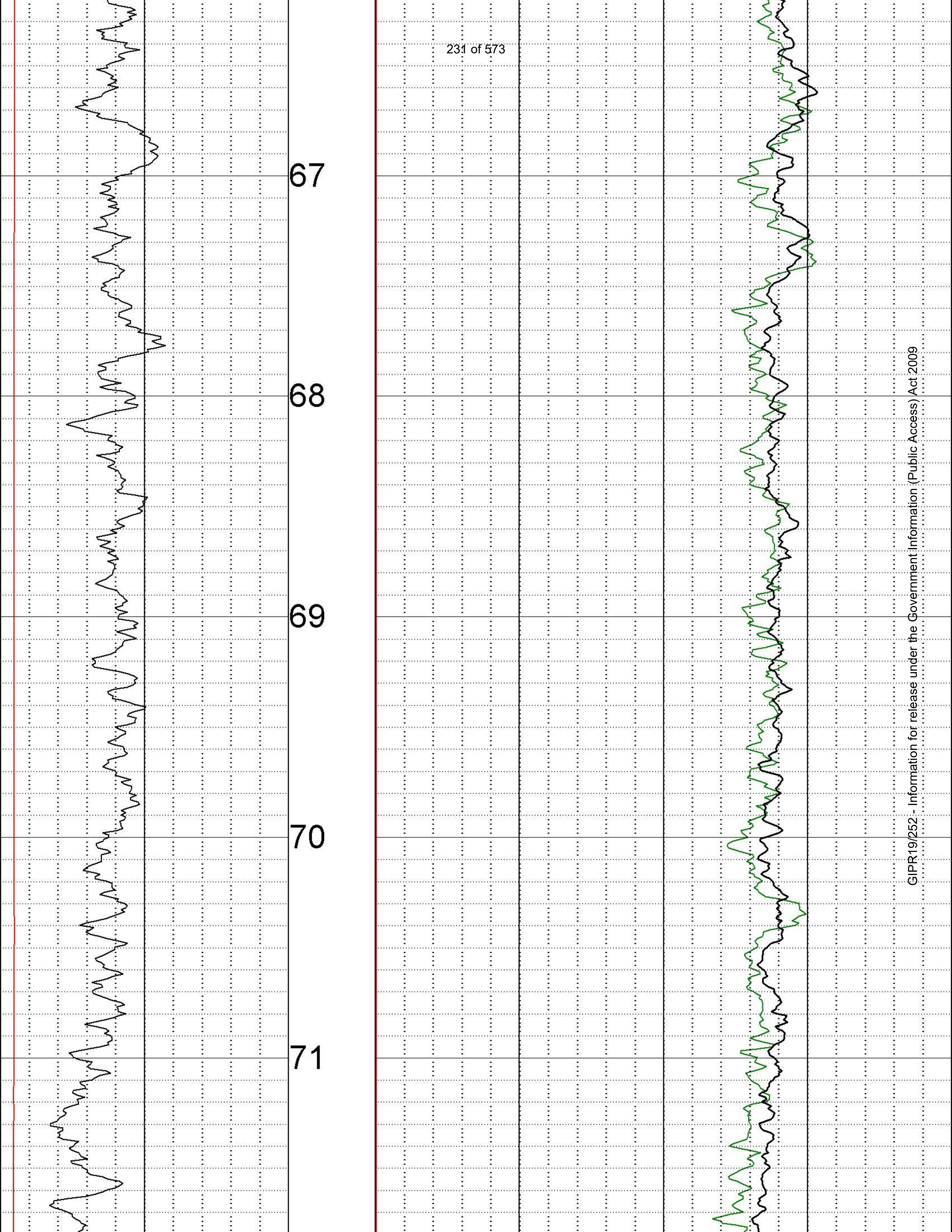
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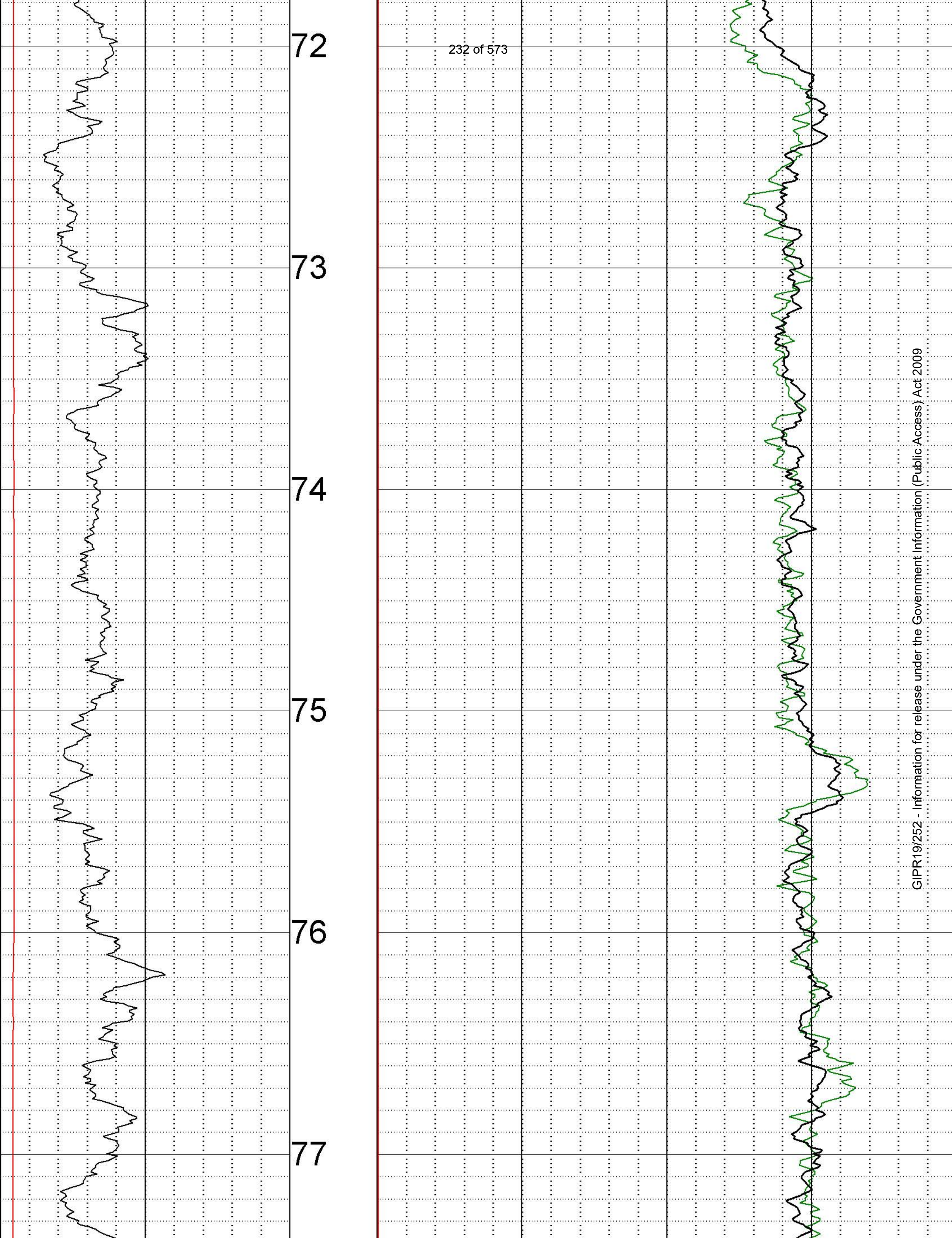
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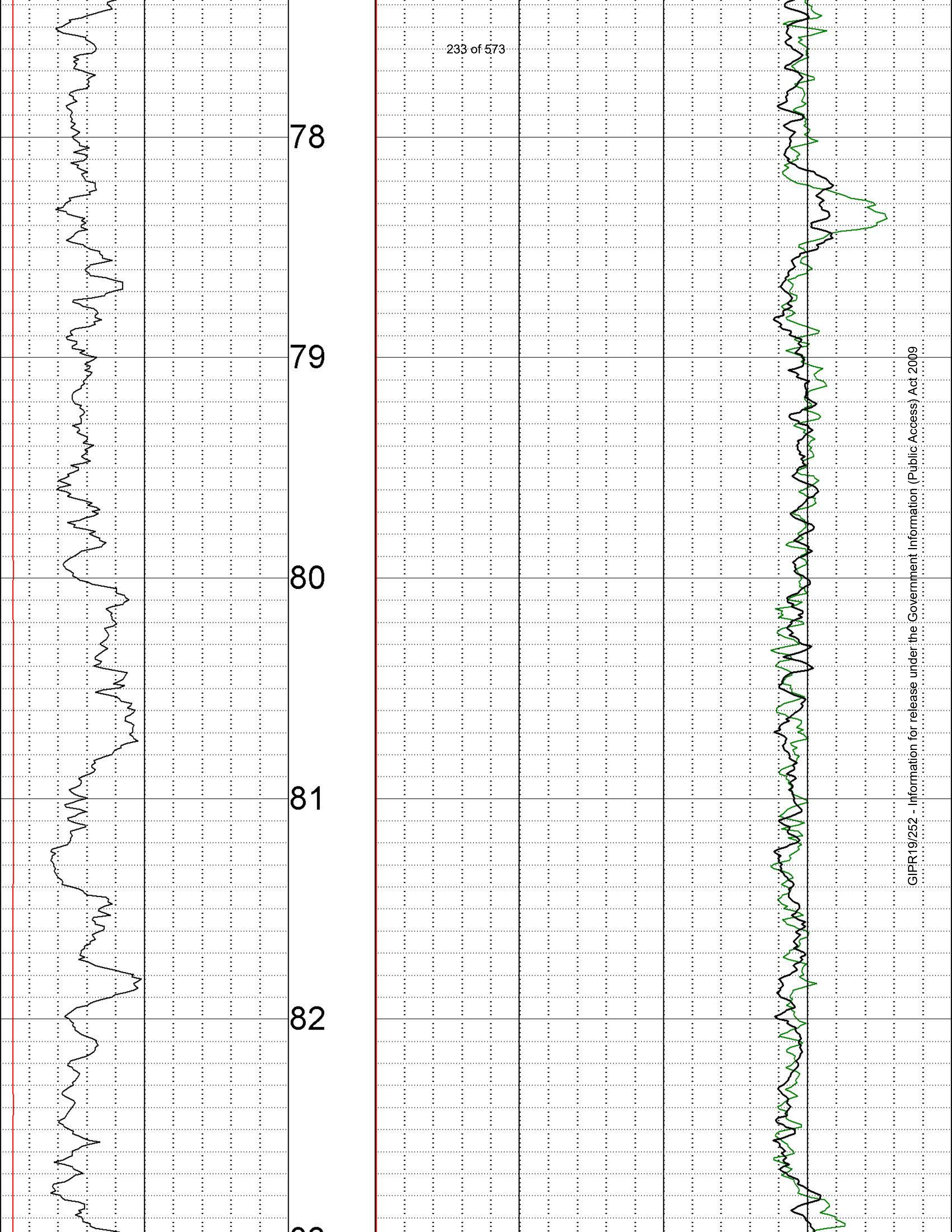
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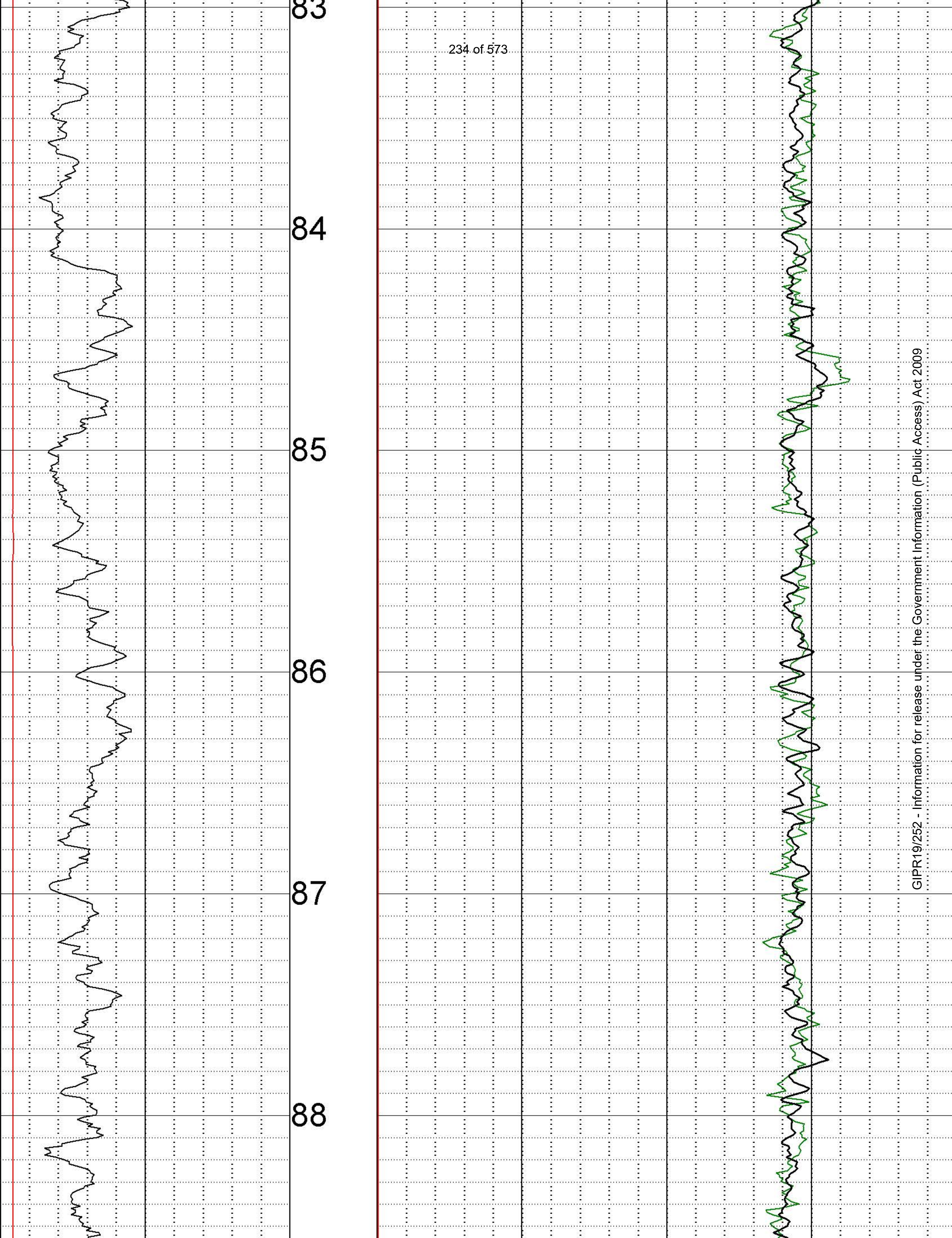
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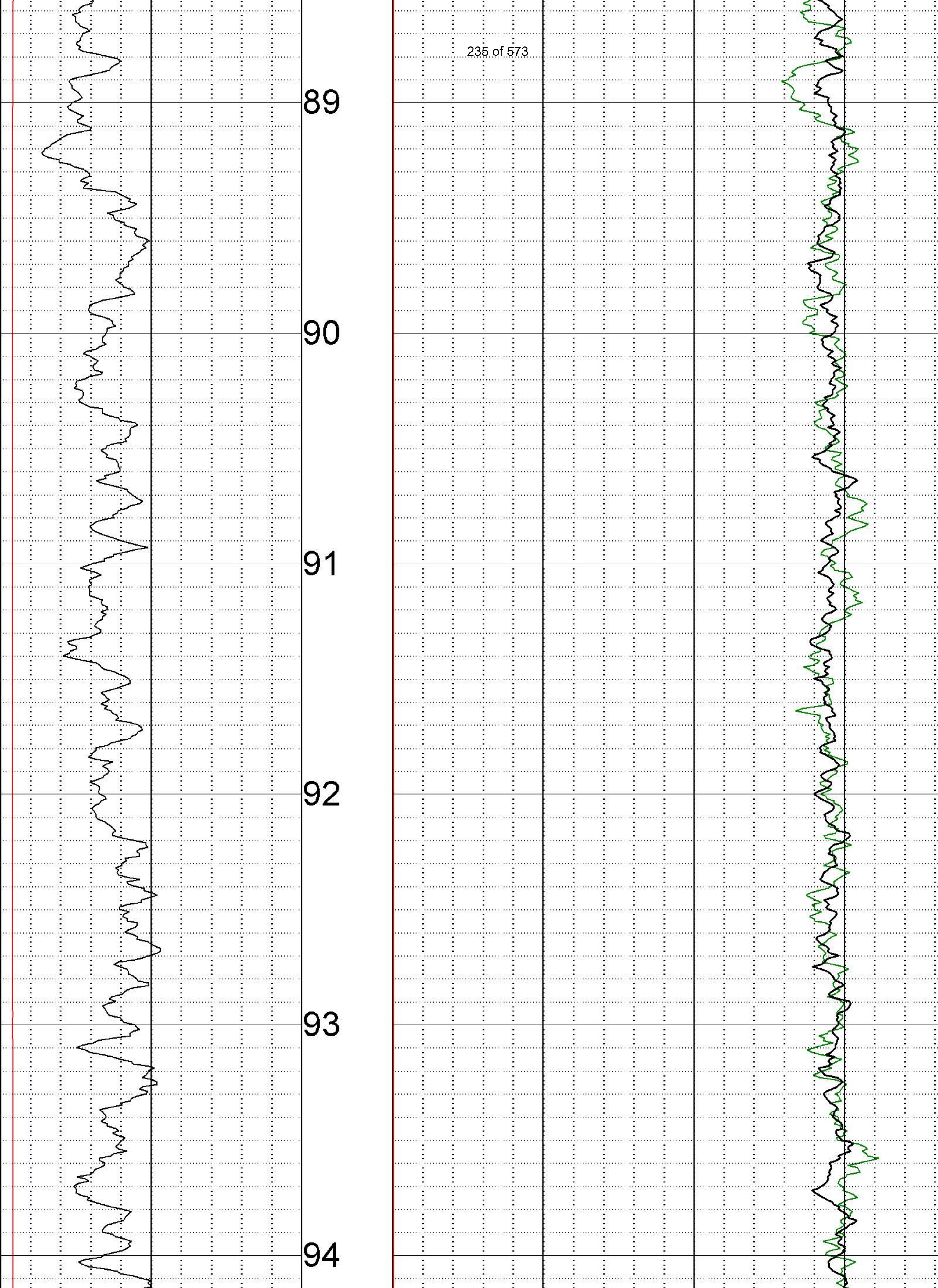
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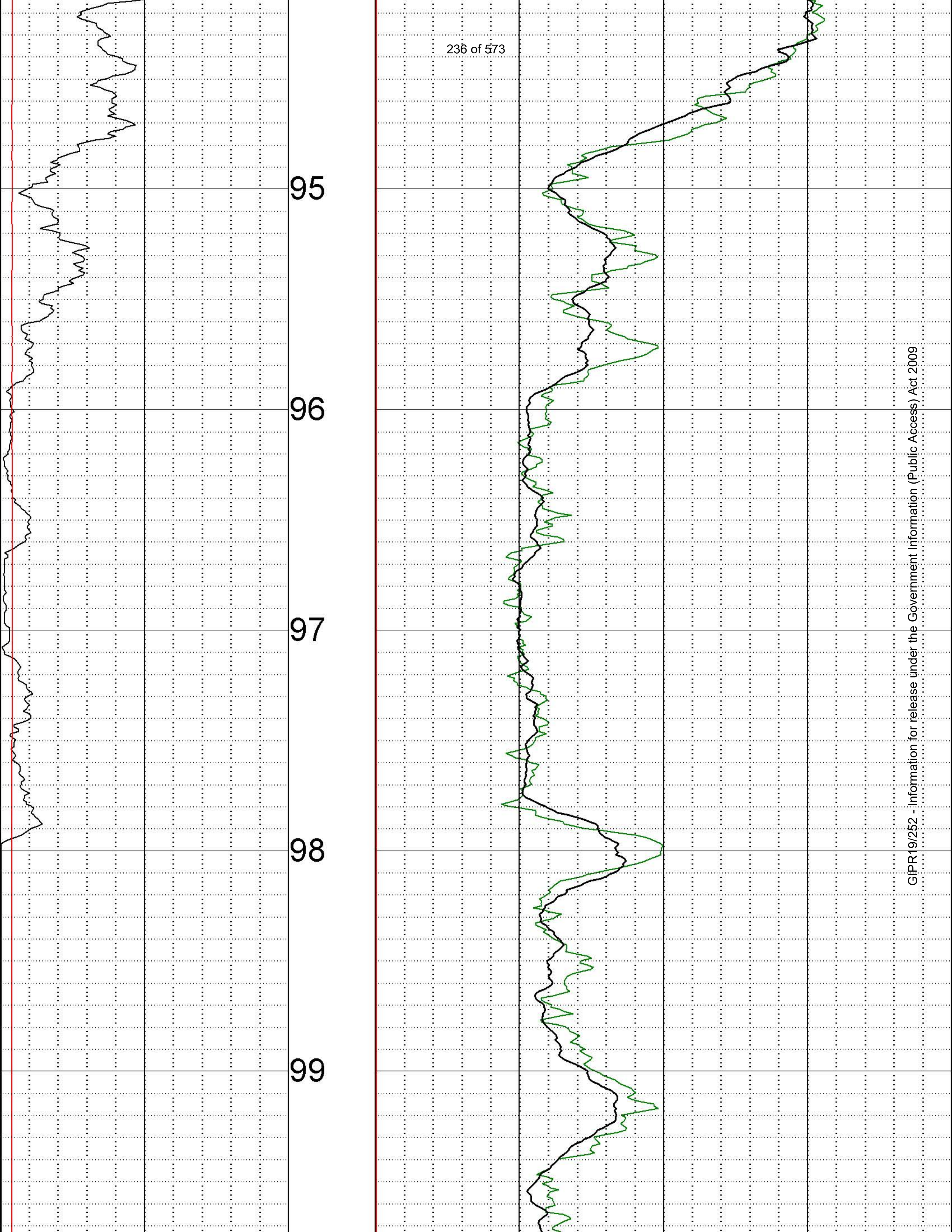
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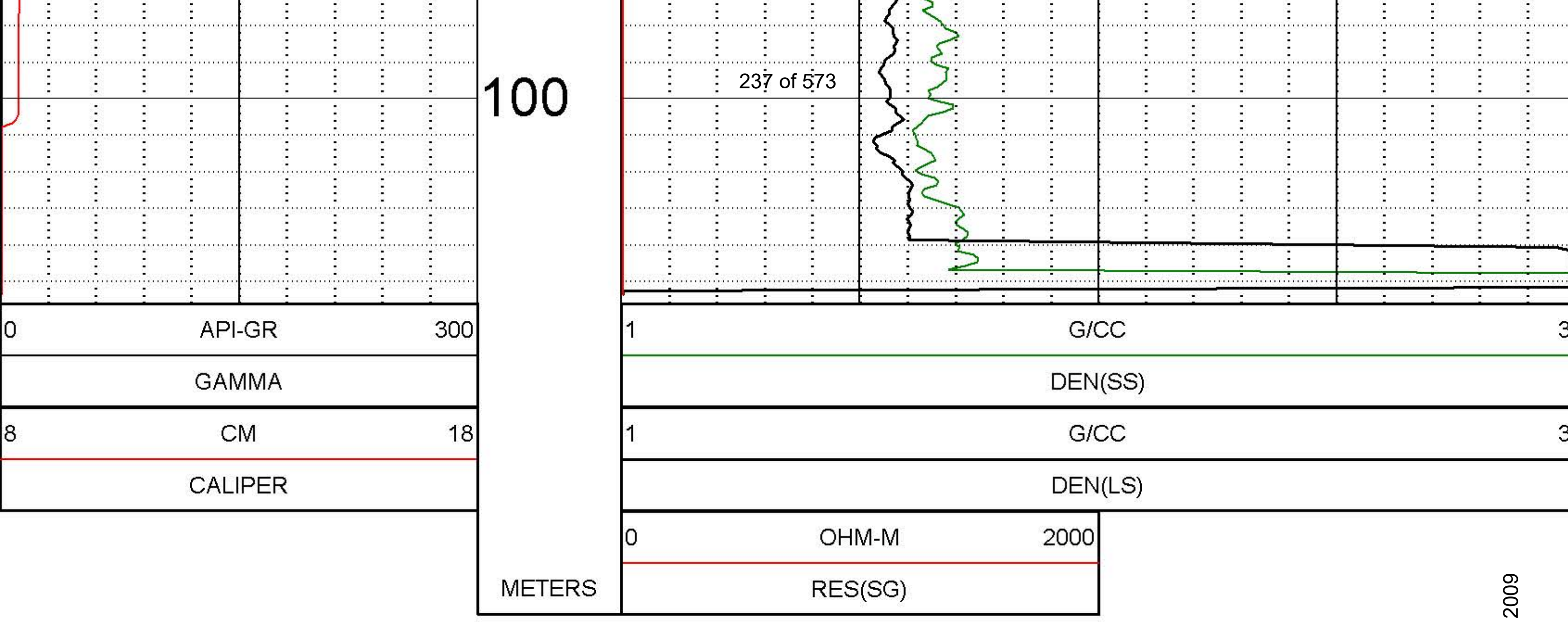
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CM
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METERS
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G/CC
3
DEN(SS)
1
G/CC
3
DEN(LS)
0
OHM-M
2000
RES(SG)

Coffey Geotechnics

Borehole BH03

ACOUSTIC TELEVIEWER PETROPHYSICAL REPORT

Groundsearch Australia Pty. Limited

3 October 2018

DISCLAIMER

The data used in this report were obtained using equipment manufactured by the Century Geophysical Corporation. The interpretations given in this report are based on judgement and experience of Groundsearch Australia's personnel. They are provided for Coffey Geotechnics sole use in accordance with a specified brief. As such, the interpretation outcomes do not necessarily address all aspects of ground conditions and behaviour on the subject site. The responsibility of Groundsearch Australia is solely to Coffey Geotechnics and it is not intended that any third party rely upon this report. This report shall not be reproduced either wholly or in part without the written permission of Groundsearch Australia Pty. Limited.

For and on behalf of Groundsearch Australia Pty. Limited

John Lea BSc (Hons) FAusIMM
Principal Geologist
Managing Director

Executive summary

The data contained in this report were obtained from one 9.6 cm diameter, vertical, cored borehole that was drilled as a component of the 2018 geotechnical exploration programme for Coffey Geotechnics at the NBN site Newcastle NSW.

Century Geophysical Corporation downhole 9804 acoustic televiewer and 9329 density tools were run to collect data in the field on 21 September 2018. This report is for data from 29.50 to 40.27 mbgl. The 9239 density tool was run inside steel casing and data were corrected for the steel. Therefore, there are no caliper or resistivity data.

The 80 identified features are interpreted as the SWL bedding, and fractures. The bedding to fractures ratio is 7:1.

The Century Display program has automatically recalculated the dip angle data to represent the borehole in the vertical position and the dip direction data is referenced to magnetic north.

1.0 Background technical information

The data contained in this report were obtained from one 9.6 cm diameter, vertical, cored borehole that was drilled as a component of the 2018 geotechnical exploration programme for Coffey Geotechnics at the NBN site Newcastle NSW.

Century Geophysical Corporation downhole 9804 acoustic televiewer and 9329 density tools were run to collect data in the field on 21 September 2018. This report is for data from 29.50 to 40.27 mbgl. The 9239 density tool was run inside steel casing and data were corrected for the steel. Therefore, there are no caliper or resistivity data.

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Subsequent processing and interpretation of data were carried out by Groundsearch.

The ATV takes an oriented image of the borehole using high-resolution sound waves. This acoustic image is displays amplitude variations. This information is used to detect bedding planes, fractures, and other borehole anomalies without the need to have clear fluid filling the boreholes. The tool works only in fluid-filled boreholes.

The televiewer digitises 256 measurements around the borehole at each high-resolution sample interval. These data can be oriented to North and displayed real-time while logging using the Visual Compu-Log System.

Analysis software includes colour adjustment, fracture dip and strike determination, and classification of features. It allows information to be displayed on the graphical screen, plot, and in report format.

2.0 Interpretation methodology

It should be noted that the ATV is a bowspring-type, centralised tool and is affected by poor wallrock conditions known as rugosity.

The ATV data interpretation procedure is based on the superposition of curves on feature logs directly onto the computer screen by using a subjective, manual; two-point definition of a feature's top and base to produce a sine curve. The sides of the time and amplitude plots represent magnetic north and magnetic south is in the centre of each plot. The low side, or trough, of the sine curve defines the dip direction of the feature.

The logging program automatically records the televiewer tool slant angle and bearing and corrects for any borehole deviations. The curves are automatically given an identification number for subsequent referencing in a report file.

There are possibly more bedding planes and structural fractures appearing in the televiewer logs that have not been included in this report due to their poor graphic definition or the inability to resolve their geometry by superposing a sine curve using the program's two point method.

This report contains a;

- Text summary of the interpreted features
- Circular representation of interpreted features
- Logs that show geological features with their subjective, numbered interpretation curves shown at 1:20 scale. The logs are in standard format whereby the optical image of the borehole wall is "flattened" onto the plot. The logs have the following additional features to enhance geological interpretations of the strata;
    - Amplitude image differentials
    - Time image differentials that indicate higher strength zones in **GREEN** and lower strength zones in **RED**
    - Tadpoles that represent feature dip and dip direction
    - Open fractures in **RED**
    - Partially open fractures in **MAGENTA**
    - Discontinuous fractures in **DARK BLUE**
  - Natural gamma
  - Slant (dip angle)
  - Slant angle bearing
  - Long and short space density
- Table containing feature curve ID, top, base, dip angle, dip azimuth, feature description and the generalised rock type that hosts the feature
- Graphical representations of the interpreted features

3.0 Borehole BH03interpretation

The 80 identified features are interpreted as the SWL bedding, and fractures. The bedding to fractures ratio is 7:1.

A description of each interpreted feature is presented in Table 1 and the log is presented in Appendix 1.

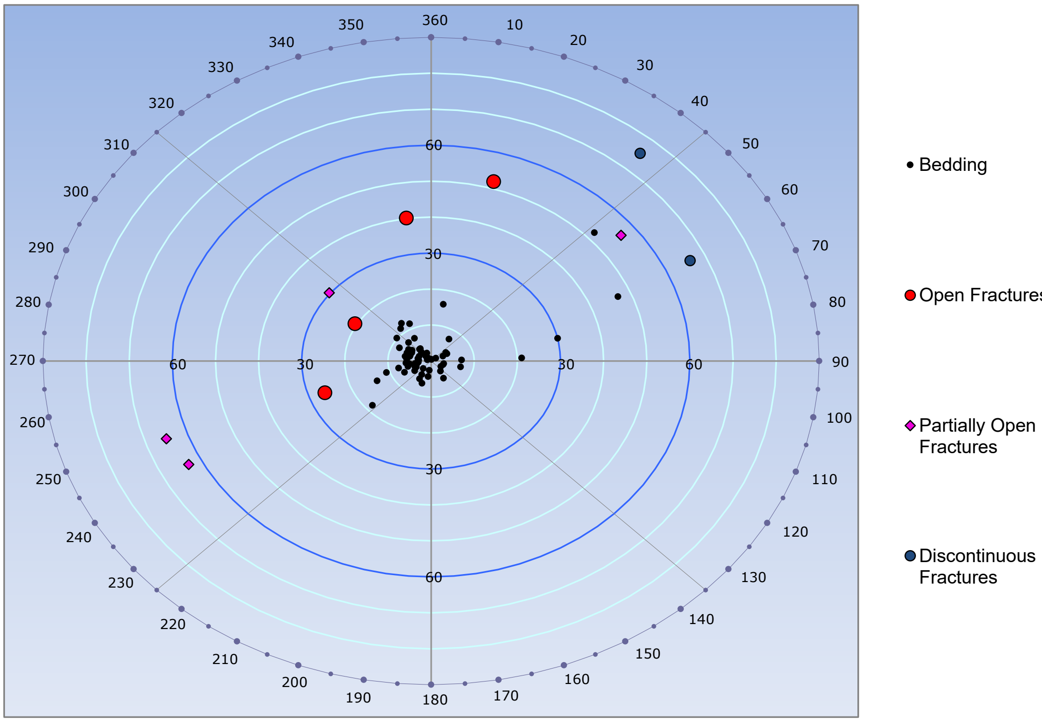
Table 1 Interpreted features report for BH03

FEATURE ID	DIP (DEG)	AZIMUTH (DEG)	MIDPOINT (MBGL)	TOP (M)	BASE (M)	TYPE OF FEATURE	GENERALISED ROCK TYPE
1			29.92	29.92	29.92	SWL	Overburden
2	52	16	30.08	30.02	30.14	Fracture plane - open	Overburden
3	6	274	30.71	30.71	30.72	Bedding plane	Overburden
4	6	254	30.88	30.88	30.89	Bedding plane	Overburden
5	4	210	30.90	30.90	30.90	Bedding plane	Overburden
6	4	189	31.05	31.04	31.05	Bedding plane	Overburden
7	3	295	31.16	31.16	31.16	Bedding plane	Overburden
8	30	309	31.23	31.20	31.26	Fracture plane - partially open	Overburden
9	12	334	31.33	31.32	31.34	Bedding plane	Overburden
10	11	322	31.47	31.47	31.48	Bedding plane	Overburden
11	12	327	31.51	31.50	31.52	Bedding plane	Overburden
12	4	253	31.67	31.67	31.67	Bedding plane	Overburden
13	40	352	31.89	31.85	31.93	Fracture plane - open	Overburden
14	63	243	31.95	31.85	32.04	Fracture plane - partially open	Overburden
15	3	63	31.98	31.98	31.98	Bedding plane	Overburden
16	4	244	32.11	32.10	32.11	Bedding plane	Overburden
17	4	62	32.37	32.36	32.37	Bedding plane	Overburden
18	3	282	32.49	32.49	32.49	Bedding plane	Overburden
19	0	16	32.82	32.82	32.82	Bedding plane	Overburden
20	6	302	32.83	32.82	32.83	Bedding plane	Overburden
21	5	235	32.94	32.93	32.94	Bedding plane	Overburden
22	8	255	33.04	33.03	33.05	Bedding plane	Overburden
23	5	297	33.21	33.21	33.21	Bedding plane	Overburden
24	1	54	33.31	33.31	33.31	Bedding plane	Overburden
25	4	259	33.40	33.40	33.40	Bedding plane	Overburden
26	6	264	33.43	33.43	33.44	Bedding plane	Overburden
27	4	324	33.52	33.52	33.52	Bedding plane	Overburden
28	4	320	33.54	33.53	33.54	Bedding plane	Overburden
29	65	251	33.59	33.49	33.70	Fracture plane - partially open	Overburden
30	3	274	33.61	33.61	33.61	Bedding plane	Overburden
31	3	104	33.66	33.66	33.66	Bedding plane	Overburden
32	3	110	33.68	33.68	33.68	Bedding plane	Overburden
33	1	321	33.75	33.75	33.75	Bedding plane	Overburden
34	2	336	33.86	33.86	33.86	Bedding plane	Overburden
35	2	319	33.88	33.88	33.88	Bedding plane	Overburden
36	4	142	33.93	33.93	33.93	Bedding plane	Overburden
37	7	88	34.07	34.07	34.08	Bedding plane	Overburden
38	7	103	34.11	34.11	34.12	Bedding plane	Overburden

Coffey Geotechnics
Borehole BH03 Acoustic Televiewer Petrophysical Report

FEATURE ID	DIP (DEG)	AZIMUTH (DEG)	MIDPOINT (MBGL)	TOP (M)	BASE (M)	TYPE OF FEATURE	GENERALISED ROCK TYPE
39	2	323	34.24	34.23	34.24	Bedding plane	Overburden
40	1	310	34.51	34.51	34.51	Bedding plane	Overburden
41	2	328	34.82	34.82	34.82	Bedding plane	Overburden
42	1	292	34.84	34.84	34.84	Bedding plane	Overburden
43	5	287	34.86	34.86	34.87	Bedding plane	Overburden
44	56	52	34.98	34.91	35.05	Fracture plane - partially open	Overburden
45	2	326	35.07	35.07	35.07	Bedding plane	Overburden
46	0	11	35.18	35.18	35.18	Bedding plane	Overburden
47	6	292	35.32	35.31	35.32	Bedding plane	Overburden
48	7	329	35.40	35.39	35.40	Bedding plane	Overburden
49	5	285	35.63	35.63	35.64	Bedding plane	Overburden
50	6	149	35.85	35.85	35.86	Bedding plane	Overburden
51	3	123	35.88	35.88	35.88	Bedding plane	Overburden
52	6	208	35.98	35.97	35.98	Bedding plane	Overburden
53	7	199	36.01	36.00	36.01	Bedding plane	Overburden
54	3	189	36.04	36.04	36.04	Bedding plane	Overburden
55	7	34	36.07	36.06	36.07	Bedding plane	Overburden
56	11	253	36.13	36.12	36.14	Bedding plane	Overburden
57	10	309	36.69	36.68	36.70	Bedding plane	Overburden
58	66	65	36.71	36.61	36.82	Fracture plane - discontinuous	Overburden
59	16	10	36.73	36.71	36.74	Bedding plane	Overburden
60	5	303	37.00	37.00	37.01	Bedding plane	Overburden
61	3	264	37.21	37.21	37.21	Bedding plane	Overburden
62	4	55	37.42	37.42	37.42	Bedding plane	Overburden
63	3	317	37.67	37.67	37.67	Bedding plane	Overburden
64	7	243	37.99	37.98	37.99	Bedding plane	Overburden
65	21	301	38.34	38.33	38.36	Fracture plane - open	Overburden
66	21	88	38.49	38.47	38.51	Bedding plane	Overburden
67	30	78	38.52	38.50	38.55	Bedding plane	Overburden
68	26	250	38.60	38.58	38.63	Fracture plane - open	Overburden
69	4	249	38.69	38.68	38.69	Bedding plane	Overburden
70	5	304	38.77	38.77	38.78	Bedding plane	Overburden
71	75	40	38.82	38.64	39.00	Fracture plane - discontinuous	Overburden
72	5	261	38.85	38.84	38.85	Bedding plane	Overburden
73	8	296	39.16	39.15	39.17	Bedding plane	Overburden
74	7	314	39.19	39.19	39.20	Bedding plane	Overburden
75	52	47	39.44	39.38	39.51	Bedding plane	Overburden
76	47	68	39.54	39.49	39.59	Bedding plane	Overburden
77	3	221	39.79	39.79	39.79	Bedding plane	Overburden
78	6	282	39.95	39.95	39.96	Bedding plane	Overburden
79	18	228	40.09	40.07	40.10	Bedding plane	Overburden
80	14	246	40.18	40.17	40.19	Bedding plane	Overburden

Figure 1 BH03 circular plan representation of interpreted features



The 69 identified sedimentary features are predominantly bedding planes that appear to range in dip from flat-lying to 52^0. Figures 2 and 3 show the distribution of the planes' dip angles and dip direction with depth.

Table 2 details the variation in the dip angle and dip direction data. Figure 4 shows the dip direction data in a rose diagram with the bedding planes' dip angle and dip direction data shown as histograms in Figures 5 and 6.

The 10 fractures are identified as open (4), partially open (4) and discontinuous (2). The fracture dip angles range from 21 to 75^0.

Table 3 details the variation in the fractures' dip angle and dip direction data. Figure 7 shows the dip direction data in a rose diagram with the fractures' plane dip angle and dip direction data as histograms in Figures 8 and 9.

Figure 2 BH03 feature dip angle data distribution

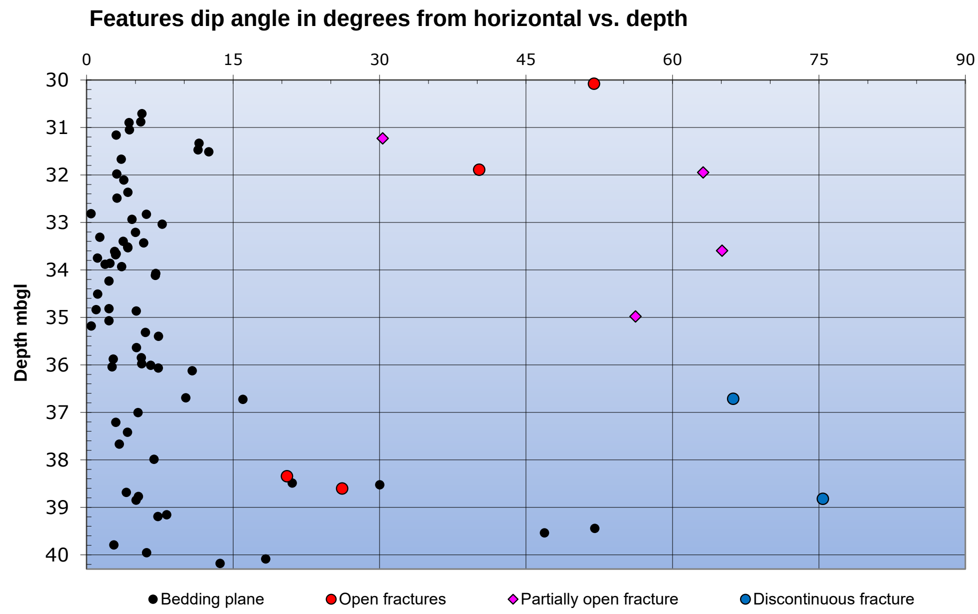
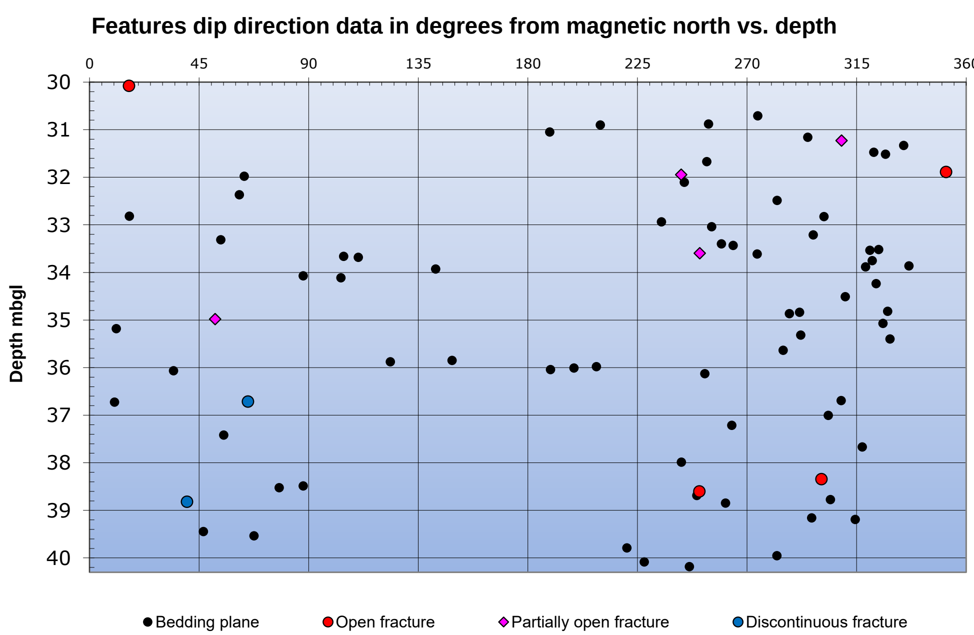


Figure 3 BH03 feature dip direction data distribution



GIPR19/252 - Information for release under the Government Information (Public Access) Act 2009

Table 2 BH03 bedding histogram data

Dip Distribution
Total: 69

Dip Range	Count	%
0 to 10	57	82.6
10 to 20	8	11.6
20 to 30	1	1.4
30 to 40	1	1.4
40 to 50	1	1.4
50 to 60	1	1.4
60 to 70	0	0.0
70 to 80	0	0.0
80 to 90	0	0.0

Orientation Distribution
Total: 69

Bearing Range	Count	%
0 to 10	0	0.0
10 to 20	3	4.3
20 to 30	0	0.0
30 to 40	1	1.4
40 to 50	1	1.4
50 to 60	2	2.9
60 to 70	3	4.3
70 to 80	1	1.4
80 to 90	2	2.9
90 to 100	0	0.0
100 to 110	2	2.9
110 to 120	1	1.4
120 to 130	1	1.4
130 to 140	0	0.0
140 to 150	2	2.9
150 to 160	0	0.0
160 to 170	0	0.0
170 to 180	0	0.0
180 to 190	2	2.9
190 to 200	1	1.4
200 to 210	2	2.9
210 to 220	0	0.0
220 to 230	2	2.9
230 to 240	1	1.4
240 to 250	4	5.8
250 to 260	5	7.2
260 to 270	3	4.3
270 to 280	2	2.9
280 to 290	4	5.8
290 to 300	5	7.2
300 to 310	4	5.8
310 to 320	4	5.8
320 to 330	9	13.0
330 to 340	2	2.9
340 to 350	0	0.0
350 to 360	0	0.0

Figure 5 BH03 bedding dip angles histogram

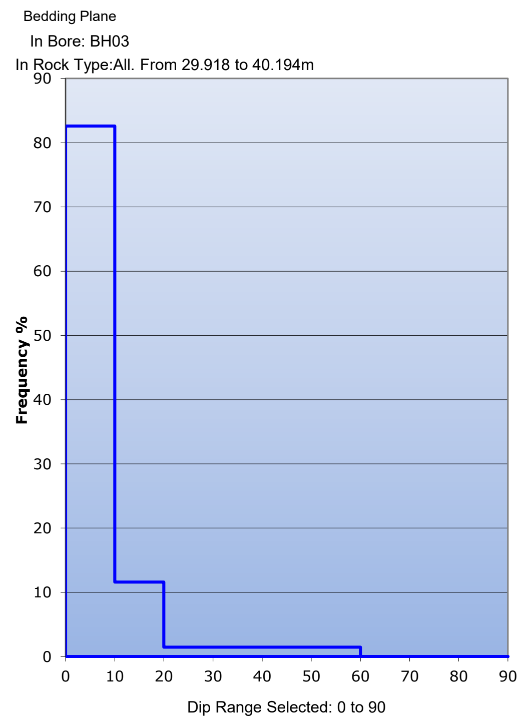


Figure 4 BH03 bedding dip direction data rose diagram

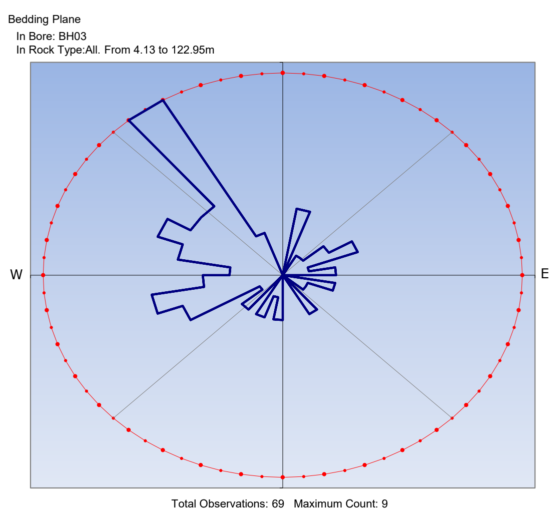


Figure 6 BH03 bedding dip directions histogram

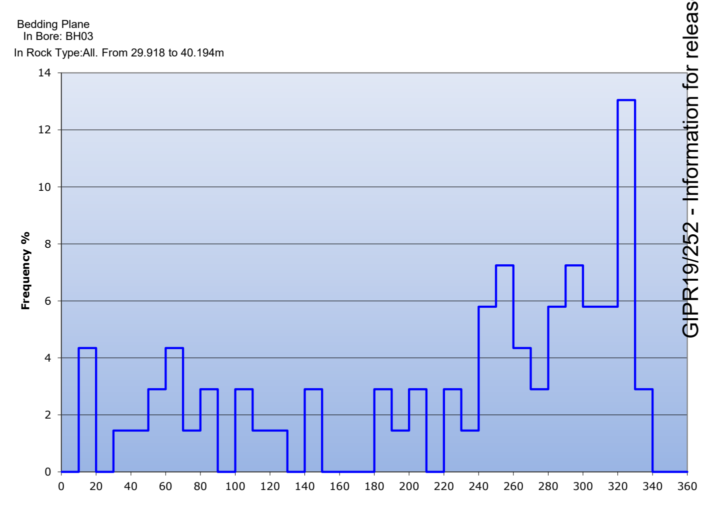


Table 3 BH03 fractures histogram data

Dip Distribution — Total: 10

Dip Range	Count	%
0 to 10	0	0.0
10 to 20	0	0.0
20 to 30	2	20.0
30 to 40	1	10.0
40 to 50	1	10.0
50 to 60	2	20.0
60 to 70	3	30.0
70 to 80	1	10.0
80 to 90	0	0.0

Orientation Distribution — Total: 10

Bearing Range	Count	%
0 to 10	0	0.0
10 to 20	1	10.0
20 to 30	0	0.0
30 to 40	0	0.0
40 to 50	1	10.0
50 to 60	1	10.0
60 to 70	1	10.0
70 to 80	0	0.0
80 to 90	0	0.0
90 to 100	0	0.0
100 to 110	0	0.0
110 to 120	0	0.0
120 to 130	0	0.0
130 to 140	0	0.0
140 to 150	0	0.0
150 to 160	0	0.0
160 to 170	0	0.0
170 to 180	0	0.0
180 to 190	0	0.0
190 to 200	0	0.0
200 to 210	0	0.0
210 to 220	0	0.0
220 to 230	0	0.0
230 to 240	0	0.0
240 to 250	1	10.0
250 to 260	2	20.0
260 to 270	0	0.0
270 to 280	0	0.0
280 to 290	0	0.0
290 to 300	0	0.0
300 to 310	2	20.0
310 to 320	0	0.0
320 to 330	0	0.0
330 to 340	0	0.0
340 to 350	0	0.0
350 to 360	1	10.0

Figure 8 BH03 fractures dip angles histogram

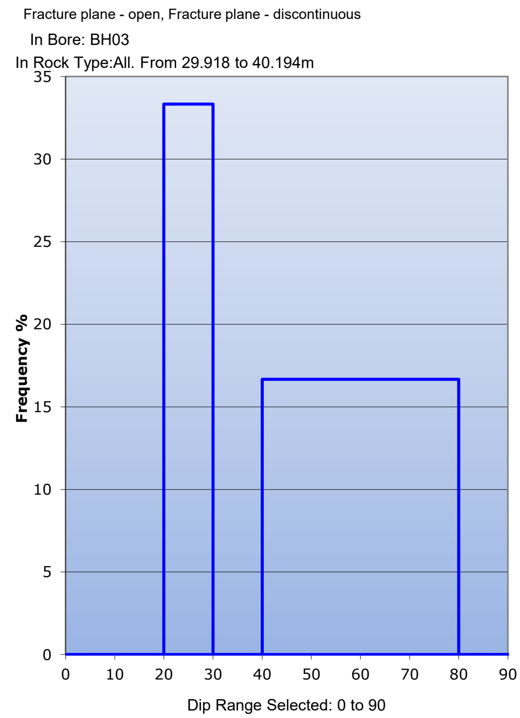


Figure 7 BH03 fractures dip direction data rose diagram

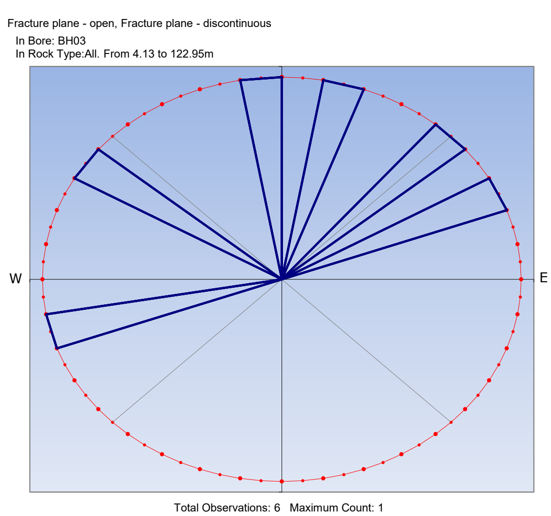
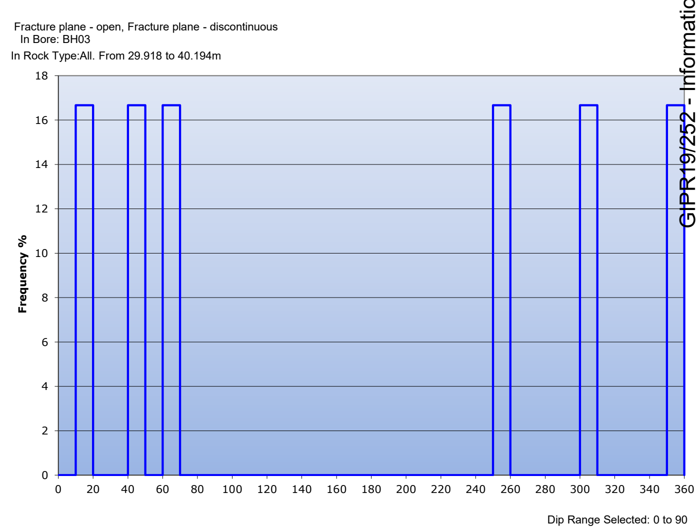


Figure 9 BH03 fractures dip directions histogram



Appendix 1

Appendix 1 *1:20 Interpretation logs – 29.50 to 40.27 mbgl*

GROUNDSEARCH AUSTRALIA

BH03 ATV 1:20

COMPANY : COFFEY GEOTECHNICS
WELL : BH03 ATV 1:20
LOCATION/FIELD : NBN
COUNTY :
LOCATION : NSW

OTHER SERVICES:
TV
ON TV
TV

UTM-E : NA
UTM-N : NA

SECTION : NA
TOWNSHIP : NA
RANGE : NA

DATE : 09/21/18
DEPTH DRILLER : 102.1
LOG BOTTOM : 40.270
LOG TOP : 29.500

PERMANENT DATUM : 0
LOG MEASURED FROM: GL
DRL MEASURED FROM: GL

KB : NA
DF : NA
GL : 0

CASING DIAMETER : 10.
CASING TYPE : PVC
CASING THICKNESS: .5

LOGGING UNIT : 121
FIELD OFFICE : RUTHERFORD
RECORDED BY : M CRANE

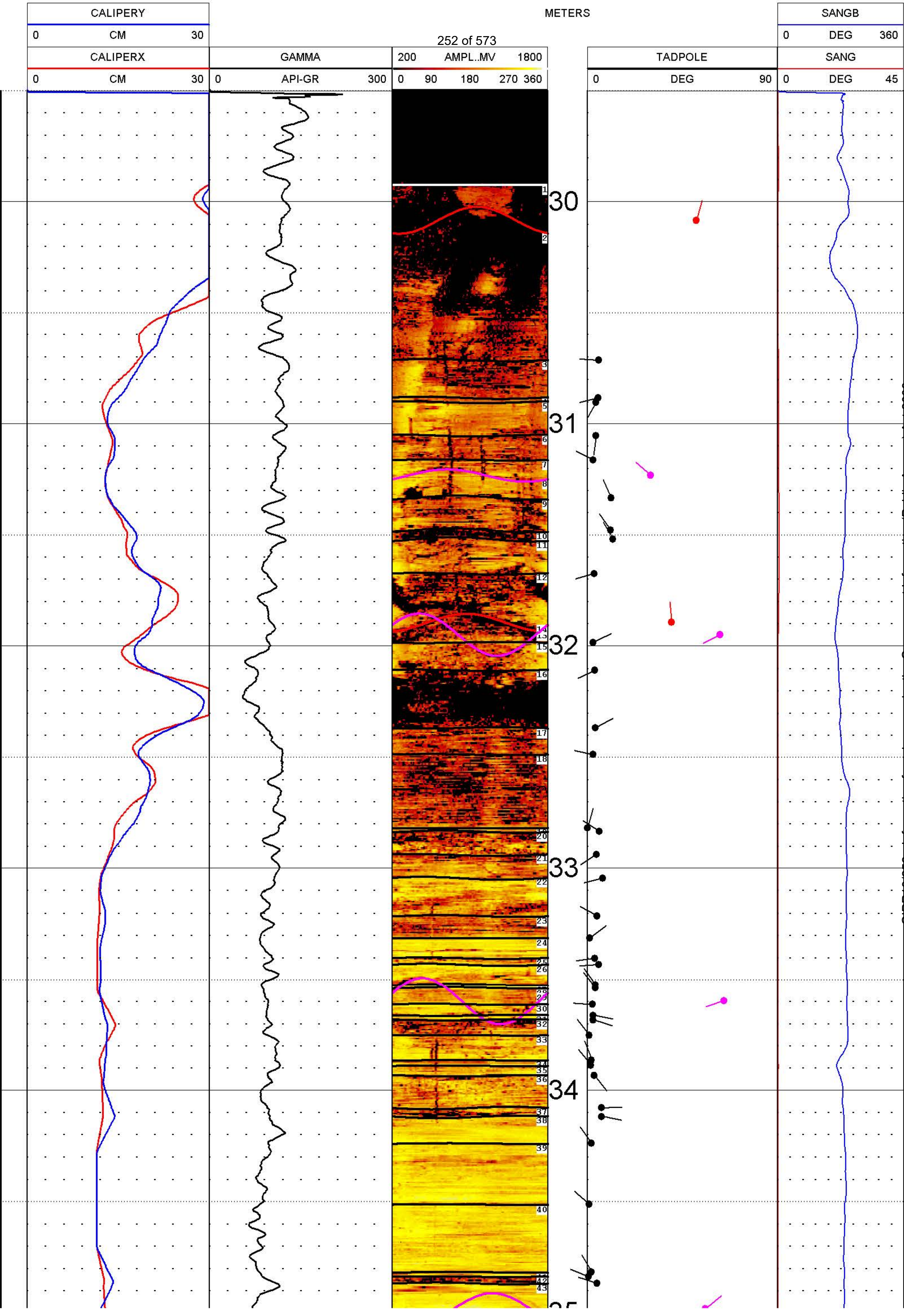
BIT SIZE : 9.6
MAGNETIC DECL. : 0
MATRIX DENSITY : 2.65
NEUTRON MATRIX : SANDSTONE

BOREHOLE FLUID : 0
RM : 0
RM TEMPERATURE : 0
MATRIX DELTA T : 177

FILE : PROCESSED
TYPE : 9804A
LGDATE: (09/21/18
LGTIME : 111:38
THRESH: 99999

VOID AROUND 40M 41M

ALL SERVICES PROVIDED SUBJECT TO STANDARD TERMS AND CONDITIONS


CALIPERY
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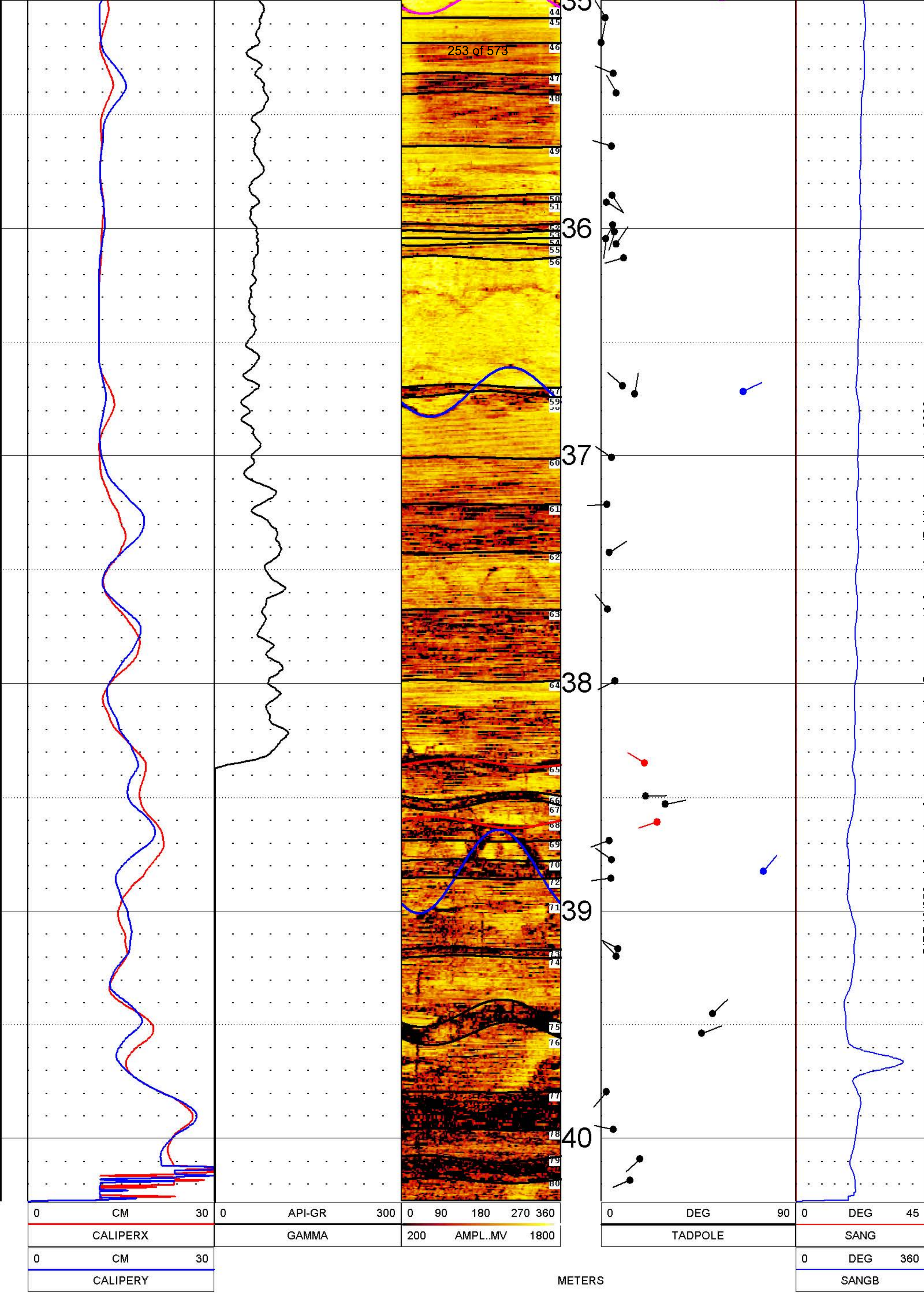
CALIPERX
0 CM 30
GAMMA
0 API-GR 300
200 AMPL..MV 1800
0 90 180 270 360
METERS
30
31
32
33
34
TADPOLE
0 DEG 90
SANGB
0 DEG 360
SANG
0 DEG 45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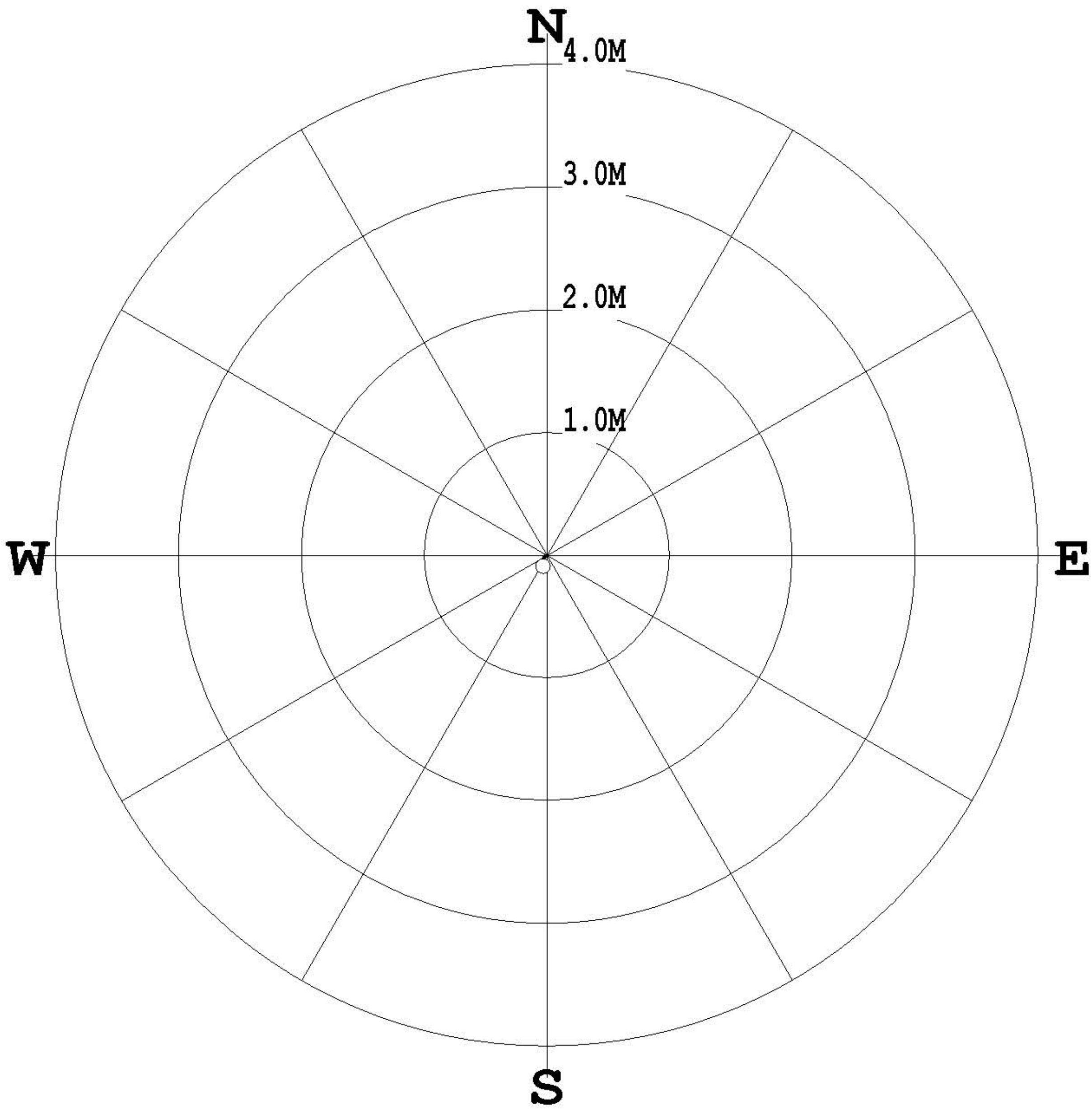
37
38
39
40
0 CM 30
CALIPERX
0 CM 30
CALIPERY
0 API-GR 300
GAMMA
0 90 180 270 360
200 AMPL..MV 1800
METERS
0 DEG 90
TADPOLE
0 DEG 45
SANG
0 DEG 360
SANGB

PLAN VIEW
COMPU-LOG DEVIATION

CLIENT: COFFEY
LOCATION: NBN
HOLE ID: BH03 TELEVIEWER
DATE OF LOG: 09/21/18
PROBE: 9804A 4402

MAG DECL: 0.0

SCALE: 1 M/CM
TRUE DEPTH: 40.27 M
AZIMUTH: 197.6
DISTANCE: 0.1 M
+ = 50 M INCR
○ = BOTTOM OF HOLE



* * * * * * * COMPU-LOG - VERTICAL DEVIATION * * * * * * *

CLIENT : COFFEY
FIELD OFFICE : RUTHERFORD
DATA FROM : NA
MAG. DECL. : 0.000
HOLE ID : BH03 TELEVIEW
DATE OF LOG : 09/21/18
PROBE : 9804A , 4402
DEPTH UNITS : METERS
LOG: BH03TELEVIEWER_09-21-18_11-38_9804A_.01_26.6_40.27_DEVI.log

CABLE DEPTH	TRUE DEPTH	NORTH DEV.	EAST DEV.	DISTANCE	AZIMUTH	SANG	SANGB
26.60	26.60	-0.00	-0.00	0.0	246.5	0.6	246.5
36.60	36.60	-0.07	-0.04	0.1	205.3	0.4	173.6
40.27	40.26	-0.09	-0.03	0.1	197.7	0.3	165.2

GROUNDSEARCH AUSTRALIA

BH03 DENSITY C 1:20

COMPANY	: COFFEY GEOTECH	OTHER SERVICES: DEN			
WELL	: BH03 DENSITY C 1:20				
LOCATION/FIELD	:				
COUNTRY	: AUST				
LOCATION	: MOSBRI CRES				
SECTION	: NA	TOWNSHIP	: NA	RANGE	: NA
DATE	: 09/19/18	PERMANENT DATUM	: 0		
DEPTH DRILLER	: 102.15			KB	: NA
LOG BOTTOM	: 99.29	LOG MEASURED FROM	: GL	DF	: NA
LOG TOP	: 0.00	DRL MEASURED FROM	: GL	GL	: 0
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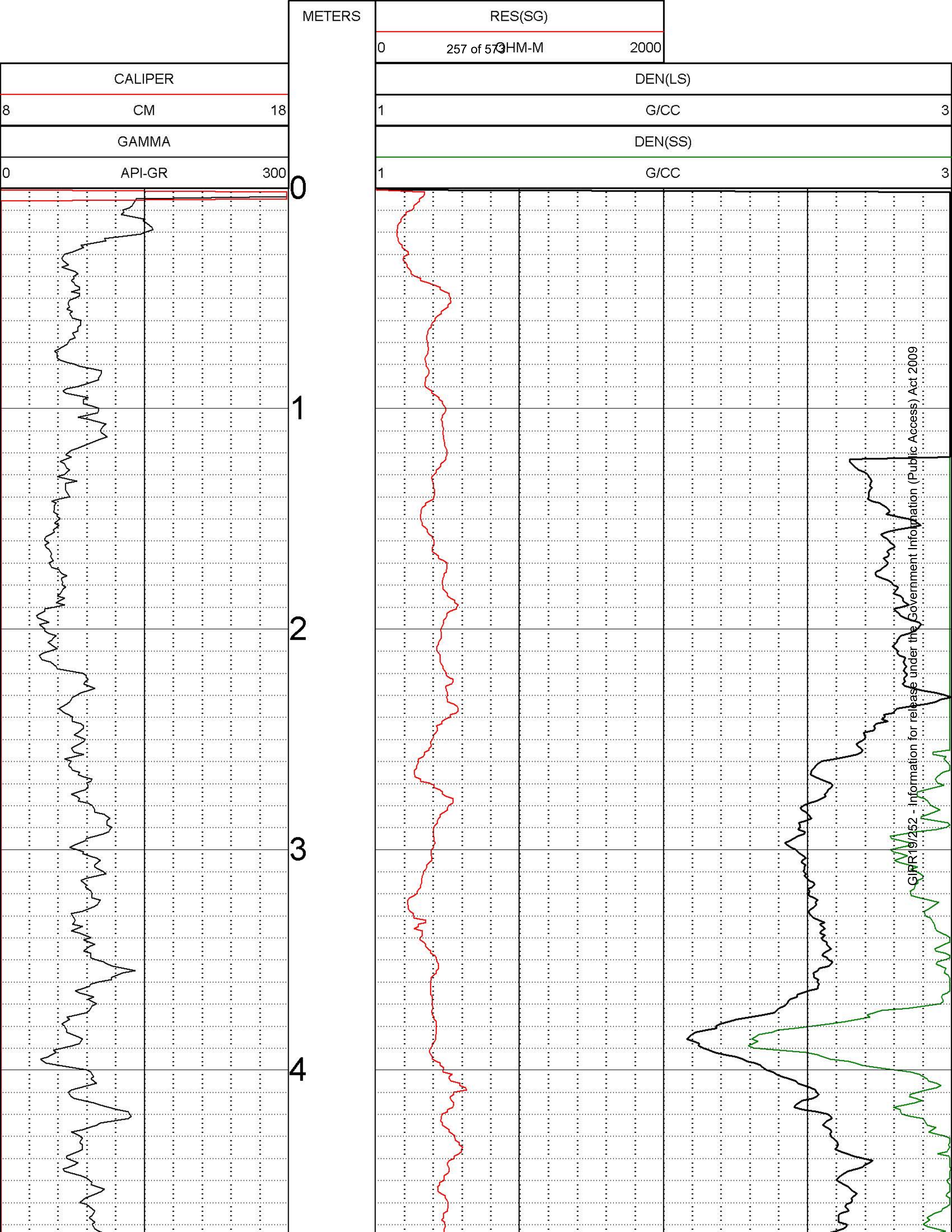
CASING TYPE	: STEEL	FIELD OFFICE	: RUTHERFORD		
CASING THICKNESS	: .5	RECORDED BY	: P WOODWARD		
BIT SIZE	: 9.60	BOREHOLE FLUID	: 0	FILE	: PROCESSED
MAGNETIC DECL.	: 0	RM	: 0	TYPE	: 9239B
MATRIX DENSITY	: 2.65	RM TEMPERATURE	: 0	LGDATE	: 09/19/18
NEUTRON MATRIX	: SANDSTONE	MATRIX DELTA T	: 177	LGTIME	: 15:16:
				THRESH	: 99999

LOGGED THROUGH THE RODS
CORRECTED FOR STEEL

ALL SERVICES PROVIDED SUBJECT TO STANDARD TERMS AND CONDITIONS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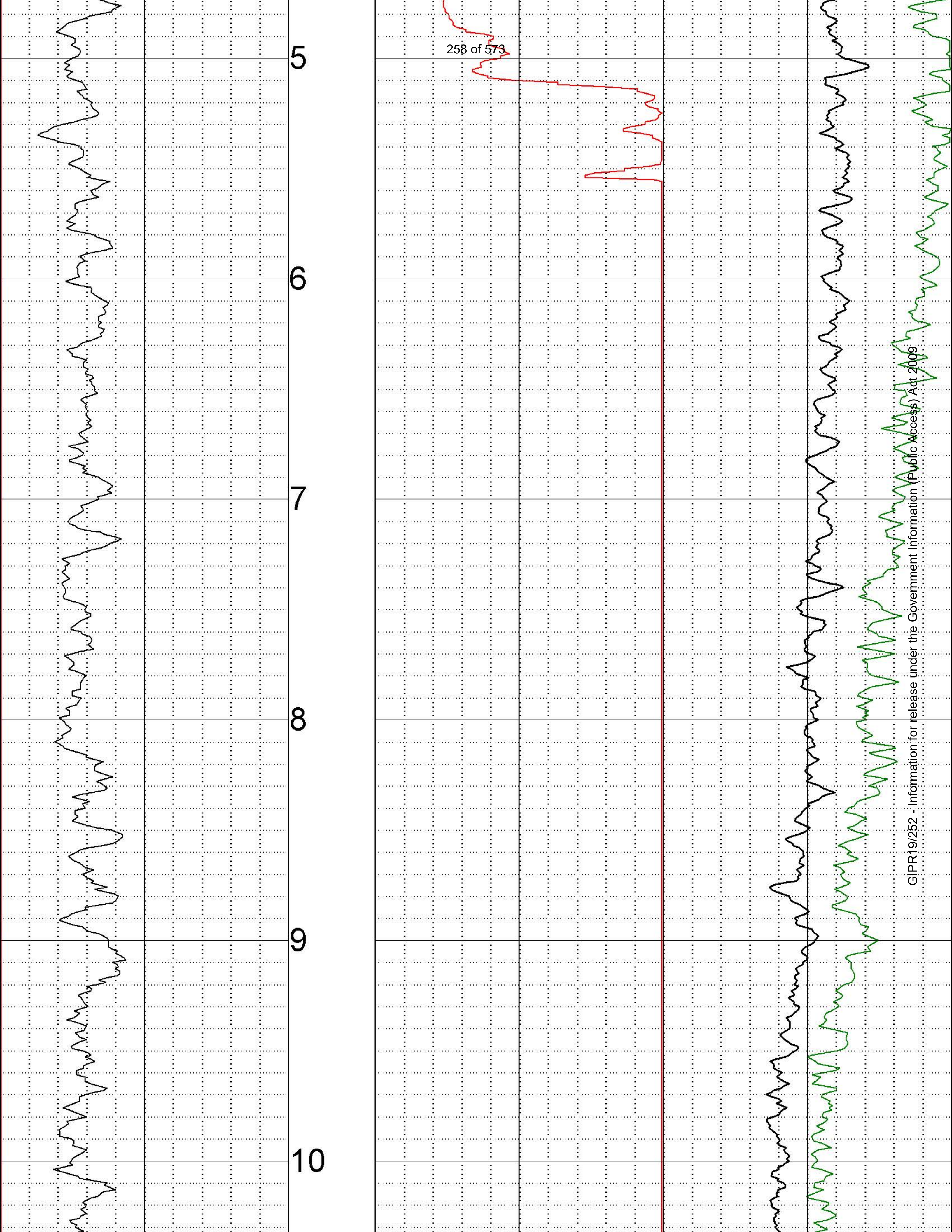
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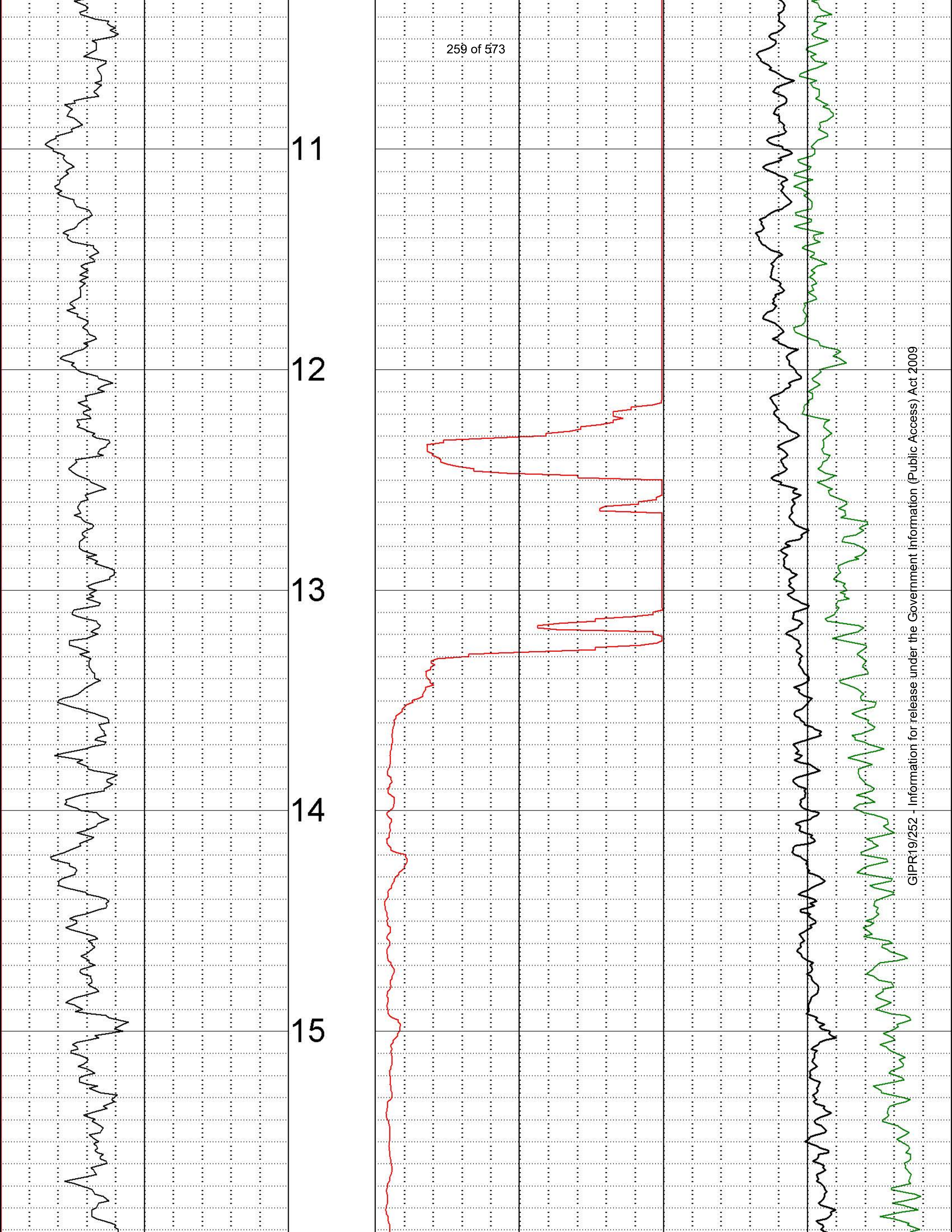
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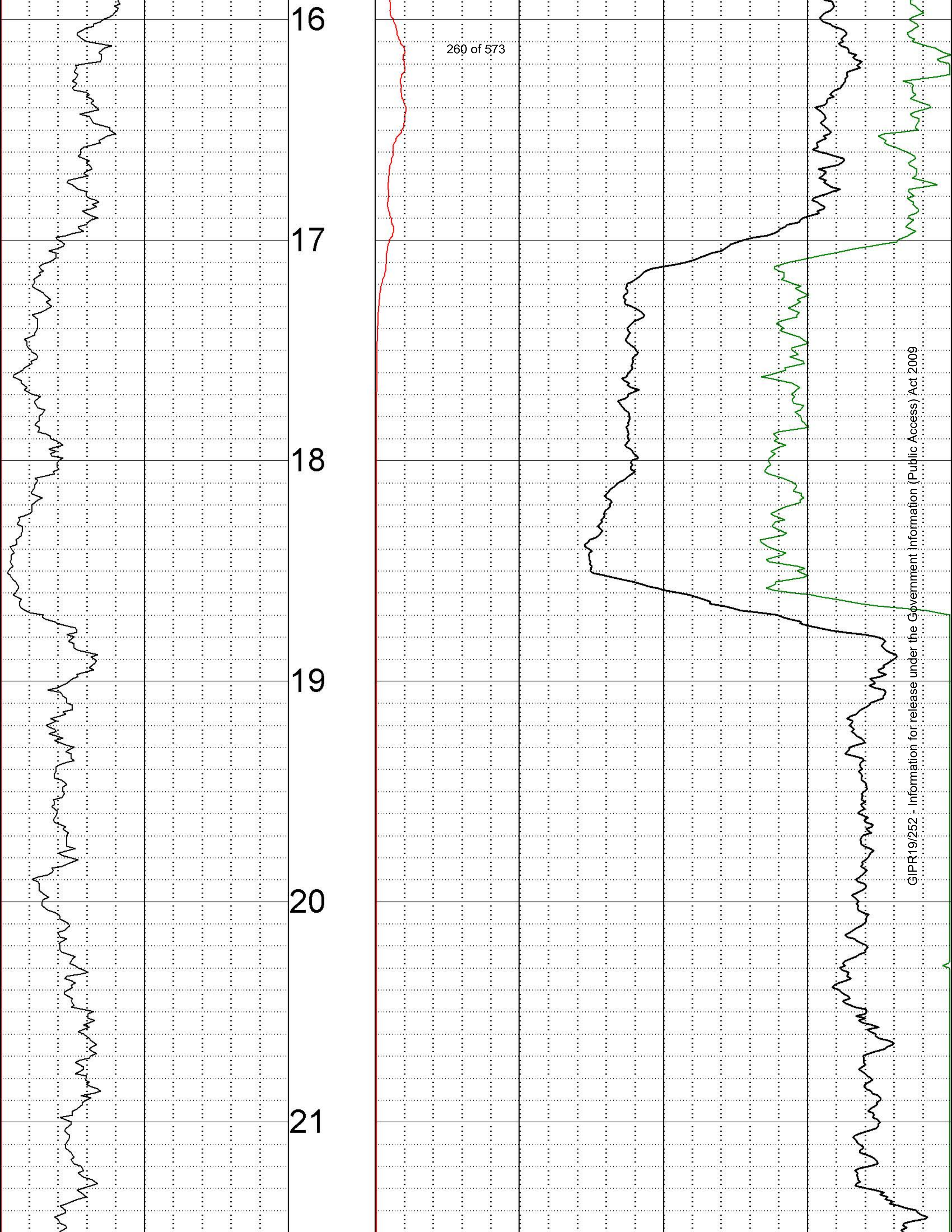
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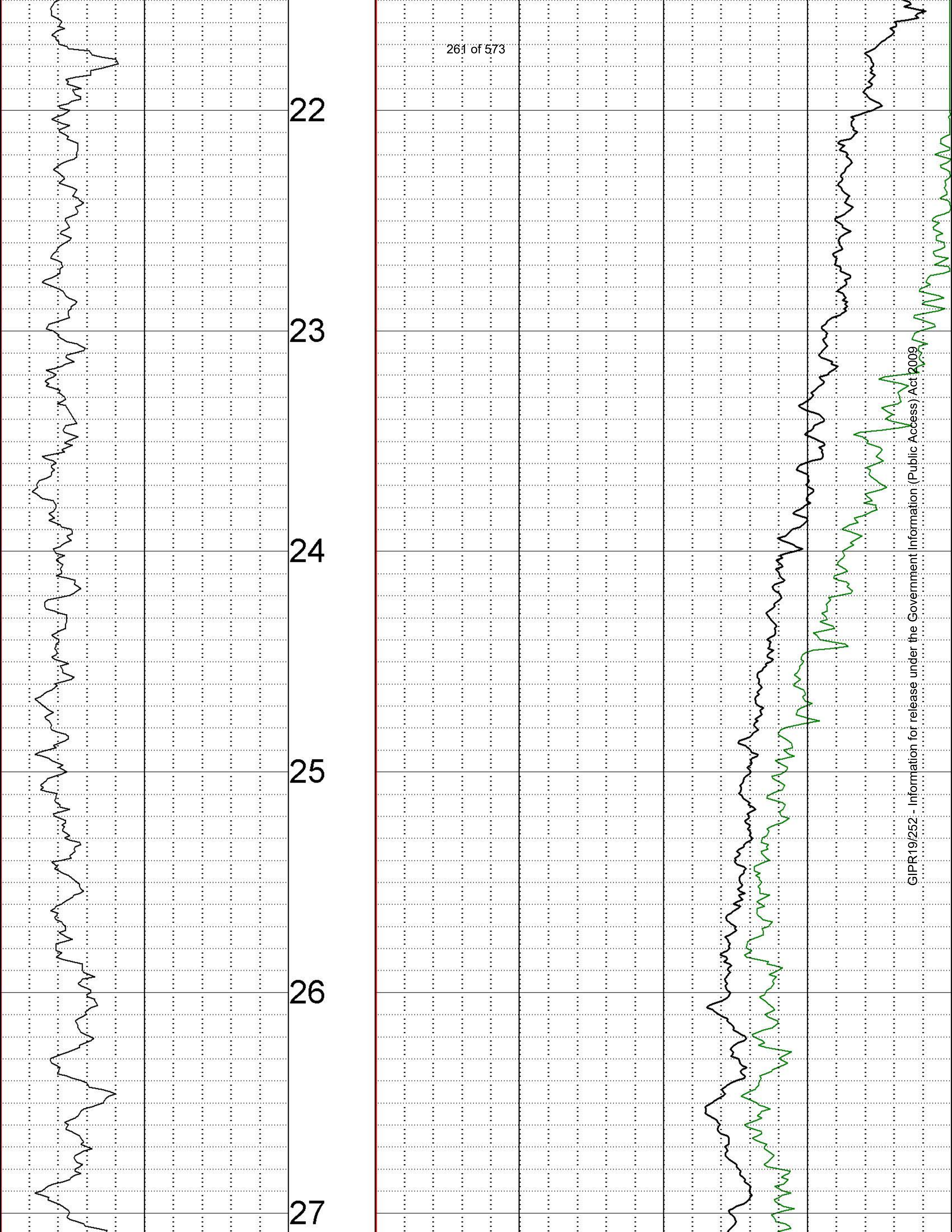
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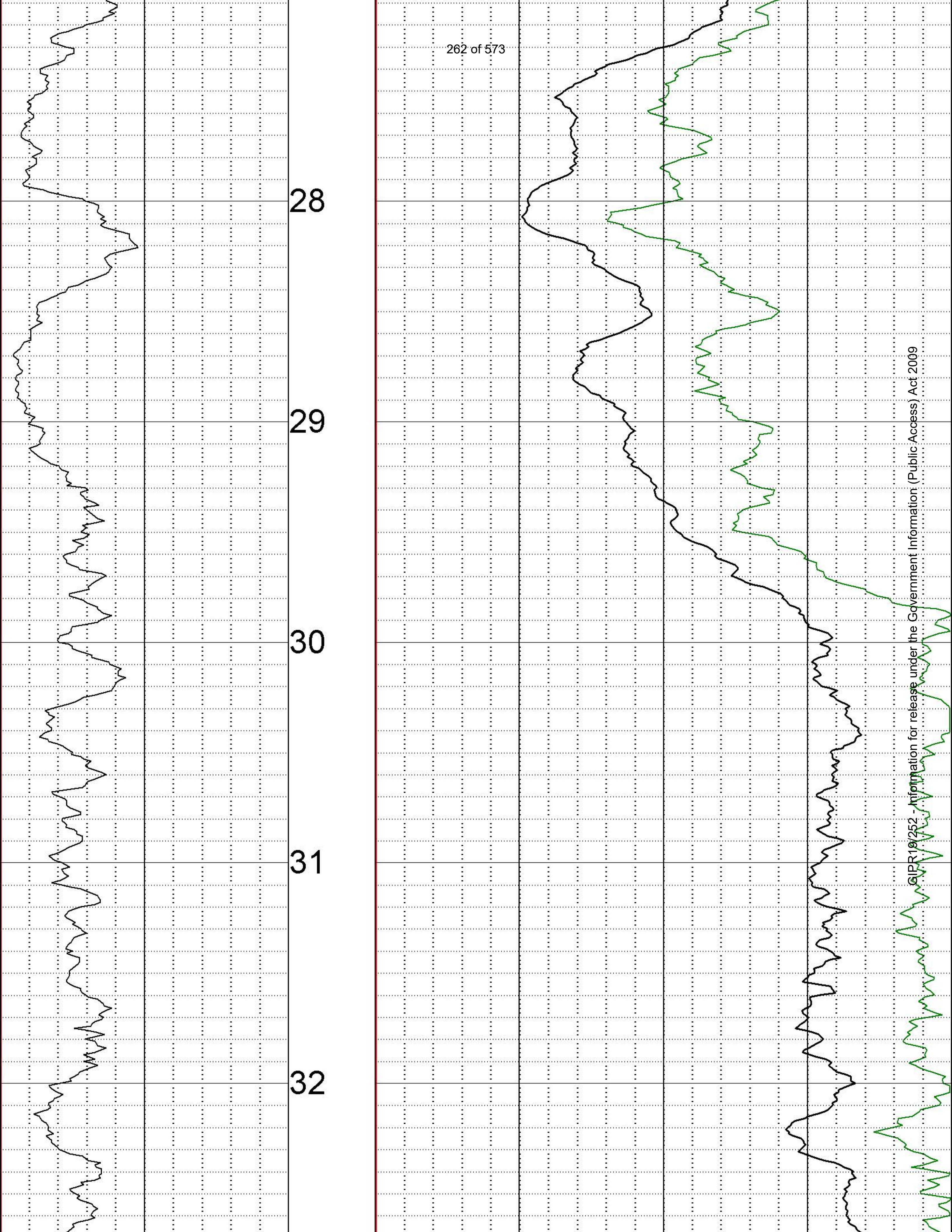
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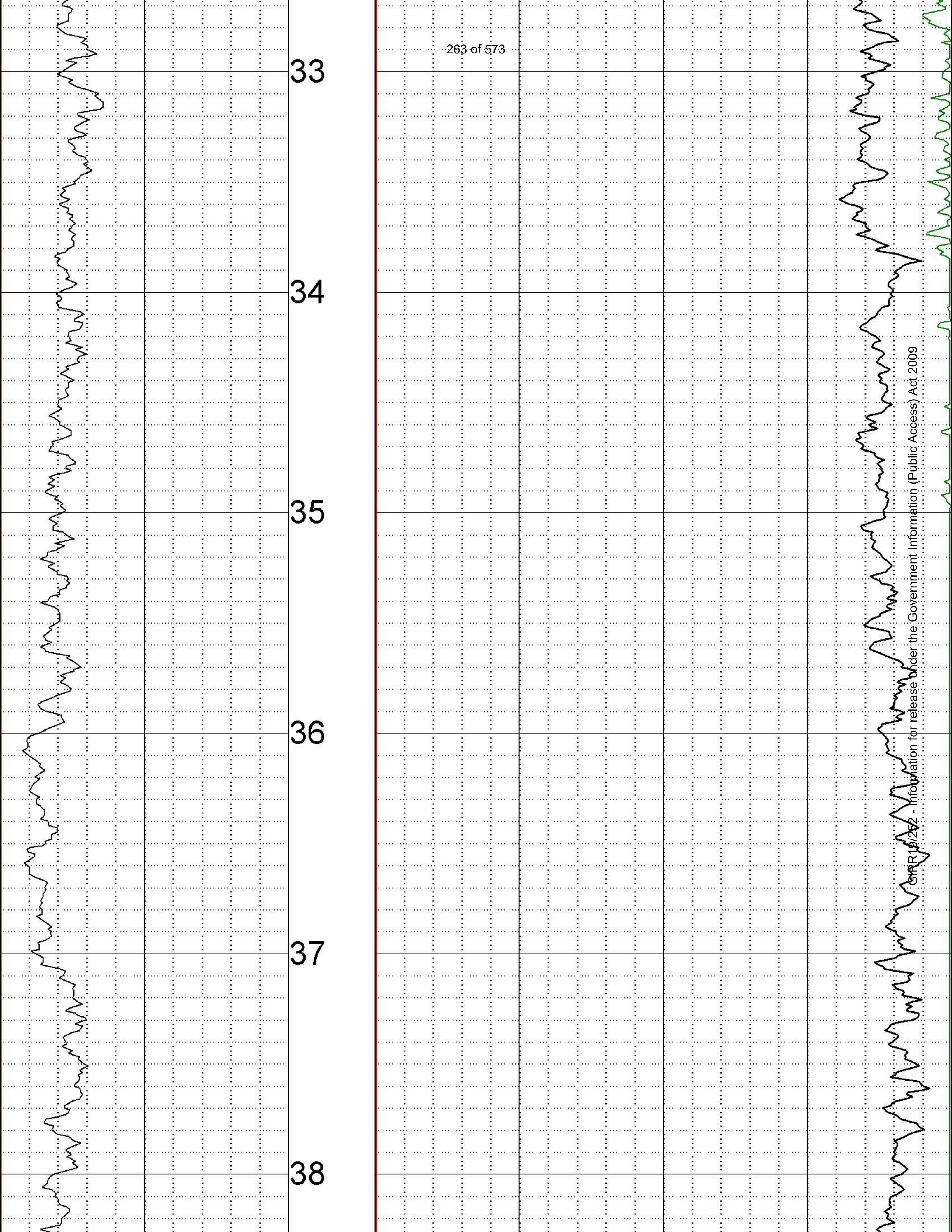
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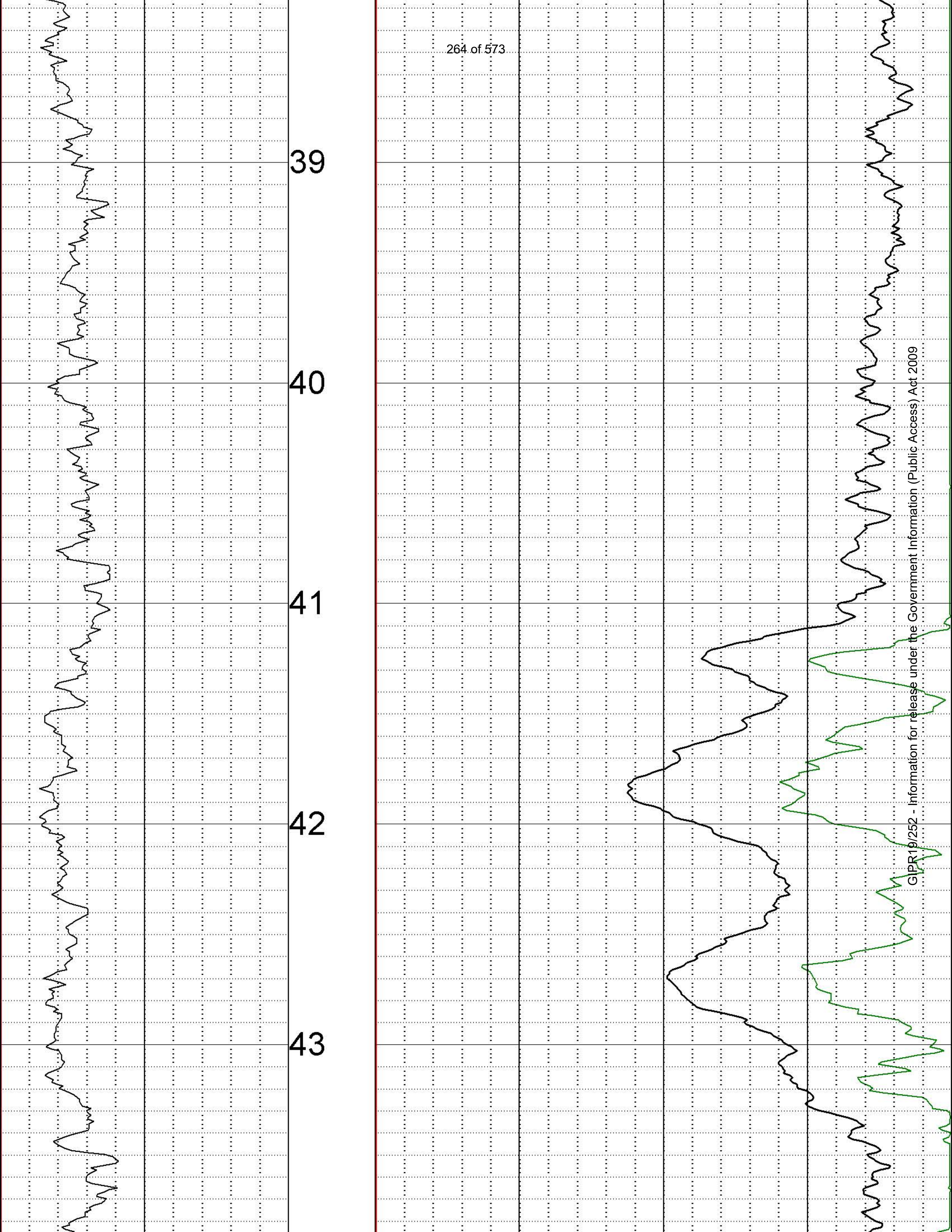
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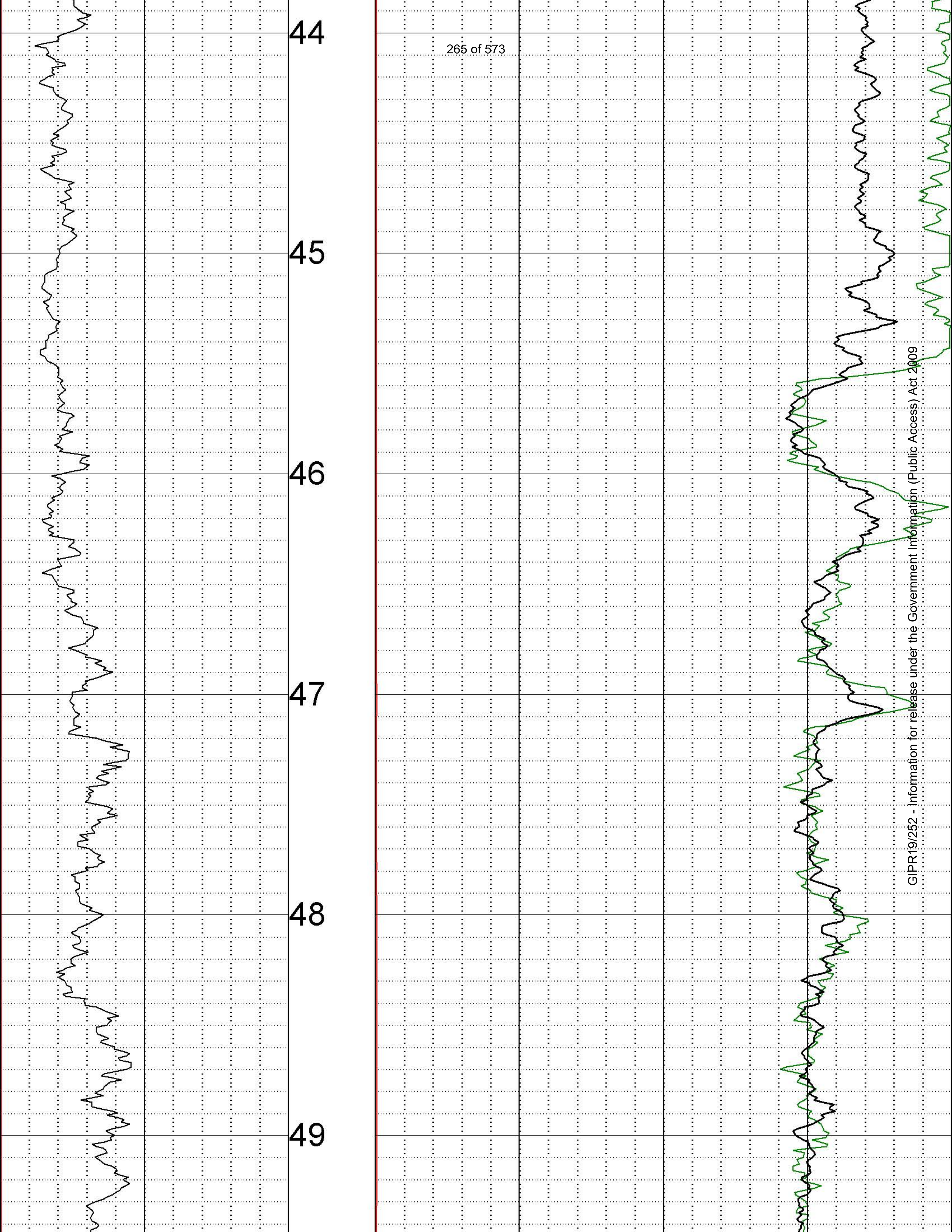
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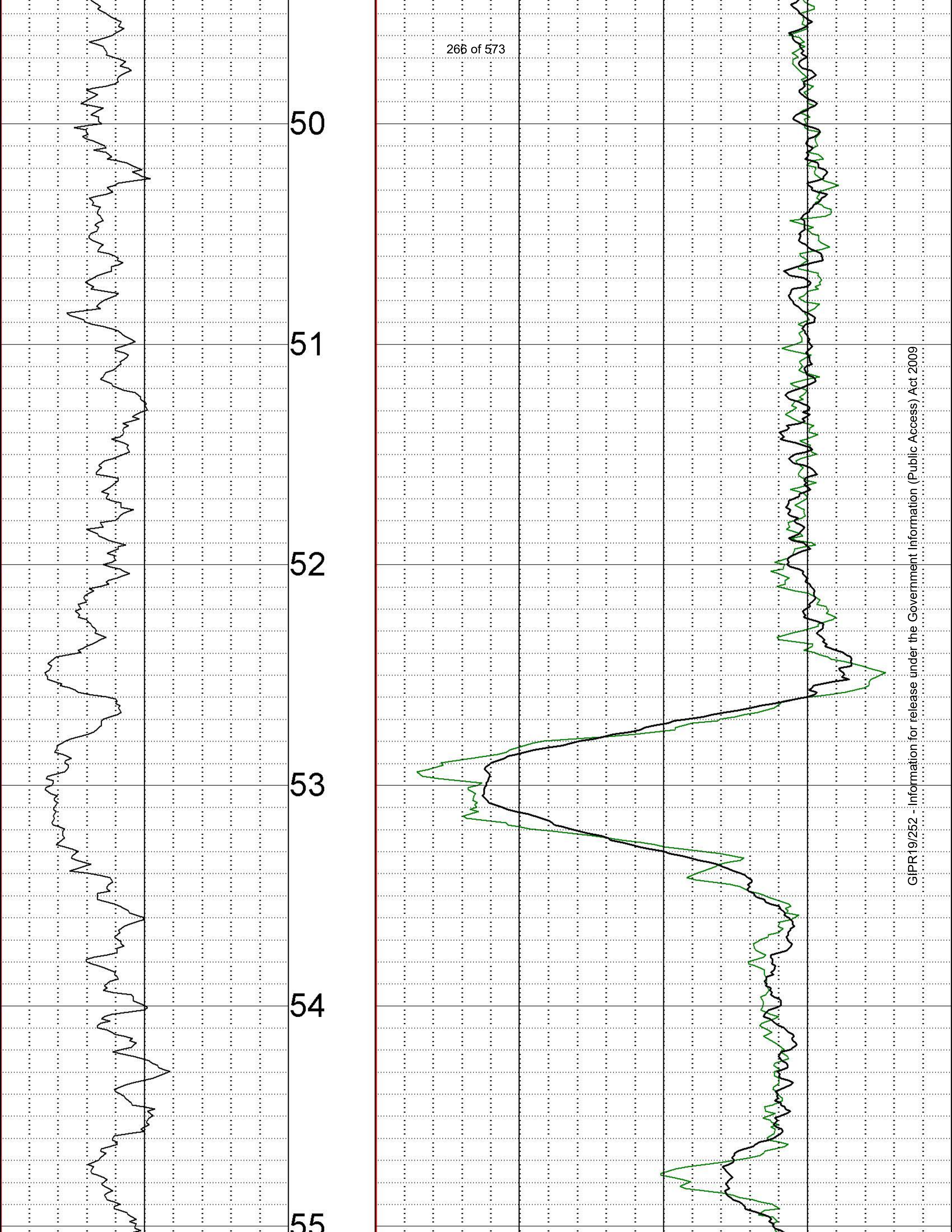
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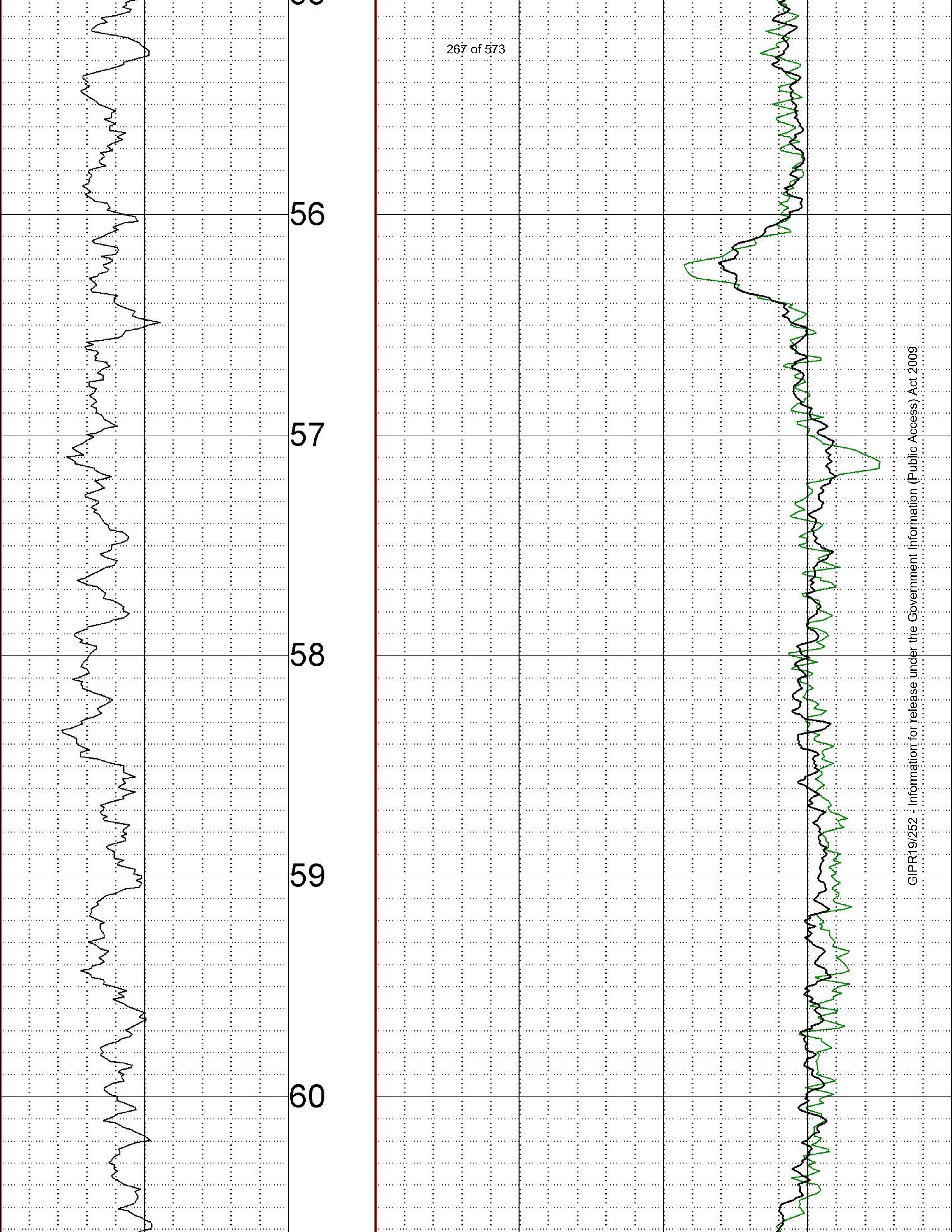
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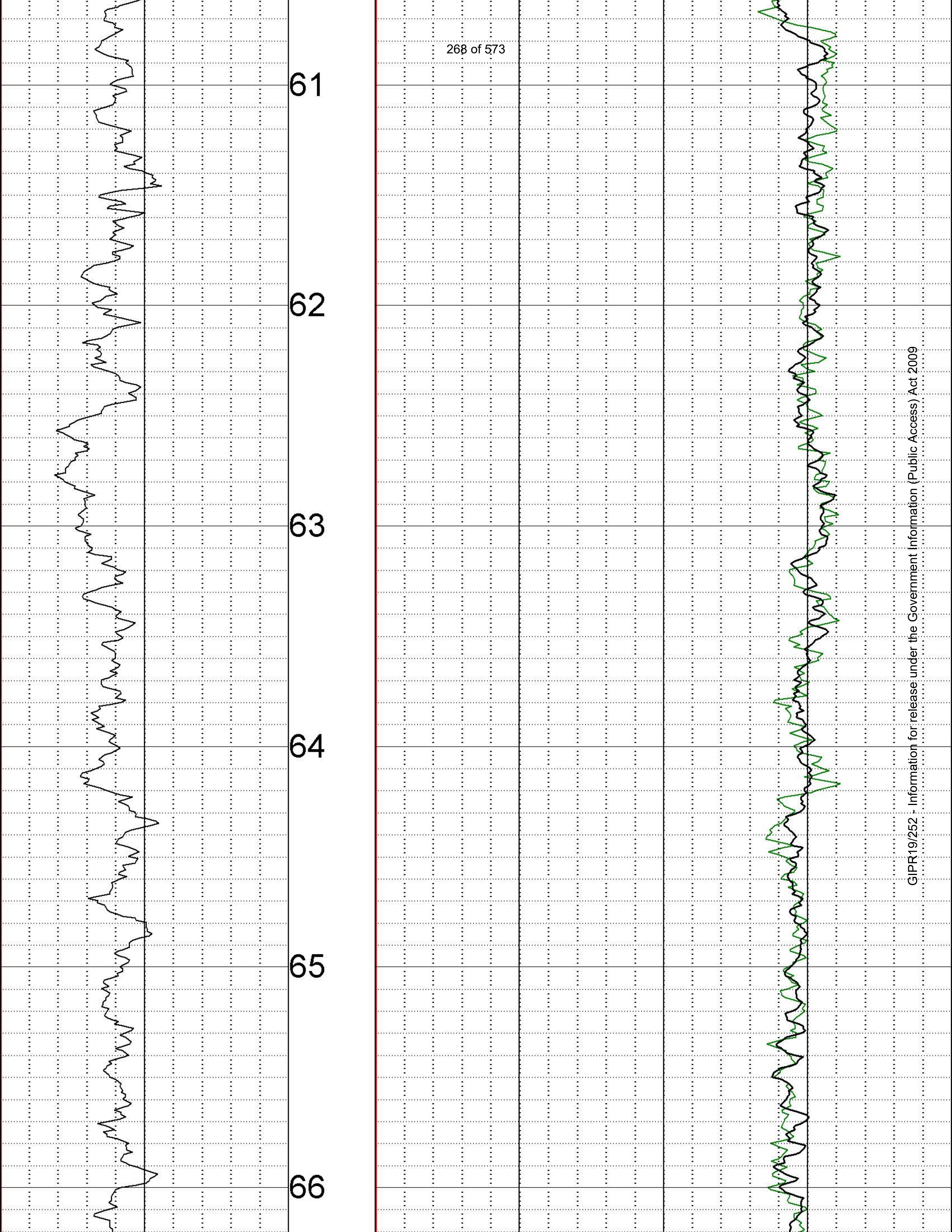
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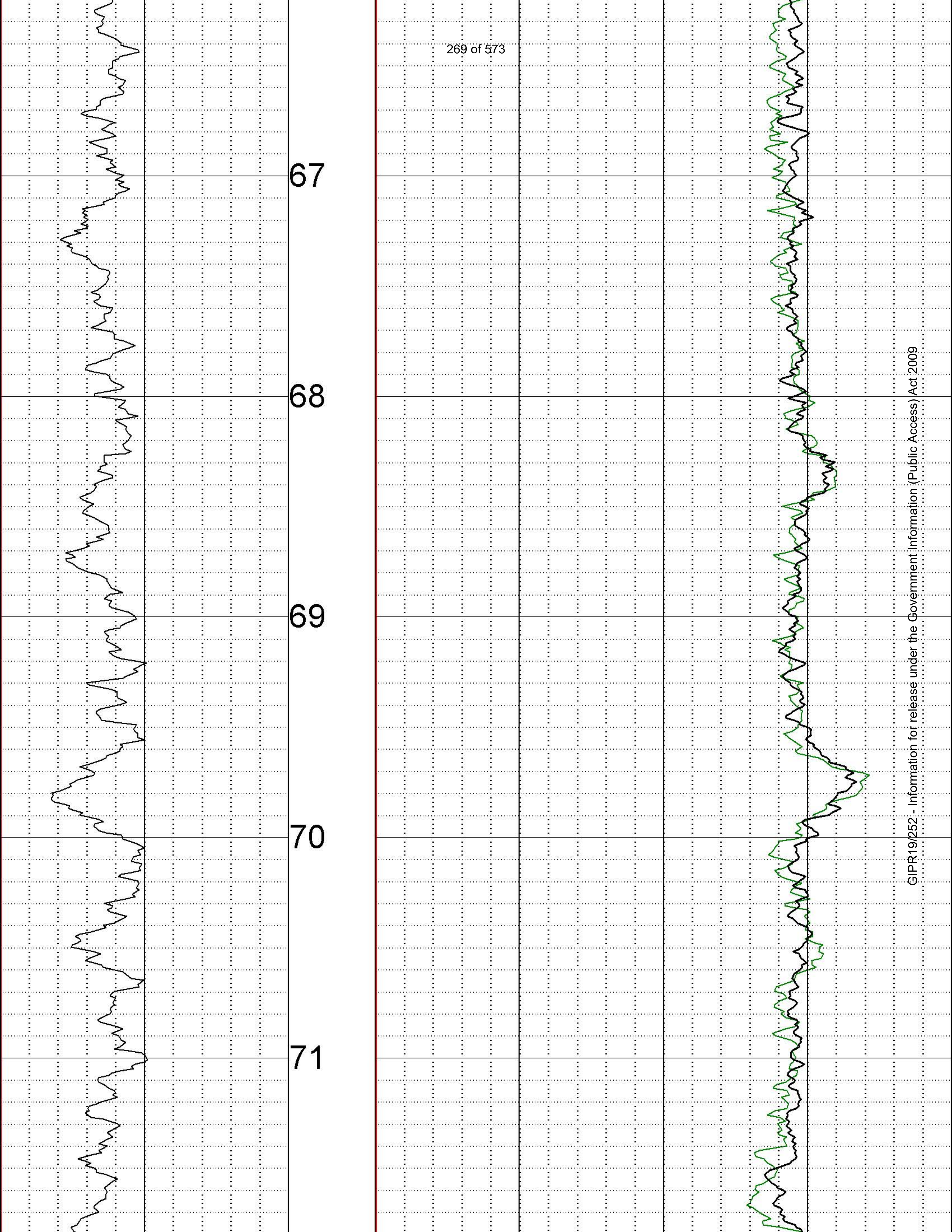
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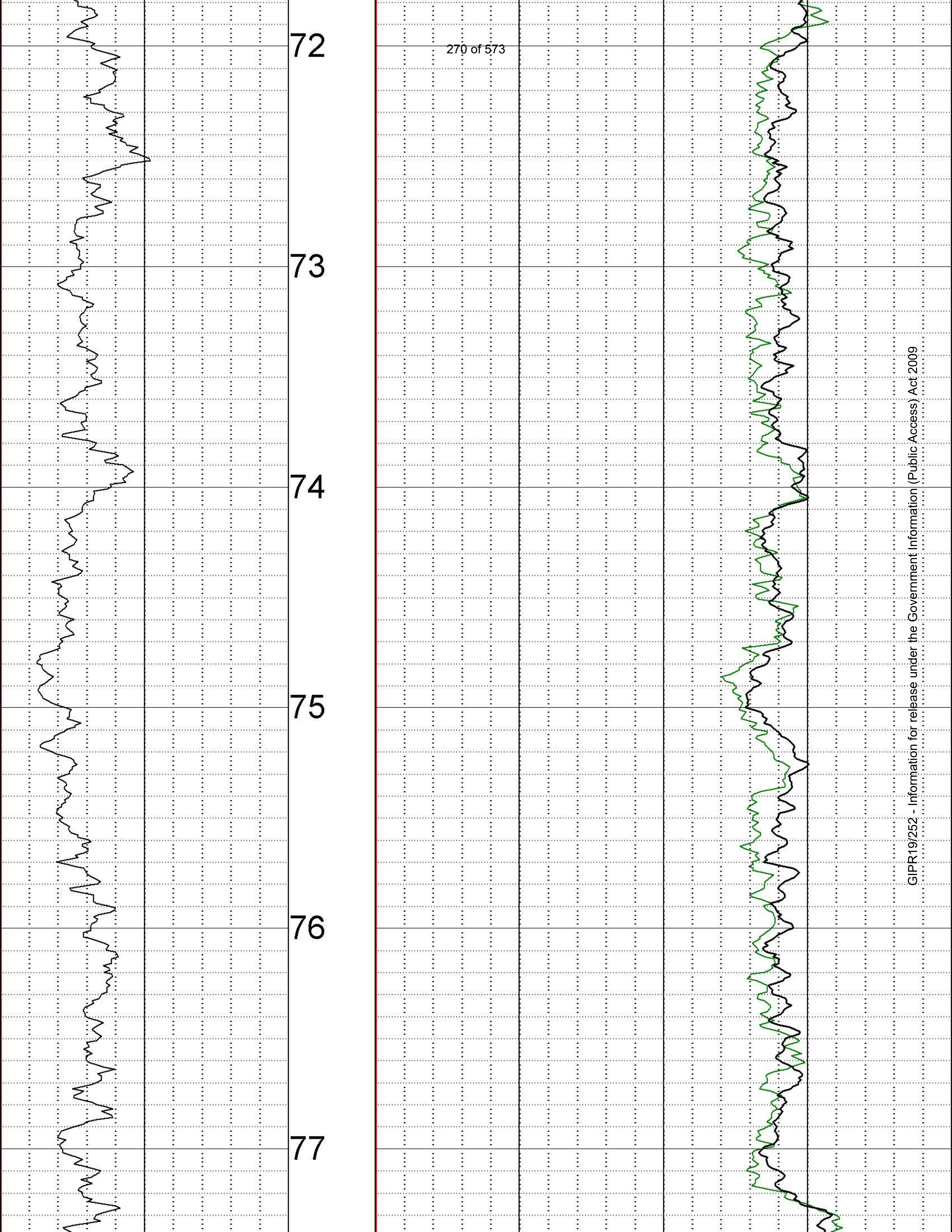
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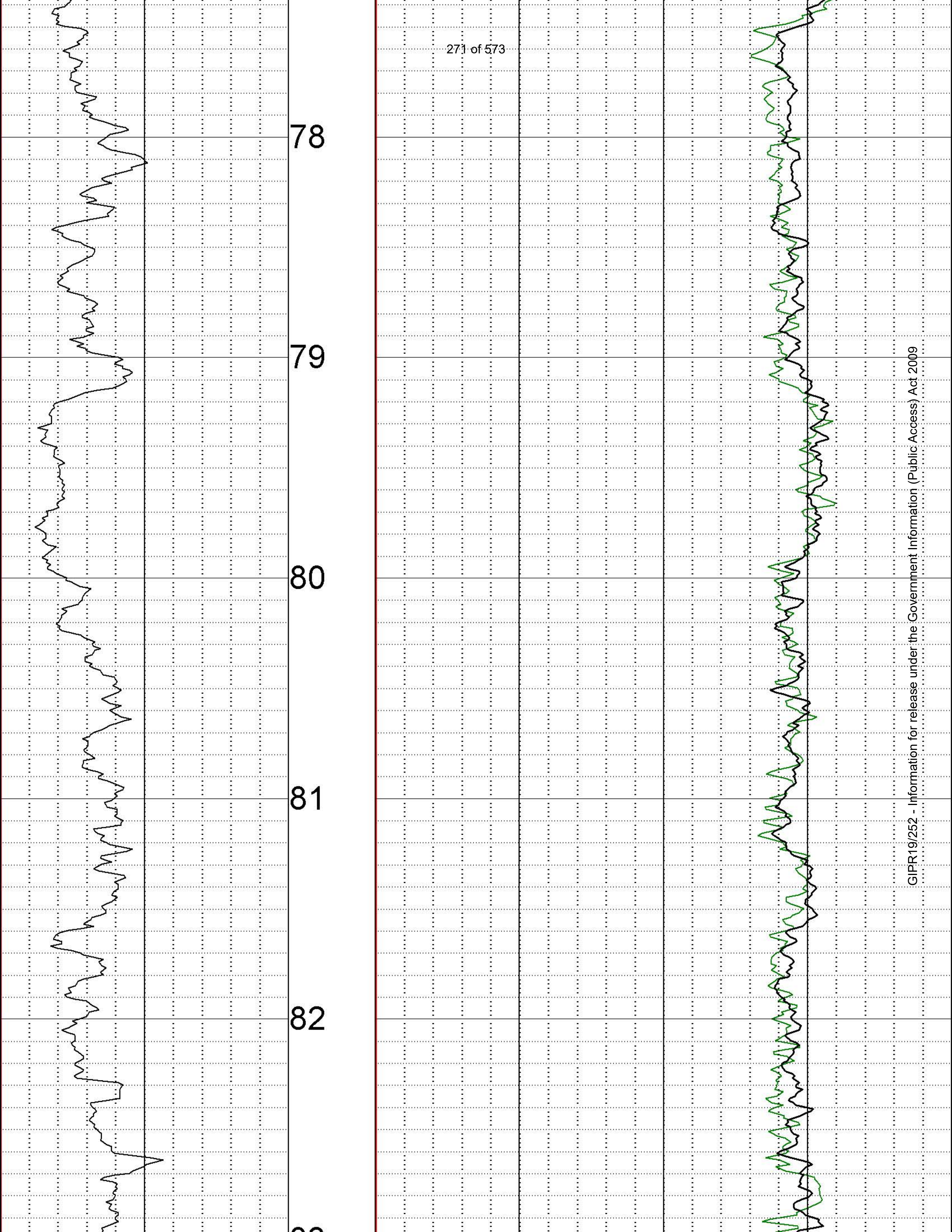
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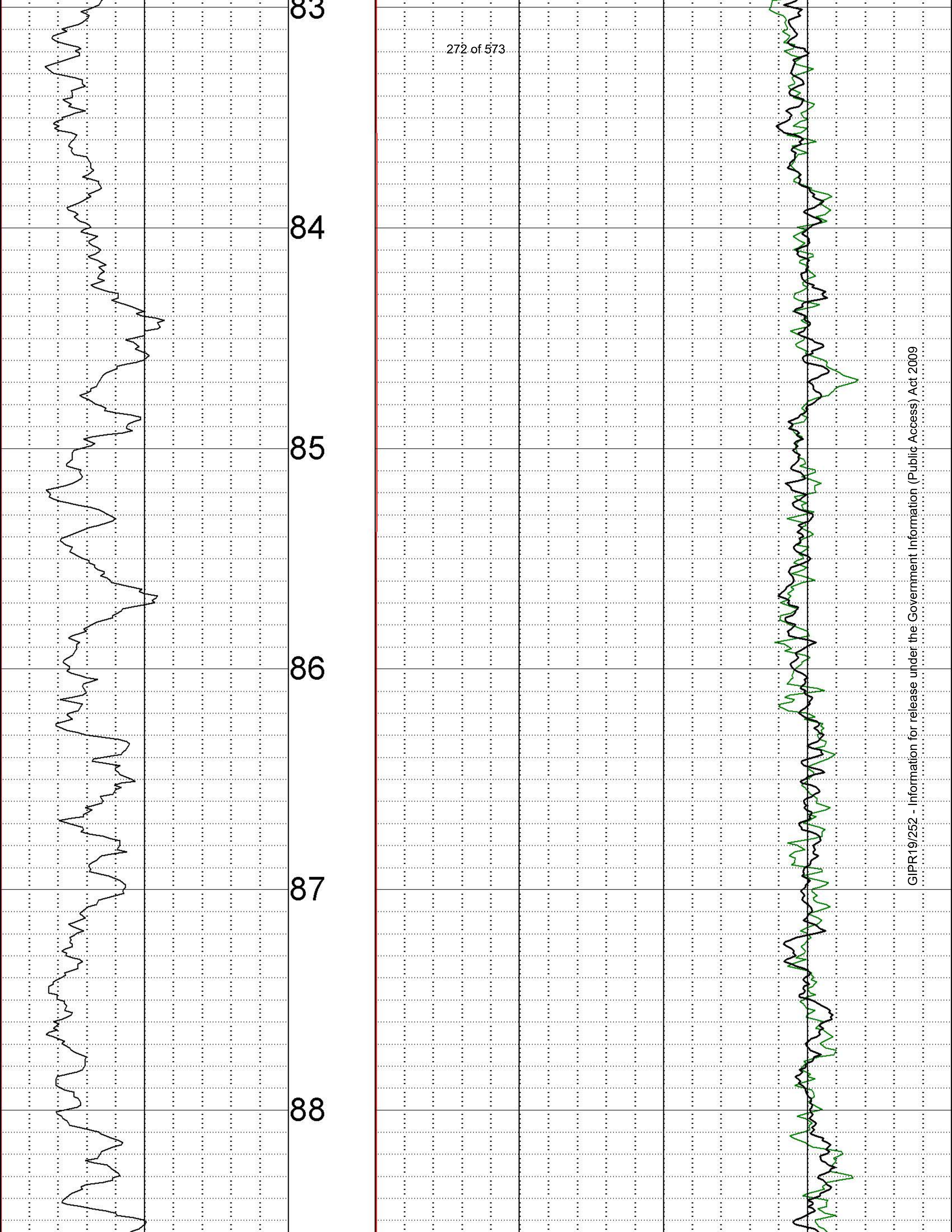
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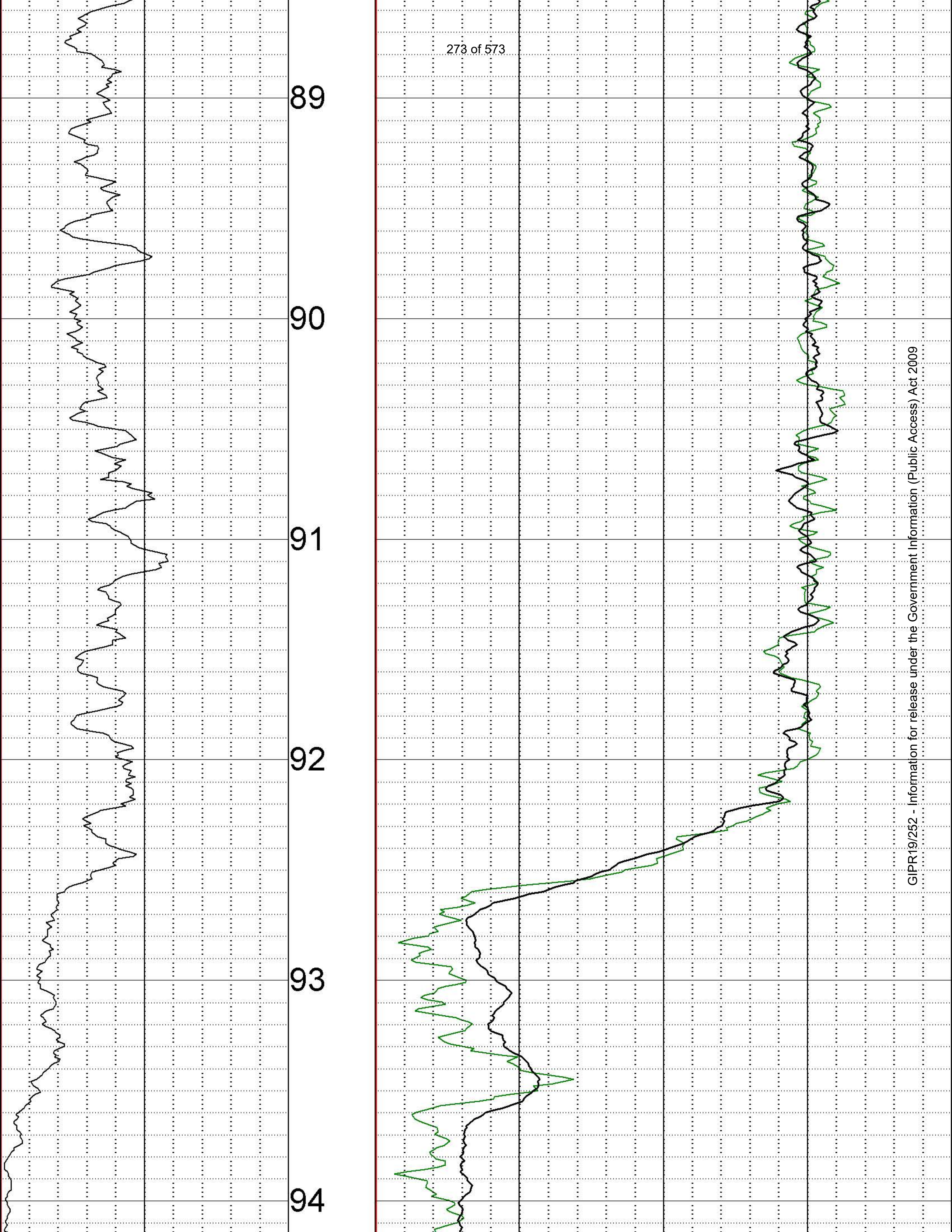

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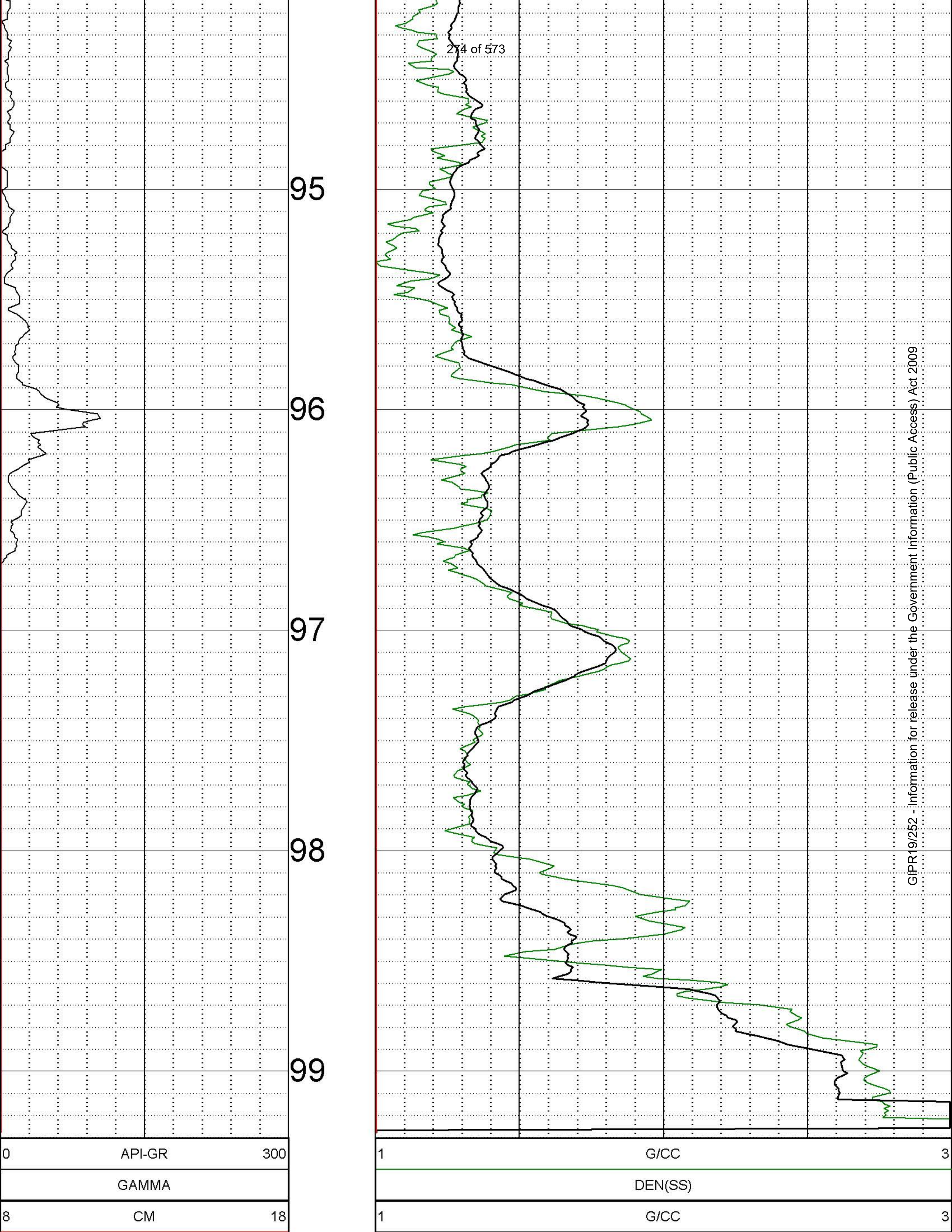
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G/CC
3

CALIPER	METERS	DEN(LS)
		0 OHM-M 2000
		RES(SG)

Coffey Geotechnics

Borehole BH04 TOP

ACOUSTIC TELEVIEWER
PETROPHYSICAL REPORT

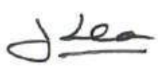
Groundsearch Australia Pty. Limited

2 October 2018

DISCLAIMER

The data used in this report were obtained using equipment manufactured by the Century Geophysical Corporation. The interpretations given in this report are based on judgement and experience of Groundsearch Australia's personnel. They are provided for Coffey Geotechnics sole use in accordance with a specified brief. As such, the interpretation outcomes do not necessarily address all aspects of ground conditions and behaviour on the subject site. The responsibility of Groundsearch Australia is solely to Coffey Geotechnics and it is not intended that any third party rely upon this report. This report shall not be reproduced either wholly or in part without the written permission of Groundsearch Australia Pty. Limited.

For and on behalf of Groundsearch Australia Pty. Limited



John Lea BSc (Hons) FAusIMM
Principal Geologist
Managing Director

Executive summary

The data contained in this report were obtained from one 9.6 cm diameter, vertical, cored borehole that was drilled as a component of the 2018 geotechnical exploration programme for Coffey Geotechnics at Lingard Street Newcastle NSW.

Century Geophysical Corporation downhole 9804 acoustic televiewer and 9329 density tools were run to collect data in the field on 14 September 2018. This report is for data from 30.00 to 41.32 mbgl. The 9239 density tool was run inside steel casing and data were corrected for the steel. Therefore, there are no caliper or resistivity data.

The 67 identified features are interpreted as the SWL bedding and fractures. The bedding to fractures ratio is 5:1.

The Century Display program has automatically recalculated the dip angle data to represent the borehole in the vertical position and the dip direction data is referenced to magnetic north.

1.0 Background technical information

The data contained in this report were obtained from one 9.6 cm diameter, vertical, cored borehole that was drilled as a component of the 2018 geotechnical exploration programme for Coffey Geotechnics at Lingard Street Newcastle NSW.

Century Geophysical Corporation downhole 9804 acoustic televiewer and 9329 density tools were run to collect data in the field on 14 September 2018. This report is for data from 30.00 to 41.32 mbgl. The 9239 density tool was run inside steel casing and data were corrected for the steel. Therefore, there are no caliper or resistivity data.

The 67 identified features are interpreted as the SWL bedding and fractures. The bedding to fractures ratio is 5:1.

The Century Display program has automatically recalculated the dip angle data to represent the borehole in the vertical position and the dip direction data is referenced to magnetic north.

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Subsequent processing and interpretation of data were carried out by Groundsearch.

The ATV takes an oriented image of the borehole using high-resolution sound waves. This acoustic image is displays amplitude variations. This information is used to detect bedding planes, fractures, and other borehole anomalies without the need to have clear fluid filling the boreholes. The tool works only in fluid-filled boreholes.

The televiewer digitises 256 measurements around the borehole at each high-resolution sample interval. These data can be oriented to North and displayed real-time while logging using the Visual Compu-Log System.

Analysis software includes colour adjustment, fracture dip and strike determination, and classification of features. It allows information to be displayed on the graphical screen, plot, and in report format.

2.0 Interpretation methodology

It should be noted that the ATV is a bowspring-type, centralised tool and is affected by poor wallrock conditions known as rugosity.

The ATV data interpretation procedure is based on the superposition of curves on feature logs directly onto the computer screen by using a subjective, manual; two-point definition of a feature's top and base to produce a sine curve. The sides of the time and amplitude plots represent magnetic north and magnetic south is in the centre of each plot. The low side, or trough, of the sine curve defines the dip direction of the feature.

The logging program automatically records the televiewer tool slant angle and bearing and corrects for any borehole deviations. The curves are automatically given an identification number for subsequent referencing in a report file.

There are possibly more bedding planes and structural fractures appearing in the televiewer logs that have not been included in this report due to their poor graphic definition or the inability to resolve their geometry by superposing a sine curve using the program's two point method.

This report contains a;

- Text summary of the interpreted features
- Circular representation of interpreted features
- Logs that show geological features with their subjective, numbered interpretation curves shown at 1:20 scale. The logs are in standard format whereby the optical image of the borehole wall is "flattened" onto the plot. The logs have the following additional features to enhance geological interpretations of the strata;
    - Amplitude image differentials
    - Time image differentials that indicate higher strength zones in **GREEN** and lower strength zones in **RED**
    - Tadpoles that represent feature dip and dip direction
    - Open fractures in **RED**
    - Partially open fractures in **MAGENTA**
  - Natural gamma
  - Slant (dip angle)
  - Slant angle bearing
  - Long and short space density
- Table containing feature curve ID, top, base, dip angle, dip azimuth, feature description and the generalised rock type that hosts the feature
- Graphical representations of the interpreted features

3.0 Borehole BH04 TOP interpretation

The 67 identified features are interpreted as the SWL bedding and fractures. The bedding to fractures ratio is 5:1.

A description of each interpreted feature is presented in Table 1 and the log is presented in Appendix 1.

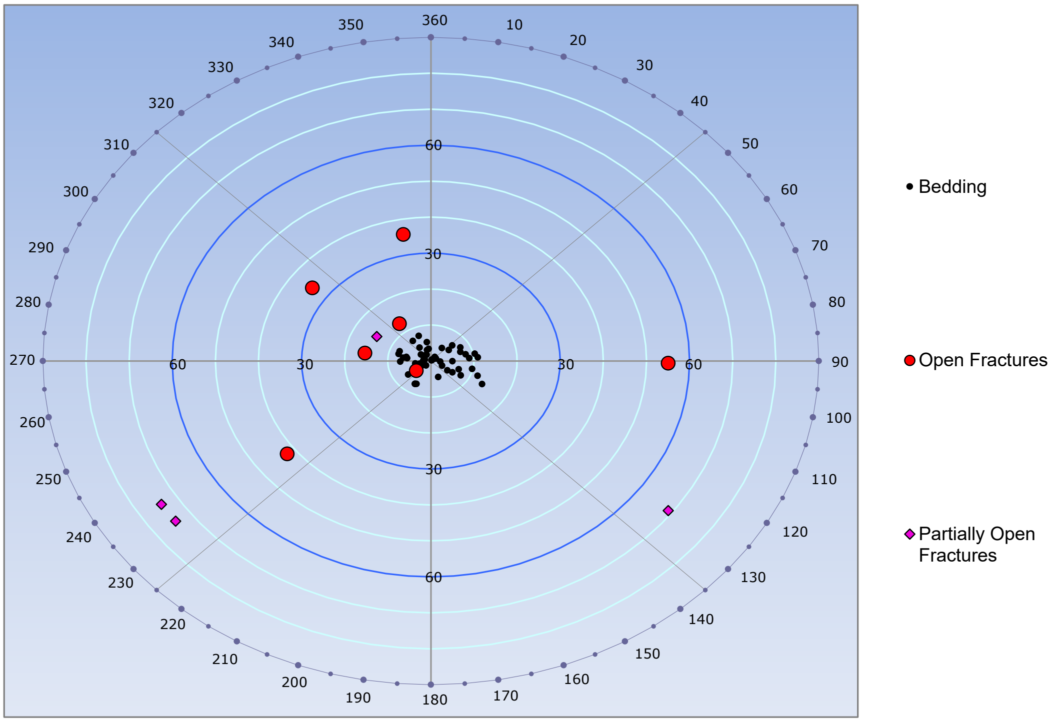
Table 1 Interpreted features report for BH04 TOP

FEATURE ID	DIP (DEG)	AZIMUTH (DEG)	MIDPOINT (MBGL)	TOP (M)	BASE (M)	TYPE OF FEATURE	GENERALISED ROCK TYPE
1			30.17	30.17	30.17	SWL	Overburden
2	2	319	30.48	30.48	30.48	Bedding plane	Overburden
3	0	44	30.96	30.96	30.96	Bedding plane	Overburden
4	15	278	31.19	31.18	31.21	Fracture plane - open	Overburden
5	14	298	31.29	31.28	31.30	Fracture plane - partially open	Overburden
6	8	338	31.33	31.32	31.33	Bedding plane	Overburden
7	8	61	31.56	31.56	31.57	Bedding plane	Overburden
8	7	70	31.77	31.76	31.77	Bedding plane	Overburden
9	8	77	31.83	31.83	31.84	Bedding plane	Overburden
10	12	111	31.92	31.91	31.93	Bedding plane	Overburden
11	7	208	32.39	32.38	32.39	Bedding plane	Overburden
12	7	323	32.53	32.52	32.53	Bedding plane	Overburden
13	8	120	32.70	32.70	32.71	Bedding plane	Overburden
14	69	127	32.78	32.65	32.91	Fracture plane - partially open	Overburden
15	2	312	32.93	32.93	32.94	Bedding plane	Overburden
16	2	94	33.16	33.15	33.16	Bedding plane	Overburden
17	5	238	34.48	34.47	34.48	Bedding plane	Overburden
18	2	255	34.65	34.65	34.65	Bedding plane	Overburden
19	3	117	34.72	34.71	34.72	Bedding plane	Overburden
20	3	254	34.79	34.79	34.80	Bedding plane	Overburden
21	7	49	34.83	34.83	34.84	Bedding plane	Overburden
22	3	352	35.09	35.09	35.09	Bedding plane	Overburden
23	5	350	35.13	35.13	35.14	Bedding plane	Overburden
24	0	47	35.62	35.62	35.62	Bedding plane	Overburden
25	4	232	35.67	35.66	35.67	Fracture plane - open	Overburden
26	1	38	35.72	35.72	35.72	Bedding plane	Overburden
27	2	282	35.77	35.77	35.77	Bedding plane	Overburden
28	7	269	35.84	35.84	35.85	Bedding plane	Overburden
29	4	35	35.95	35.95	35.95	Bedding plane	Overburden
30	2	222	36.15	36.15	36.15	Bedding plane	Overburden
31	8	290	36.25	36.24	36.25	Bedding plane	Overburden
32	6	122	36.37	36.37	36.38	Bedding plane	Overburden
33	6	281	36.56	36.56	36.57	Bedding plane	Overburden
34	55	91	36.74	36.67	36.82	Fracture plane - open	Overburden
35	13	325	36.90	36.89	36.91	Fracture plane - open	Overburden
36	6	278	37.06	37.06	37.07	Bedding plane	Overburden
37	0	26	37.15	37.15	37.15	Bedding plane	Overburden
38	3	308	37.18	37.18	37.18	Bedding plane	Overburden

Coffey Geotechnics
Borehole BH04 TOP Acoustic Televiewer Petrophysical Report

39	2	266	37.28	37.27	37.28	Bedding plane	Overburden
40	6	278	37.51	37.50	37.52	Bedding plane	Overburden
41	1	285	37.53	37.53	37.54	Bedding plane	Overburden
42	2	239	37.60	37.60	37.60	Bedding plane	Overburden
43	6	235	37.63	37.63	37.64	Bedding plane	Overburden
44	8	285	37.69	37.68	37.70	Bedding plane	Overburden
45	36	350	38.33	38.30	38.37	Fracture plane - open	Overburden
46	3	344	38.34	38.34	38.34	Bedding plane	Overburden
47	7	110	38.39	38.38	38.39	Bedding plane	Overburden
48	5	325	38.68	38.67	38.68	Bedding plane	Overburden
49	7	210	38.82	38.82	38.83	Bedding plane	Overburden
50	7	210	38.84	38.84	38.85	Bedding plane	Overburden
51	5	159	38.96	38.96	38.96	Bedding plane	Overburden
52	1	61	39.00	39.00	39.00	Bedding plane	Overburden
53	10	103	39.02	39.01	39.02	Bedding plane	Overburden
54	13	118	39.07	39.06	39.09	Bedding plane	Overburden
55	9	85	39.12	39.11	39.13	Bedding plane	Overburden
56	11	85	39.17	39.16	39.18	Bedding plane	Overburden
57	34	307	39.49	39.45	39.52	Fracture plane - open	Overburden
58	42	232	39.59	39.55	39.64	Fracture plane - open	Overburden
59	4	260	39.73	39.72	39.73	Bedding plane	Overburden
60	0	45	40.15	40.15	40.14	Bedding plane	Overburden
61	2	331	40.25	40.25	40.25	Bedding plane	Overburden
62	10	79	40.57	40.56	40.58	Bedding plane	Overburden
63	5	124	40.69	40.68	40.69	Bedding plane	Overburden
64	74	237	40.69	40.51	40.87	Fracture plane - partially open	Overburden
65	5	91	40.73	40.72	40.73	Bedding plane	Overburden
66	74	233	40.74	40.56	40.92	Fracture plane - partially open	Overburden
67	5	54	40.75	40.74	40.75	Bedding plane	Overburden
FEATURE ID	**DIP (DEG)**	**AZIMUTH (DEG)**	**MIDPOINT (MBGL)**	**TOP (M)**	**BASE (M)**	**TYPE OF FEATURE**	**GENERALISED ROCK TYPE**

Figure 1 BH04 TOP circular plan representation of interpreted features



The 55 identified sedimentary features are predominantly bedding planes that appear to range in dip from flat-lying to 13^0. Figures 2 and 3 show the distribution of the planes' dip angles and dip direction with depth.

Table 2 details the variation in the dip angle and dip direction data. Figure 4 shows the dip direction data in a rose diagram with the bedding planes' dip angle and dip direction data shown as histograms in Figures 5 and 6.

The 11 fractures are identified as open (64%) and partially open (36%). The fracture dip angles range from 4 to 74^0.

Table 3 details the variation in the fractures' dip angle and dip direction data. Figure 7 shows the dip direction data in a rose diagram with the fractures' plane dip angle and dip direction data as histograms in Figures 8 and 9.

Figure 2 BH04 TOP feature dip angle data distribution

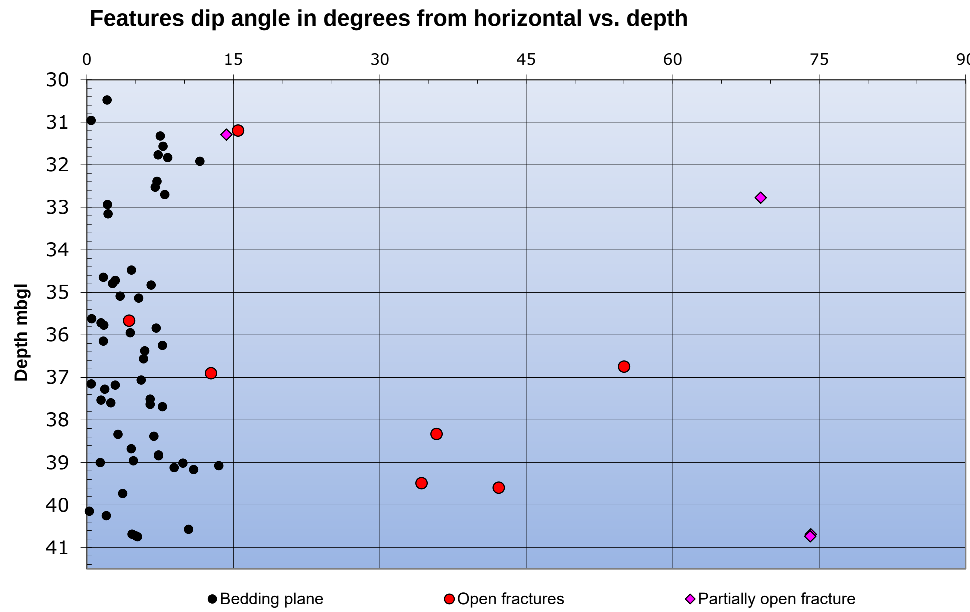


Figure 3 BH04 TOP feature dip direction data distribution

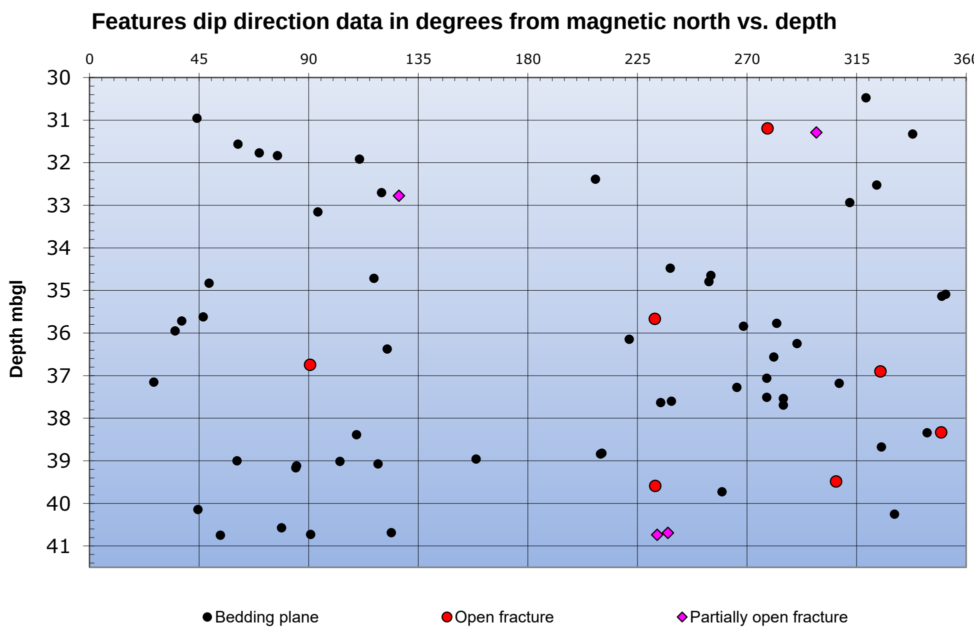


Table 2 BH04 TOP bedding histogram data

Dip Distribution Total: 55			Orientation Distribution Total: 55		
Dip Range	Count	%	Bearing Range	Count	%
0 to 10	51	92.7	0 to 10	0	0.0
10 to 20	4	7.3	10 to 20	0	0.0
20 to 30	0	0.0	20 to 30	1	1.8
30 to 40	0	0.0	30 to 40	2	3.6
40 to 50	0	0.0	40 to 50	4	7.3
50 to 60	0	0.0	50 to 60	1	1.8
60 to 70	0	0.0	60 to 70	3	5.5
70 to 80	0	0.0	70 to 80	2	3.6
80 to 90	0	0.0	80 to 90	2	3.6
			90 to 100	2	3.6
			100 to 110	2	3.6
			110 to 120	4	7.3
			120 to 130	2	3.6
			130 to 140	0	0.0
			140 to 150	0	0.0
			150 to 160	1	1.8
			160 to 170	0	0.0
			170 to 180	0	0.0
			180 to 190	0	0.0
			190 to 200	0	0.0
			200 to 210	2	3.6
			210 to 220	1	1.8
			220 to 230	1	1.8
			230 to 240	3	5.5
			240 to 250	0	0.0
			250 to 260	3	5.5
			260 to 270	2	3.6
			270 to 280	2	3.6
			280 to 290	4	7.3
			290 to 300	1	1.8
			300 to 310	1	1.8
			310 to 320	2	3.6
			320 to 330	2	3.6
			330 to 340	2	3.6
			340 to 350	2	3.6
			350 to 360	1	1.8

Figure 5 BH04 TOP bedding dip angles histogram

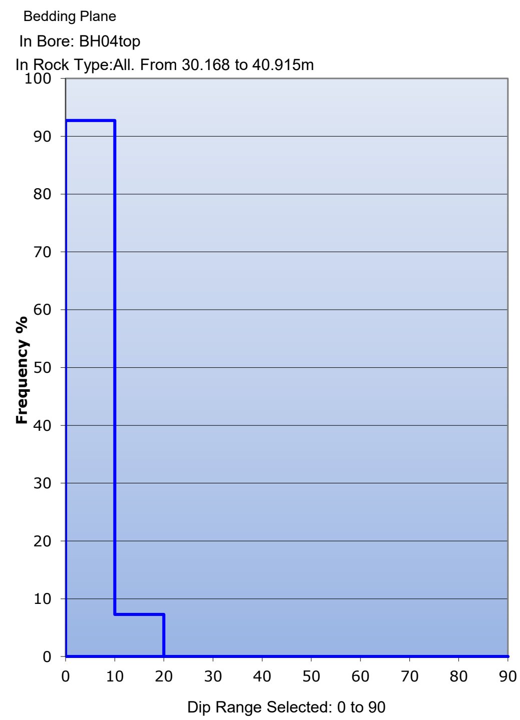


Figure 4 BH04 TOP bedding dip direction data rose diagram

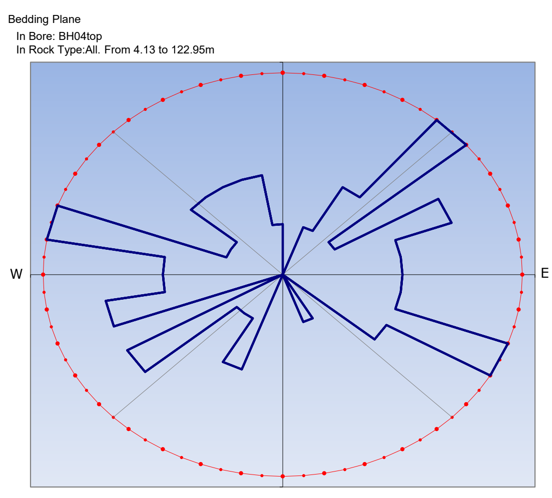


Figure 6 BH04 TOP bedding dip directions histogram

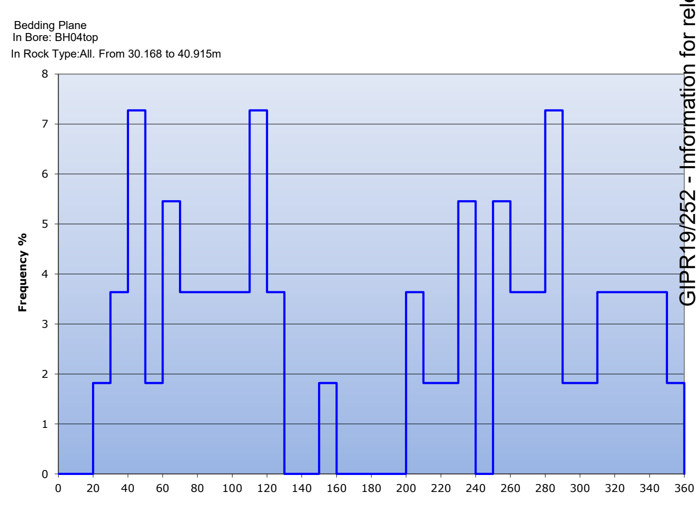


Table 3 BH04 TOP fractures histogram data

Dip Distribution	Total: 11		Orientation Distribution	Total: 11	
Dip Range	**Count**	**%**	**Bearing Range**	**Count**	**%**
0 to 10	1	9.1	0 to 10	0	0.0
10 to 20	3	27.3	10 to 20	0	0.0
20 to 30	0	0.0	20 to 30	0	0.0
30 to 40	2	18.2	30 to 40	0	0.0
40 to 50	1	9.1	40 to 50	0	0.0
50 to 60	1	9.1	50 to 60	0	0.0
60 to 70	1	9.1	60 to 70	0	0.0
70 to 80	2	18.2	70 to 80	0	0.0
80 to 90	0	0.0	80 to 90	0	0.0
			90 to 100	1	9.1
			100 to 110	0	0.0
			110 to 120	0	0.0
			120 to 130	1	9.1
			130 to 140	0	0.0
			140 to 150	0	0.0
			150 to 160	0	0.0
			160 to 170	0	0.0
			170 to 180	0	0.0
			180 to 190	0	0.0
			190 to 200	0	0.0
			200 to 210	0	0.0
			210 to 220	0	0.0
			220 to 230	0	0.0
			230 to 240	4	36.4
			240 to 250	0	0.0
			250 to 260	0	0.0
			260 to 270	0	0.0
			270 to 280	1	9.1
			280 to 290	0	0.0
			290 to 300	1	9.1
			300 to 310	1	9.1
			310 to 320	0	0.0
			320 to 330	1	9.1
			330 to 340	0	0.0
			340 to 350	1	9.1
			350 to 360	0	0.0

Figure 8 BH04 TOP fractures dip angles histogram

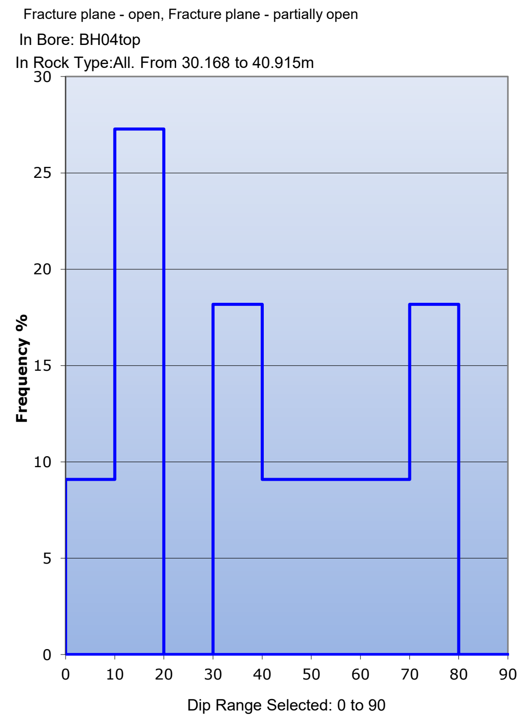


Figure 7 BH04 TOP fractures dip direction data rose diagram

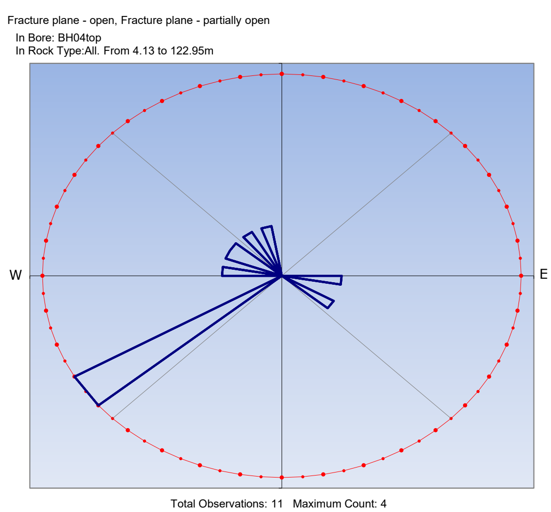
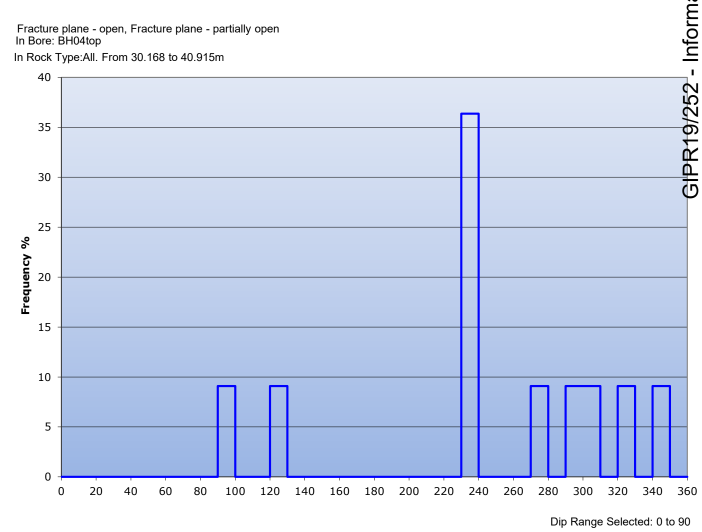


Figure 9 BH04 TOP fractures dip directions histogram



Appendix 1

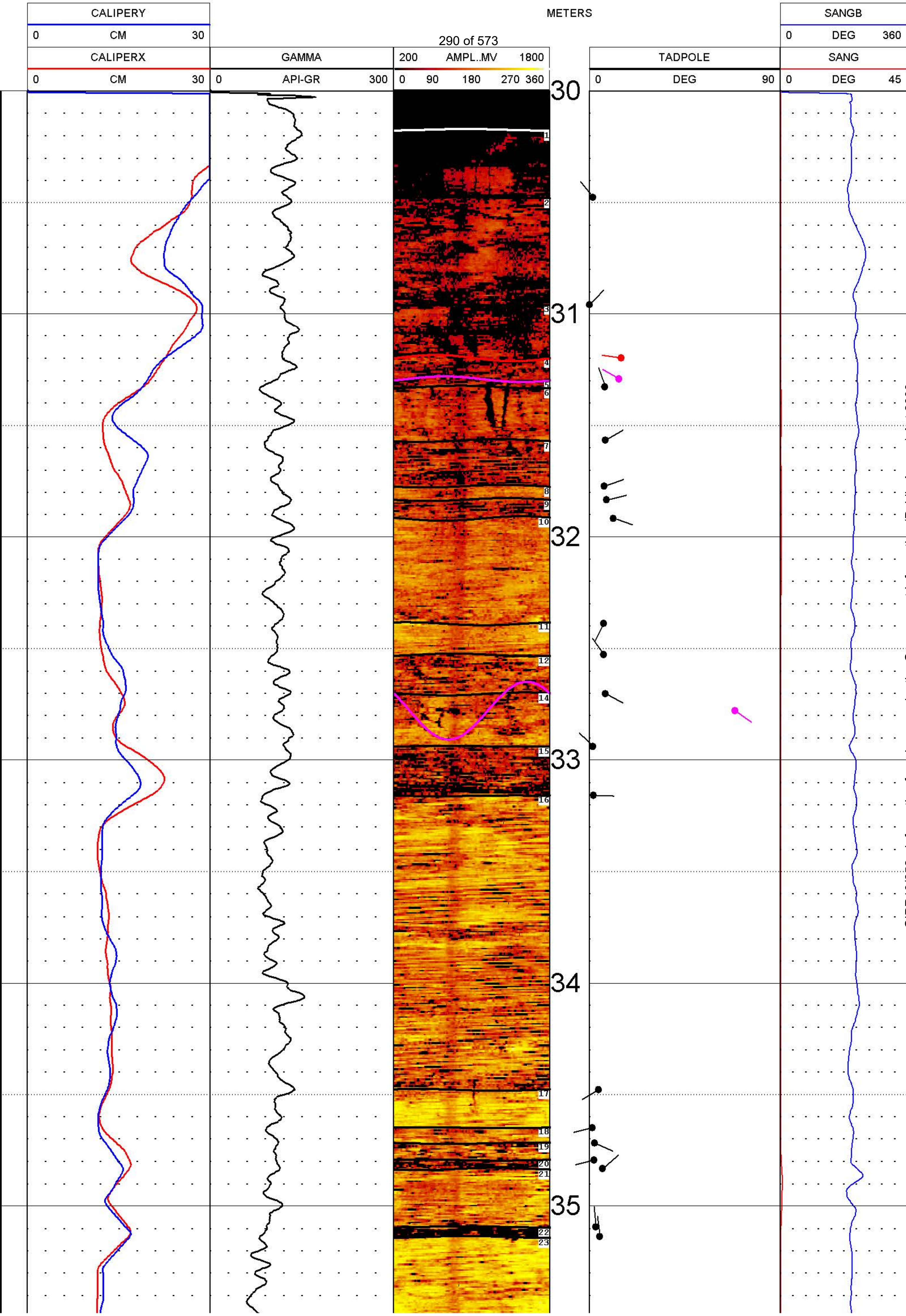
Appendix 1 *1:20 Interpretation logs – 30.00 to 41.32 mbgl*

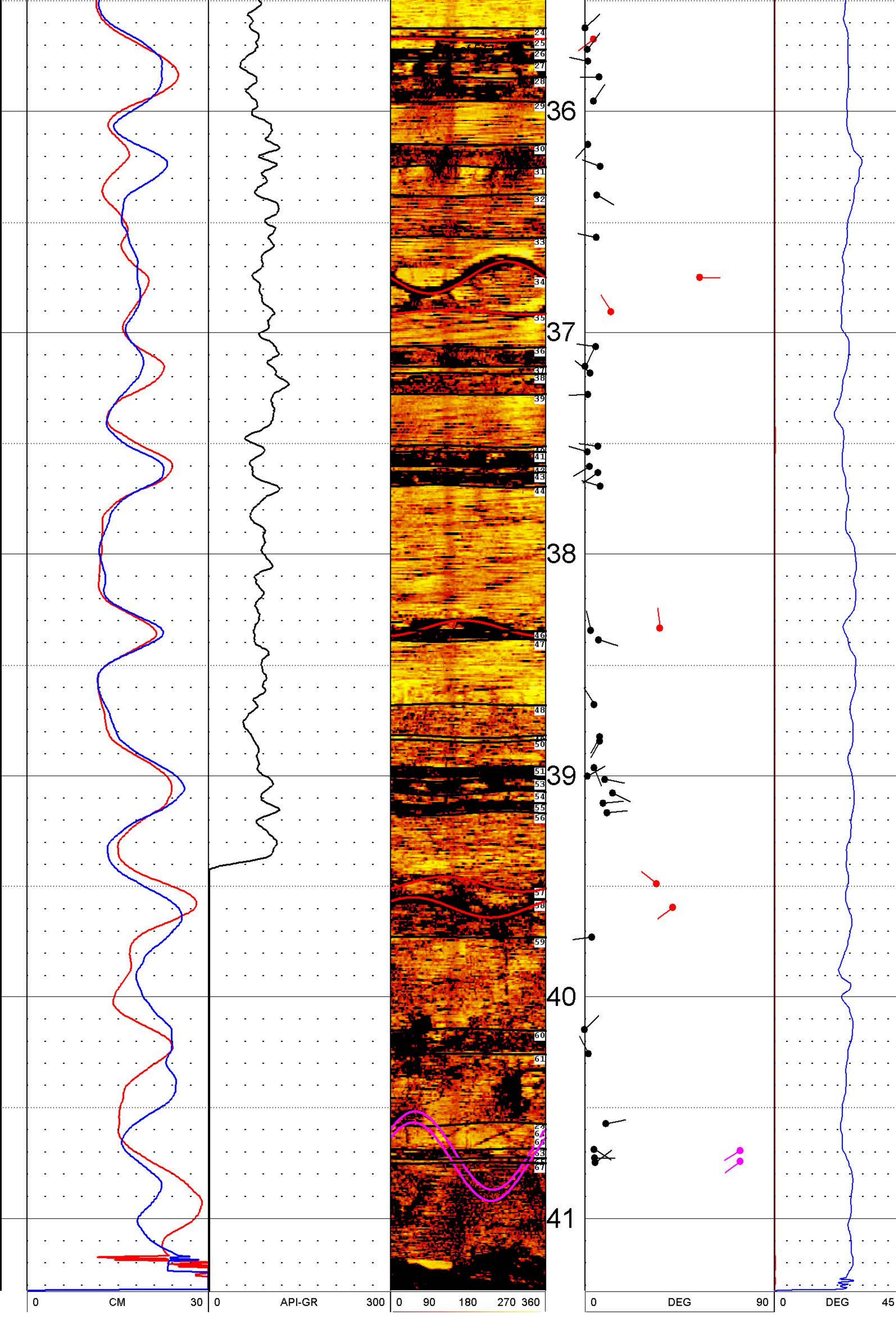
GROUNDSEARCH AUSTRALIA

BOREHOLE04 TOP ATV 1:20

COMPANY	: COFFEY GEOTECHNICS	OTHER SERVICES:	DEN ATV ON,TV	UTM-E	: N/A
WELL	: BOREHOLE04 TOP ATV 1:20			UTM-N	: N/A
LOCATION/FIELD	: LINGARD				
COUNTY	:				
LOCATION	: NEWCASTLE				
SECTION	: N/A	TOWNSHIP	: N/A	RANGE	: N/A
DATE	: 09/14/18	PERMANENT DATUM	:		
DEPTH DRILLER	: 101.6			KB	: N/A
LOG BOTTOM	: 41.320	LOG MEASURED FROM	: N/A	DF	: N/A
LOG TOP	: 30.000	DRL MEASURED FROM	: N/A	GL	: NA
CASING DIAMETER	: 10.	LOGGING UNIT	: T107		
CASING TYPE	: STEEL	FIELD OFFICE	: RUTHERFORD		
CASING THICKNESS	: .5	RECORDED BY	: P WOODWARD		
BIT SIZE	: 9.9	BOREHOLE FLUID	: 0	FILE	: PROCESSED
MAGNETIC DECL.	: 0	RM	: N/A	TYPE	: 9804A
MATRIX DENSITY	: 2.65	RM TEMPERATURE	: N/A	LGDATE	: 09/14/18
NEUTRON MATRIX	: SANDSTONE	MATRIX DELTA T	: 177	LGTIME	: 12:20
				THRESH	: 99999

ALL SERVICES PROVIDED SUBJECT TO STANDARD TERMS AND CONDITIONS


CALIPERY
0 CM 30
CALIPERX
0 CM 30
GAMMA
0 API-GR 300
200 AMPL..MV 1800
0 90 180 270 360
METERS
30
31
32
33
34
35
TADPOLE
0 DEG 90
SANGB
0 DEG 360
SANG
0 DEG 45
1
2
3
4
5
6
7
8
9
10
11
12
14
15
16
17
18
19
20
21
22
23


36
37
38
39
40
41
0 CM 30
0 API-GR 300
0 90 180 270 360
0 DEG 90
0 DEG 45

Coffey Geotechnics

Borehole BH04

ACOUSTIC TELEVIEWER
PETROPHYSICAL REPORT

Groundsearch Australia Pty. Limited

24 September 2018

DISCLAIMER

The data used in this report were obtained using equipment manufactured by the Century Geophysical Corporation. The interpretations given in this report are based on judgement and experience of Groundsearch Australia's personnel. They are provided for Coffey Geotechnics sole use in accordance with a specified brief. As such, the interpretation outcomes do not necessarily address all aspects of ground conditions and behaviour on the subject site. The responsibility of Groundsearch Australia is solely to Coffey Geotechnics and it is not intended that any third party rely upon this report. This report shall not be reproduced either wholly or in part without the written permission of Groundsearch Australia Pty. Limited.

For and on behalf of Groundsearch Australia Pty. Limited

John Lea BSc (Hons) FAusIMM
Principal Geologist
Managing Director

Executive summary

The data contained in this report were obtained from one 9.6 cm diameter, vertical, cored borehole that was drilled as a component of the 2018 geotechnical exploration programme for Coffey Geotechnics at Lingard Street Newcastle NSW.

Century Geophysical Corporation downhole 9804 acoustic televiewer and 9329 density tools were run to collect data in the field on 14 September 2018. This report is for data from 44.50 to 93.26 mbgl. The 9239 density tool was run inside steel casing and data were corrected for the steel. Therefore, there are no caliper or resistivity data.

The 212 identified features are interpreted as bedding, fractures, the SWL and a void at the base of the log. The bedding to fractures ratio is 6.8:1.

The Century Display program has automatically recalculated the dip angle data to represent the borehole in the vertical position and the dip direction data is referenced to magnetic north.

1.0 Background technical information

The data contained in this report were obtained from one 9.6 cm diameter, vertical, cored borehole that was drilled as a component of the 2018 geotechnical exploration programme for Coffey Geotechnics at Lingard Street Newcastle NSW.

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Subsequent processing and interpretation of data were carried out by Groundsearch.

The ATV takes an oriented image of the borehole using high-resolution sound waves. This acoustic image is displays amplitude variations. This information is used to detect bedding planes, fractures, and other borehole anomalies without the need to have clear fluid filling the boreholes. The tool works only in fluid-filled boreholes.

The televiewer digitises 256 measurements around the borehole at each high-resolution sample interval. These data can be oriented to North and displayed real-time while logging using the Visual Compu-Log System.

Analysis software includes colour adjustment, fracture dip and strike determination, and classification of features. It allows information to be displayed on the graphical screen, plot, and in report format.

2.0 Interpretation methodology

It should be noted that the ATV is a bowspring-type, centralised tool and is affected by poor wallrock conditions known as rugosity.

The ATV data interpretation procedure is based on the superposition of curves on feature logs directly onto the computer screen by using a subjective, manual; two-point definition of a feature’s top and base to produce a sine curve. The sides of the time and amplitude plots represent magnetic north and magnetic south is in the centre of each plot. The low side, or trough, of the sine curve defines the dip direction of the feature.

The logging program automatically records the televiewer tool slant angle and bearing and corrects for any borehole deviations. The curves are automatically given an identification number for subsequent referencing in a report file.

There are possibly more bedding planes and structural fractures appearing in the televiewer logs that have not been included in this report due to their poor graphic definition or the inability to resolve their geometry by superposing a sine curve using the program's two point method.

This report contains a;

- Text summary of the interpreted features
- Circular representation of interpreted features
- Logs that show geological features with their subjective, numbered interpretation curves shown at 1:20 scale. The logs are in standard format whereby the optical image of the borehole wall is "flattened" onto the plot. The logs have the following additional features to enhance geological interpretations of the strata;
    - Amplitude image differentials
    - Time image differentials that indicate higher strength zones in **GREEN** and lower strength zones in **RED**
    - Tadpoles that represent feature dip and dip direction
    - Open fractures in **RED**
    - Partially open fractures in **MAGENTA**
    - Discontinuous fractures in **DARK BLUE**
  - Natural gamma
  - Slant (dip angle)
  - Slant angle bearing
  - Long and short space density
- Table containing feature curve ID, top, base, dip angle, dip azimuth, feature description and the generalised rock type that hosts the feature
- Graphical representations of the interpreted features

3.0 Borehole BH04interpretation

The 212 identified features are interpreted as bedding, fractures, the SWL and a void at the base of the log. The bedding to fractures ratio is 6.8:1.

A description of each interpreted feature is presented in Table 1 and the log is presented in Appendix 1.

Table 1 Interpreted features report for BH04

FEATURE ID	DIP (DEG)	AZIMUTH (DEG)	MIDPOINT (MBGL)	TOP (M)	BASE (M)	TYPE OF FEATURE	GENERALISED ROCK TYPE
1			44.81	44.81	44.81	SWL	Overburden
2	2	288	46.31	46.30	46.31	Bedding plane	Overburden
3	5	214	46.42	46.41	46.42	Bedding plane	Overburden
4	3	315	47.58	47.58	47.58	Bedding plane	Overburden
5	4	306	47.80	47.79	47.80	Bedding plane	Overburden
6	7	278	47.93	47.92	47.94	Bedding plane	Overburden
7	9	293	48.00	48.00	48.01	Bedding plane	Overburden
8	9	293	48.09	48.08	48.09	Bedding plane	Overburden
9	2	267	48.62	48.62	48.63	Bedding plane	Overburden
10	7	155	49.07	49.07	49.08	Bedding plane	Overburden
11	3	284	51.99	51.99	51.99	Bedding plane	Overburden
12	3	278	52.10	52.09	52.10	Bedding plane	Overburden
13	60	117	52.10	52.01	52.18	Fracture plane - partially open	Overburden
14	64	122	52.17	52.07	52.26	Fracture plane - open	Overburden
15	5	340	52.32	52.31	52.32	Bedding plane	Overburden
16	7	278	52.48	52.48	52.49	Bedding plane	Overburden
17	11	70	52.65	52.64	52.66	Bedding plane	Overburden
18	11	51	52.97	52.97	52.98	Bedding plane	Overburden
19	3	299	53.02	53.02	53.03	Bedding plane	Overburden
20	1	95	53.30	53.30	53.30	Bedding plane	Overburden
21	14	72	53.39	53.38	53.40	Bedding plane	Overburden
22	8	113	53.44	53.43	53.45	Bedding plane	Overburden
23	7	291	53.51	53.50	53.51	Bedding plane	Overburden
24	61	238	53.65	53.56	53.75	Fracture plane - partially open	Overburden
25	2	214	53.76	53.75	53.76	Bedding plane	Overburden
26	2	321	53.87	53.87	53.87	Bedding plane	Overburden
27	4	245	53.90	53.90	53.91	Bedding plane	Overburden
28	2	330	54.21	54.21	54.22	Bedding plane	Overburden
29	4	90	54.41	54.41	54.42	Bedding plane	Overburden
30	4	256	54.56	54.55	54.56	Bedding plane	Overburden
31	4	268	54.60	54.60	54.61	Bedding plane	Overburden
32	1	296	54.71	54.71	54.71	Bedding plane	Overburden
33	3	299	54.74	54.74	54.75	Bedding plane	Overburden
34	5	249	54.80	54.80	54.81	Bedding plane	Overburden
35	1	70	54.89	54.89	54.89	Bedding plane	Overburden
36	7	327	54.96	54.96	54.97	Bedding plane	Overburden
37	2	276	55.07	55.07	55.08	Bedding plane	Overburden
38	3	272	55.20	55.20	55.20	Bedding plane	Overburden

39	9	42	55.30	55.29	55.30	Bedding plane	Overburden
40	6	277	56.12	56.11	56.12	Bedding plane	Overburden
41	2	312	56.33	56.33	56.33	Bedding plane	Overburden
42	2	123	56.43	56.42	56.43	Bedding plane	Overburden
43	55	270	56.53	56.46	56.60	Fracture plane - partially open	Overburden
44	1	185	56.69	56.69	56.69	Bedding plane	Overburden
45	2	62	56.89	56.89	56.89	Bedding plane	Overburden
46	4	258	57.19	57.19	57.20	Bedding plane	Overburden
47	7	275	57.33	57.33	57.34	Bedding plane	Overburden
48	13	312	57.91	57.90	57.92	Bedding plane	Overburden
49	8	333	58.00	57.99	58.01	Bedding plane	Overburden
50	6	91	58.13	58.13	58.14	Bedding plane	Overburden
51	3	335	58.49	58.49	58.49	Bedding plane	Overburden
52	6	219	58.59	58.58	58.59	Bedding plane	Overburden
53	3	304	58.78	58.78	58.78	Bedding plane	Overburden
54	4	259	58.84	58.84	58.84	Bedding plane	Overburden
55	3	275	58.99	58.99	58.99	Bedding plane	Overburden
56	4	293	59.01	59.01	59.01	Bedding plane	Overburden
57	7	233	59.11	59.11	59.12	Bedding plane	Overburden
58	4	239	59.17	59.16	59.17	Bedding plane	Overburden
59	3	285	59.28	59.28	59.28	Bedding plane	Overburden
60	9	231	59.60	59.59	59.60	Bedding plane	Overburden
61	7	238	59.95	59.94	59.96	Bedding plane	Overburden
62	3	82	60.05	60.05	60.06	Bedding plane	Overburden
63	4	259	60.22	60.21	60.22	Bedding plane	Overburden
64	1	306	60.44	60.44	60.44	Bedding plane	Overburden
65	20	114	60.49	60.48	60.51	Bedding plane	Overburden
66	18	112	60.52	60.51	60.54	Bedding plane	Overburden
67	1	246	60.64	60.64	60.65	Bedding plane	Overburden
68	2	332	60.77	60.77	60.77	Bedding plane	Overburden
69	8	16	60.93	60.93	60.94	Bedding plane	Overburden
70	7	280	61.65	61.64	61.65	Bedding plane	Overburden
71	2	303	61.78	61.77	61.78	Bedding plane	Overburden
72	1	74	62.84	62.84	62.84	Bedding plane	Overburden
73	5	203	63.00	62.99	63.00	Bedding plane	Overburden
74	4	172	63.14	63.13	63.14	Bedding plane	Overburden
75	4	225	63.19	63.19	63.20	Bedding plane	Overburden
76	8	210	63.23	63.22	63.24	Bedding plane	Overburden
77	11	304	63.54	63.53	63.55	Bedding plane	Overburden
78	11	299	63.57	63.56	63.58	Bedding plane	Overburden
79	75	324	63.60	63.41	63.80	Fracture plane - partially open	Overburden
80	13	231	64.37	64.36	64.38	Bedding plane	Overburden
81	64	259	67.21	67.11	67.31	Fracture plane - partially open	Overburden
82	1	195	68.70	68.70	68.70	Bedding plane	Overburden
83	7	234	69.05	69.04	69.06	Bedding plane	Overburden
84	54	254	69.56	69.50	69.63	Fracture plane - partially open	Overburden
85	66	230	69.82	69.70	69.93	Fracture plane - partially open	Overburden
86	67	233	69.86	69.74	69.98	Fracture plane - partially open	Overburden
87	7	262	70.12	70.11	70.12	Bedding plane	Overburden
88	3	323	70.20	70.20	70.20	Bedding plane	Overburden

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89	72	233	70.30	70.15	70.46	Fracture plane - open	Overburden
90	68	243	70.40	70.27	70.53	Fracture plane - partially open	Overburden
91	71	232	70.45	70.30	70.60	Fracture plane - partially open	Overburden
92	5	256	70.70	70.70	70.70	Bedding plane	Overburden
93	5	268	70.85	70.84	70.85	Bedding plane	Overburden
94	4	322	70.87	70.87	70.87	Bedding plane	Overburden
95	7	281	70.94	70.93	70.94	Bedding plane	Overburden
96	70	36	70.95	70.82	71.08	Fracture plane - discontinuous	Overburden
97	2	304	71.03	71.02	71.03	Bedding plane	Overburden
98	2	282	71.07	71.07	71.07	Bedding plane	Overburden
99	68	240	71.08	70.95	71.20	Fracture plane - partially open	Overburden
100	1	86	71.46	71.46	71.46	Bedding plane	Overburden
101	60	243	71.63	71.54	71.72	Fracture plane - discontinuous	Overburden
102	1	77	71.65	71.65	71.65	Bedding plane	Overburden
103	1	269	71.74	71.74	71.74	Bedding plane	Overburden
104	5	340	71.83	71.83	71.84	Bedding plane	Overburden
105	5	235	71.86	71.86	71.87	Bedding plane	Overburden
106	1	320	71.91	71.91	71.91	Bedding plane	Overburden
107	20	259	72.00	71.99	72.02	Fracture plane - open	Overburden
108	4	274	72.03	72.03	72.04	Bedding plane	Overburden
109	3	315	72.15	72.15	72.15	Bedding plane	Overburden
110	2	336	72.29	72.29	72.29	Bedding plane	Overburden
111	3	265	72.47	72.46	72.47	Bedding plane	Overburden
112	1	71	72.52	72.52	72.52	Bedding plane	Overburden
113	1	357	72.56	72.56	72.56	Bedding plane	Overburden
114	78	243	74.08	73.83	74.33	Fracture plane - partially open	Overburden
115	5	300	74.25	74.25	74.25	Bedding plane	Overburden
116	30	211	74.36	74.33	74.38	Fracture plane - partially open	Overburden
117	67	252	74.38	74.26	74.50	Fracture plane - open	Overburden
118	35	221	74.39	74.35	74.42	Fracture plane - open	Overburden
119	54	250	74.58	74.50	74.65	Fracture plane - partially open	Overburden
120	5	248	74.60	74.60	74.61	Bedding plane	Overburden
121	3	274	74.62	74.62	74.62	Bedding plane	Overburden
122	15	314	74.67	74.66	74.68	Bedding plane	Overburden
123	6	82	74.98	74.97	74.98	Bedding plane	Overburden
124	7	303	75.06	75.06	75.07	Bedding plane	Overburden
125	4	265	75.75	75.75	75.76	Bedding plane	Overburden
126	5	280	76.04	76.03	76.04	Bedding plane	Overburden
127	5	52	76.13	76.12	76.13	Bedding plane	Overburden
128	5	236	76.25	76.25	76.26	Bedding plane	Overburden
129	8	318	77.14	77.13	77.15	Bedding plane	Overburden
130	2	297	77.17	77.17	77.17	Bedding plane	Overburden
131	4	260	78.06	78.06	78.06	Bedding plane	Overburden
132	12	137	78.11	78.10	78.12	Fracture plane - open	Overburden
133	1	165	78.67	78.67	78.67	Bedding plane	Overburden
134	3	190	78.72	78.71	78.72	Bedding plane	Overburden
135	9	122	79.31	79.30	79.32	Bedding plane	Overburden
136	6	239	79.69	79.69	79.70	Bedding plane	Overburden
137	6	232	79.93	79.92	79.93	Bedding plane	Overburden

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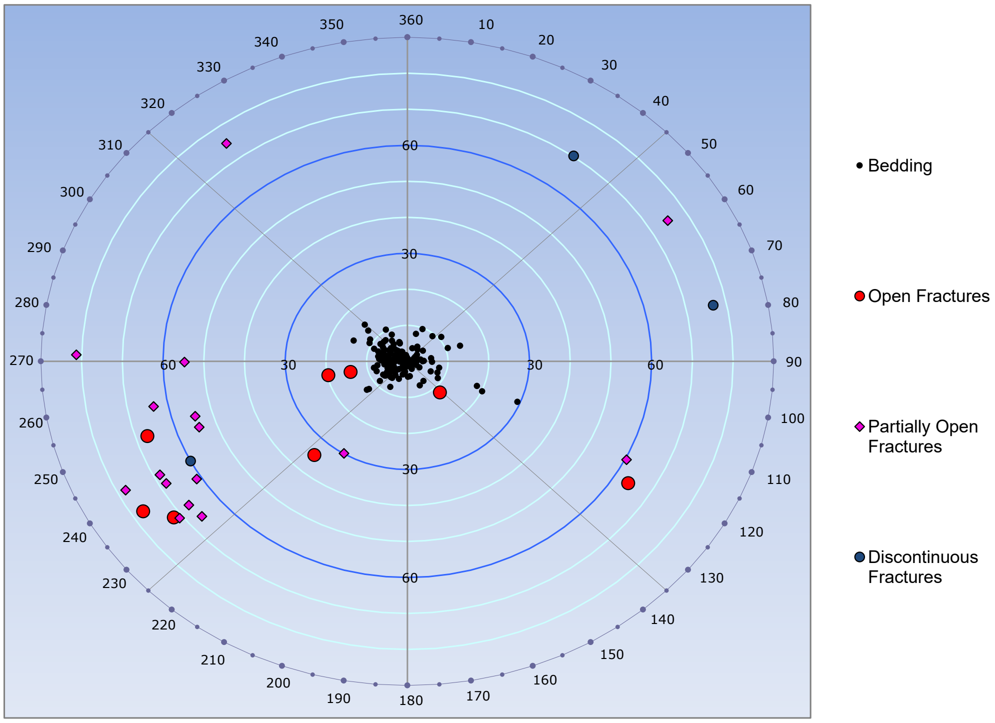
138	3	193	81.79	81.79	81.79	Bedding plane	Overburden
139	4	266	81.93	81.93	81.94	Bedding plane	Overburden
140	8	257	82.02	82.02	82.03	Bedding plane	Overburden
141	5	217	82.06	82.05	82.06	Bedding plane	Overburden
142	14	294	82.17	82.16	82.19	Bedding plane	Overburden
143	12	231	82.22	82.21	82.23	Bedding plane	Overburden
144	10	23	82.31	82.30	82.31	Bedding plane	Overburden
145	8	291	83.61	83.60	83.61	Bedding plane	Overburden
146	2	286	83.79	83.78	83.79	Bedding plane	Overburden
147	4	318	83.84	83.84	83.85	Bedding plane	Overburden
148	6	340	84.14	84.13	84.14	Bedding plane	Overburden
149	0	253	84.30	84.30	84.30	Bedding plane	Overburden
150	3	83	84.37	84.37	84.37	Bedding plane	Overburden
151	3	301	84.48	84.48	84.49	Bedding plane	Overburden
152	1	103	84.55	84.55	84.55	Bedding plane	Overburden
153	14	258	84.90	84.89	84.92	Fracture plane - open	Overburden
154	3	120	85.03	85.03	85.03	Bedding plane	Overburden
155	2	114	85.12	85.12	85.12	Bedding plane	Overburden
156	2	280	85.20	85.20	85.20	Bedding plane	Overburden
157	1	242	85.49	85.49	85.49	Bedding plane	Overburden
158	77	78	85.53	85.31	85.74	Fracture plane - discontinuous	Overburden
159	5	285	85.89	85.89	85.90	Bedding plane	Overburden
160	6	223	86.02	86.02	86.03	Bedding plane	Overburden
161	1	102	86.13	86.13	86.13	Bedding plane	Overburden
162	2	152	86.20	86.20	86.20	Bedding plane	Overburden
163	2	216	86.32	86.32	86.33	Bedding plane	Overburden
164	2	58	86.35	86.34	86.35	Bedding plane	Overburden
165	75	59	86.43	86.23	86.62	Fracture plane - partially open	Overburden
166	4	274	86.47	86.46	86.47	Bedding plane	Overburden
167	5	283	86.49	86.49	86.50	Bedding plane	Overburden
168	3	53	86.58	86.57	86.58	Bedding plane	Overburden
169	1	267	86.60	86.60	86.60	Bedding plane	Overburden
170	4	88	86.73	86.73	86.73	Bedding plane	Overburden
171	4	178	87.06	87.06	87.07	Bedding plane	Overburden
172	4	233	87.25	87.25	87.25	Bedding plane	Overburden
173	4	298	87.49	87.49	87.49	Bedding plane	Overburden
174	1	269	87.62	87.62	87.62	Bedding plane	Overburden
175	8	103	87.98	87.97	87.98	Bedding plane	Overburden
176	5	305	88.04	88.04	88.05	Bedding plane	Overburden
177	8	306	88.14	88.14	88.15	Bedding plane	Overburden
178	8	250	88.28	88.27	88.28	Bedding plane	Overburden
179	7	278	88.55	88.55	88.56	Bedding plane	Overburden
180	3	223	88.81	88.81	88.81	Bedding plane	Overburden
181	3	224	88.84	88.84	88.84	Bedding plane	Overburden
182	4	37	88.94	88.93	88.94	Bedding plane	Overburden
183	7	144	88.97	88.96	88.97	Bedding plane	Overburden
184	5	304	89.10	89.10	89.11	Bedding plane	Overburden
185	5	274	89.18	89.18	89.18	Bedding plane	Overburden
186	8	313	89.31	89.31	89.32	Bedding plane	Overburden

187	6	272	89.37	89.36	89.37	Bedding plane	Overburden
188	2	153	89.46	89.46	89.46	Bedding plane	Overburden
189	81	271	89.75	89.46	90.04	Fracture plane - partially open	Overburden
190	77	237	89.95	89.75	90.15	Fracture plane - open	Overburden
191	6	116	90.08	90.07	90.08	Bedding plane	Overburden
192	2	282	90.16	90.16	90.16	Bedding plane	Overburden
193	5	251	90.19	90.19	90.20	Bedding plane	Overburden
194	5	296	90.40	90.39	90.40	Bedding plane	Overburden
195	6	325	90.41	90.41	90.42	Bedding plane	Overburden
196	5	290	90.52	90.52	90.53	Bedding plane	Overburden
197	3	276	90.55	90.55	90.55	Bedding plane	Overburden
198	6	291	90.60	90.59	90.60	Bedding plane	Overburden
199	5	237	90.67	90.67	90.67	Bedding plane	Overburden
200	29	113	90.77	90.74	90.81	Bedding plane	Overburden
201	6	300	90.95	90.95	90.96	Bedding plane	Overburden
202	4	197	91.07	91.07	91.08	Bedding plane	Overburden
203	6	262	91.10	91.10	91.11	Bedding plane	Overburden
204	5	312	91.33	91.33	91.34	Bedding plane	Overburden
205	4	19	91.37	91.37	91.37	Bedding plane	Overburden
206	3	333	91.39	91.39	91.39	Bedding plane	Overburden
207	2	99	91.55	91.55	91.55	Bedding plane	Overburden
208	2	350	91.74	91.74	91.75	Bedding plane	Overburden
209	1	43	91.85	91.85	91.85	Bedding plane	Overburden
210	5	31	91.93	91.92	91.93	Bedding plane	Overburden
211	10	329	91.99	91.98	92.00	Bedding plane	Overburden
212	4	114	92.18	92.18	92.19	Top of void	VOID
FEATURE ID	**DIP (DEG)**	**AZIMUTH (DEG)**	**MIDPOINT (MBGL)**	**TOP (M)**	**BASE (M)**	**TYPE OF FEATURE**	**GENERALISED ROCK TYPE**

Figure 1 BH04 circular plan representation of interpreted features



The 183 identified sedimentary features are predominantly bedding planes that appear to range in dip from flat-lying to 29^0. Figures 2 and 3 show the distribution of the planes' dip angles and dip direction with depth.

Table 2 details the variation in the dip angle and dip direction data. Figure 4 shows the dip direction data in a rose diagram with the bedding planes' dip angle and dip direction data shown as histograms in Figures 5 and 6.

The 27 fractures are identified as open (30%), partially open (59%) and discontinuous (11%). The fracture dip angles range from 12 to 81^0.

Table 3 details the variation in the fractures' dip angle and dip direction data. Figure 7 shows the dip direction data in a rose diagram with the fractures' plane dip angle and dip direction data as histograms in Figures 8 and 9.

Figure 2 BH04 feature dip angle data distribution

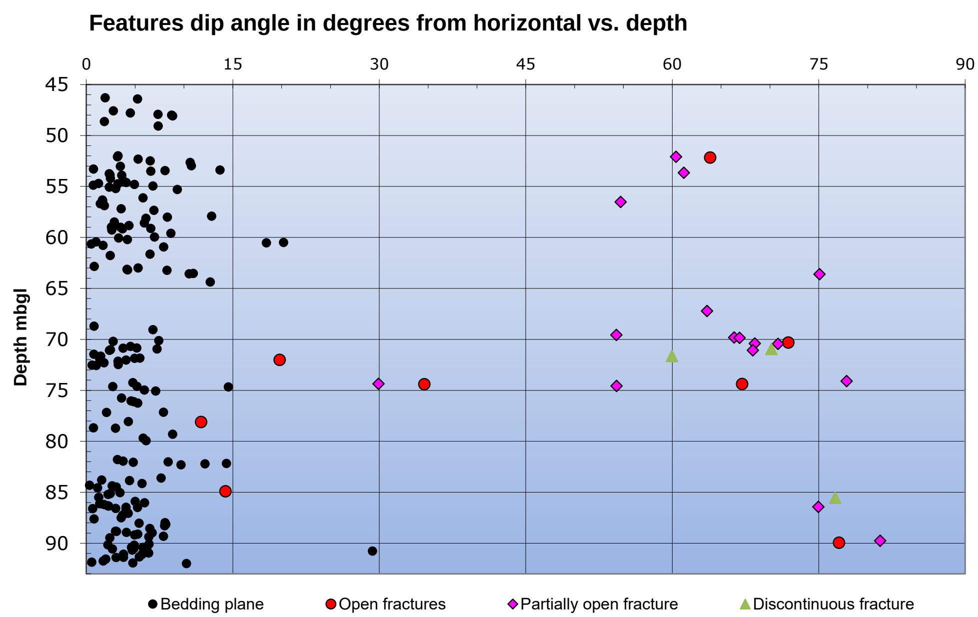


Figure 3 BH04 feature dip direction data distribution

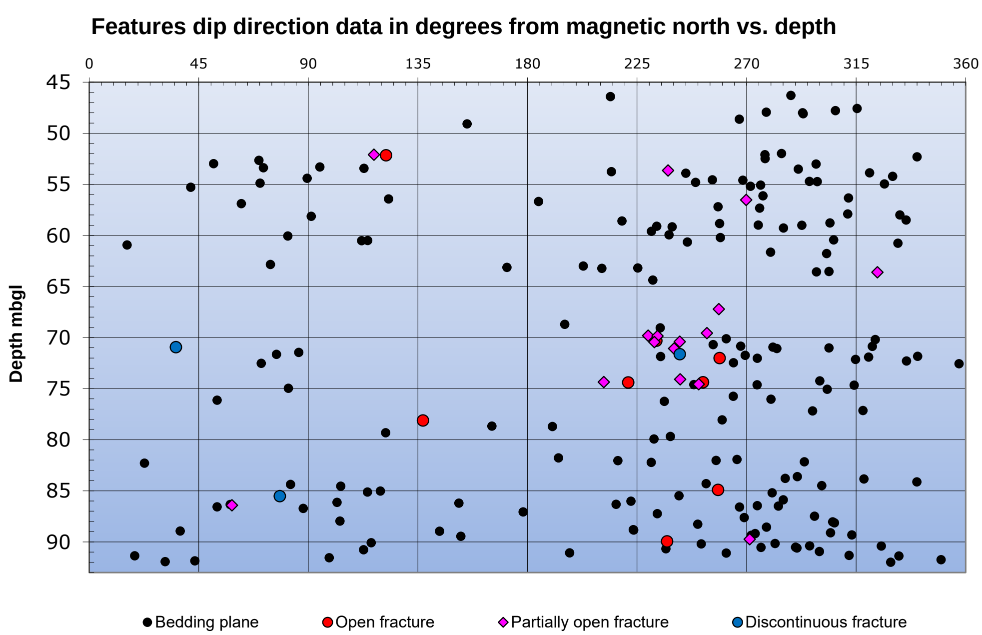


Table 2 BH04 bedding histogram data

Dip Distribution Total: 183			Orientation Distribution Total: 183		
Dip Range	Count	%	Bearing Range	Count	%
0 to 10	169	92.3	0 to 10	0	0.0
10 to 20	12	6.6	10 to 20	2	1.1
20 to 30	2	1.1	20 to 30	1	0.5
30 to 40	0	0.0	30 to 40	2	1.1
40 to 50	0	0.0	40 to 50	2	1.1
50 to 60	0	0.0	50 to 60	4	2.2
60 to 70	0	0.0	60 to 70	2	1.1
70 to 80	0	0.0	70 to 80	5	2.7
80 to 90	0	0.0	80 to 90	6	3.3
			90 to 100	3	1.6
			100 to 110	3	1.6
			110 to 120	7	3.8
			120 to 130	2	1.1
			130 to 140	0	0.0
			140 to 150	1	0.5
			150 to 160	3	1.6
			160 to 170	1	0.5
			170 to 180	2	1.1
			180 to 190	1	0.5
			190 to 200	4	2.2
			200 to 210	1	0.5
			210 to 220	6	3.3
			220 to 230	4	2.2
			230 to 240	13	7.1
			240 to 250	6	3.3
			250 to 260	9	4.9
			260 to 270	11	6.0
			270 to 280	16	8.7
			280 to 290	11	6.0
			290 to 300	16	8.7
			300 to 310	12	6.6
			310 to 320	9	4.9
			320 to 330	8	4.4
			330 to 340	6	3.3
			340 to 350	3	1.6
			350 to 360	1	0.5

Figure 5 BH04 bedding dip angles histogram

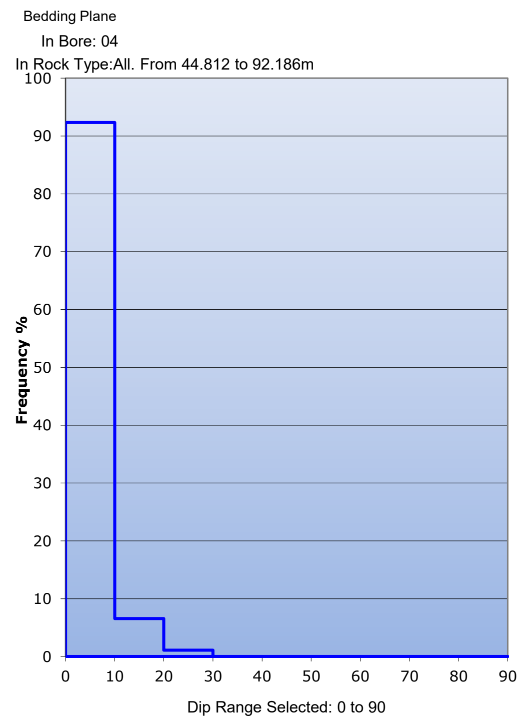


Figure 4 BH04 bedding dip direction data rose diagram

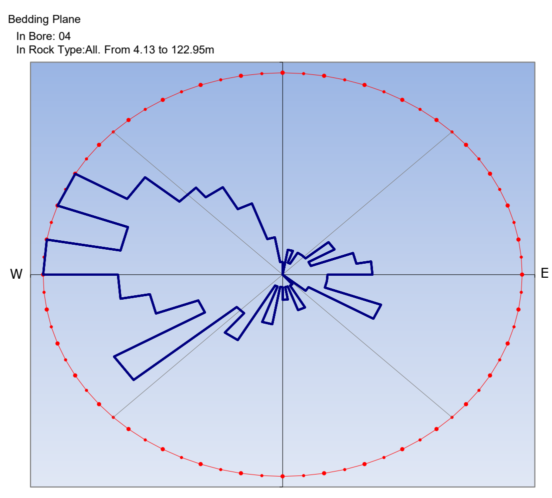


Figure 6 BH04 bedding dip directions histogram

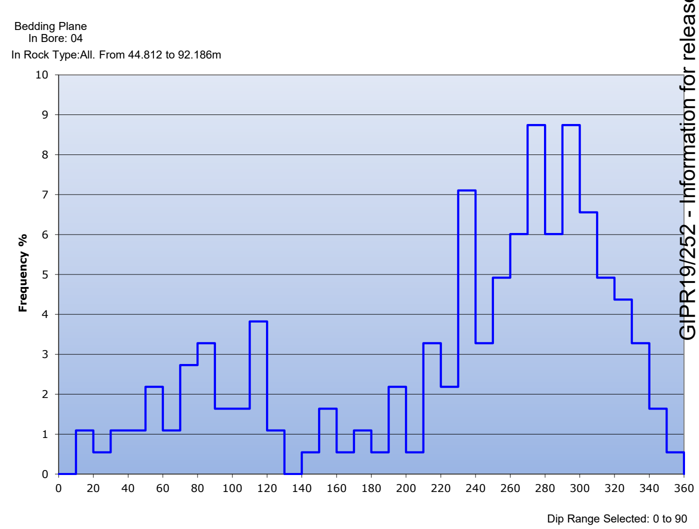


Table 3 BH04 fractures histogram data

Dip Distribution			Orientation Distribution		
	Total: 27			Total: 27	
Dip Range	Count	%	Bearing Range	Count	%
0 to 10	0	0.0	0 to 10	0	0.0
10 to 20	3	11.1	10 to 20	0	0.0
20 to 30	1	3.7	20 to 30	0	0.0
30 to 40	1	3.7	30 to 40	1	3.7
40 to 50	0	0.0	40 to 50	0	0.0
50 to 60	4	14.8	50 to 60	1	3.7
60 to 70	9	33.3	60 to 70	0	0.0
70 to 80	8	29.6	70 to 80	1	3.7
80 to 90	1	3.7	80 to 90	0	0.0
			90 to 100	0	0.0
			100 to 110	0	0.0
			110 to 120	1	3.7
			120 to 130	1	3.7
			130 to 140	1	3.7
			140 to 150	0	0.0
			150 to 160	0	0.0
			160 to 170	0	0.0
			170 to 180	0	0.0
			180 to 190	0	0.0
			190 to 200	0	0.0
			200 to 210	0	0.0
			210 to 220	1	3.7
			220 to 230	2	7.4
			230 to 240	5	18.5
			240 to 250	4	14.8
			250 to 260	6	22.2
			260 to 270	1	3.7
			270 to 280	1	3.7
			280 to 290	0	0.0
			290 to 300	0	0.0
			300 to 310	0	0.0
			310 to 320	0	0.0
			320 to 330	1	3.7
			330 to 340	0	0.0
			340 to 350	0	0.0
			350 to 360	0	0.0

Figure 8 BH04 fractures dip angles histogram

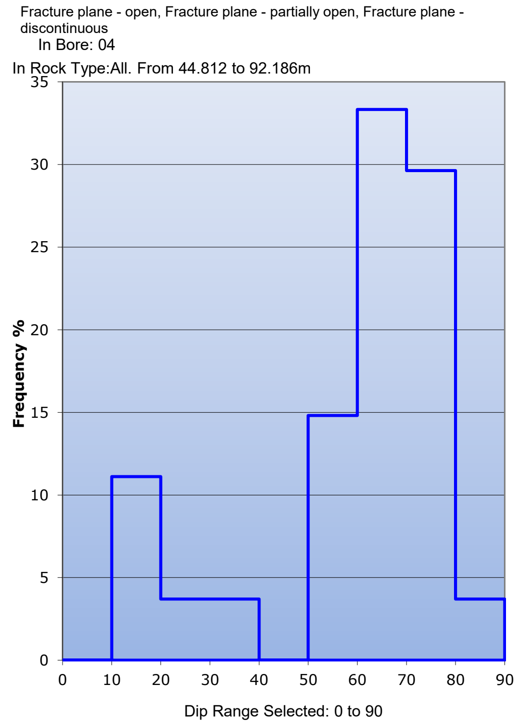


Figure 7 BH04 fractures dip direction data rose diagram

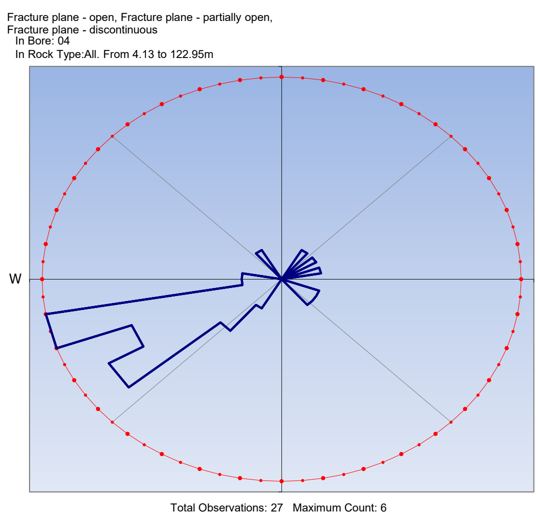
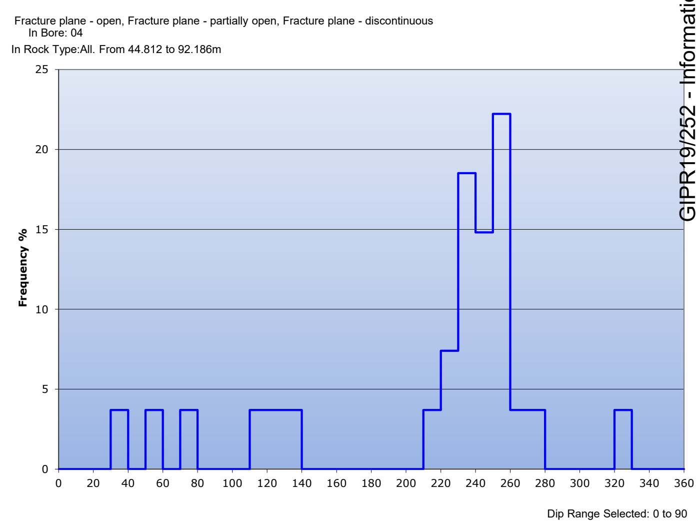


Figure 9 BH04 fractures dip directions histogram



Appendix 1

Appendix 1 *1:20 Interpretation logs – 44.50 to 93.26 mbgl*

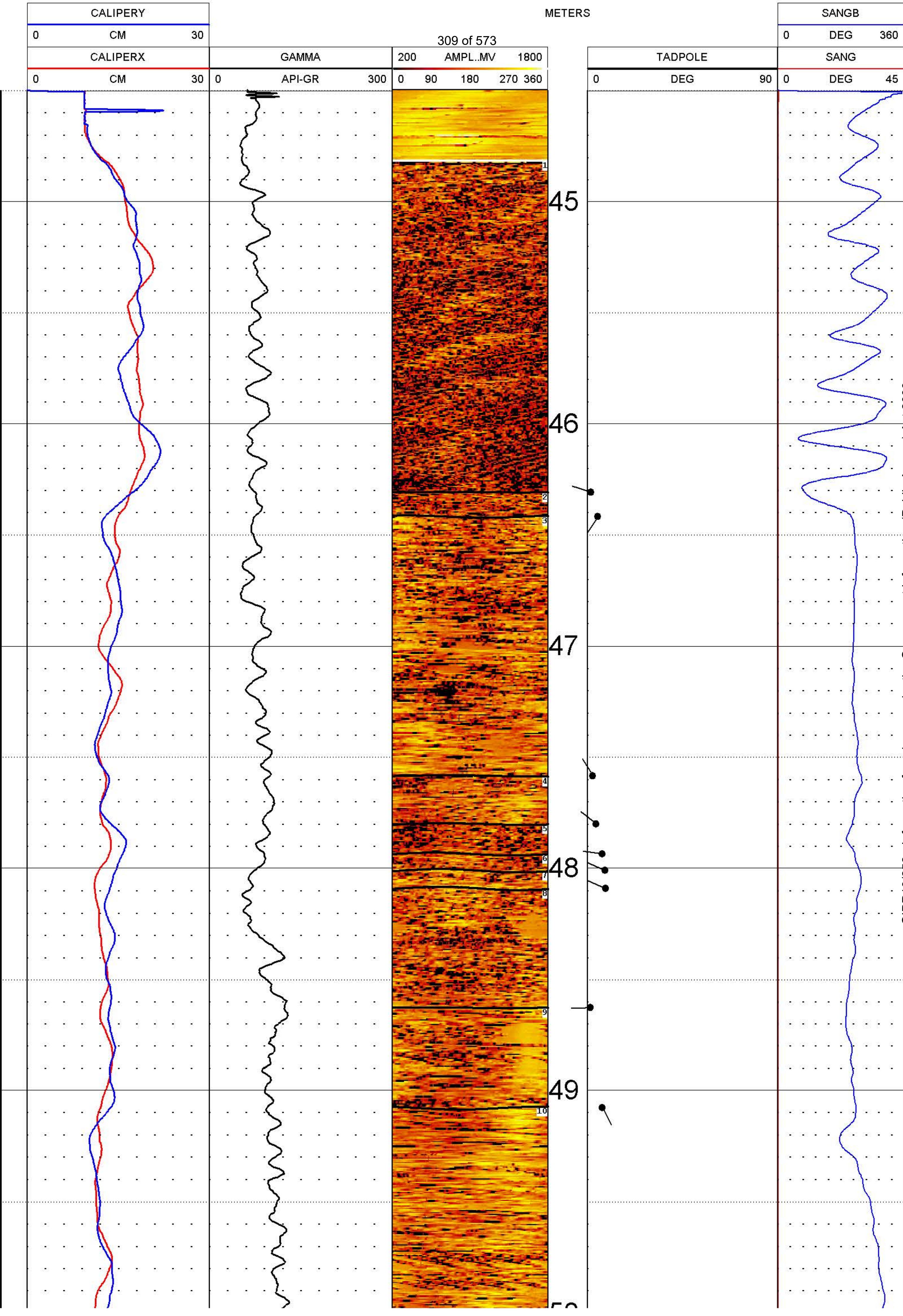
GROUNDSEARCH AUSTRALIA

BH04 ATV 1:20

COMPANY	: COFFEY GEOTECHNICS	OTHER SERVICES:		UTM-E	: N/A
WELL	: BH04 ATV 1:20	DEN ATV		UTM-N	: N/A
LOCATION/FIELD	: LINGARD	ON,TV			
COUNTY	:	ne			
LOCATION	: NEWCASTLE				
SECTION	: N/A	TOWNSHIP	: N/A	RANGE	: N/A
DATE	: 09/14/18	PERMANENT DATUM	:		
DEPTH DRILLER	: 101.6			KB	: N/A
LOG BOTTOM	: 93.260	LOG MEASURED FROM:	N/A	DF	: N/A
LOG TOP	: 44.500	DRL MEASURED FROM:	N/A	GL	: NA
CASING DIAMETER	: 10.	LOGGING UNIT	: T107		
CASING TYPE	: STEEL	FIELD OFFICE	: RUTHERFORD		
CASING THICKNESS:	.5	RECORDED BY	: P WOODWARD		
BIT SIZE	: 9.9	BOREHOLE FLUID	: 0	FILE	: PROCESSED
MAGNETIC DECL.	: 0	RM	: N/A	TYPE	: 9804A
MATRIX DENSITY	: 2.65	RM TEMPERATURE	: N/A	LGDATE	: 09/14/18
NEUTRON MATRIX	: SANDSTONE	MATRIX DELTA T	: 177	LGTIME	: 08:50
				THRESH:	99999

NE, 743'FNL, 661'FEL

ALL SERVICES PROVIDED SUBJECT TO STANDARD TERMS AND CONDITIONS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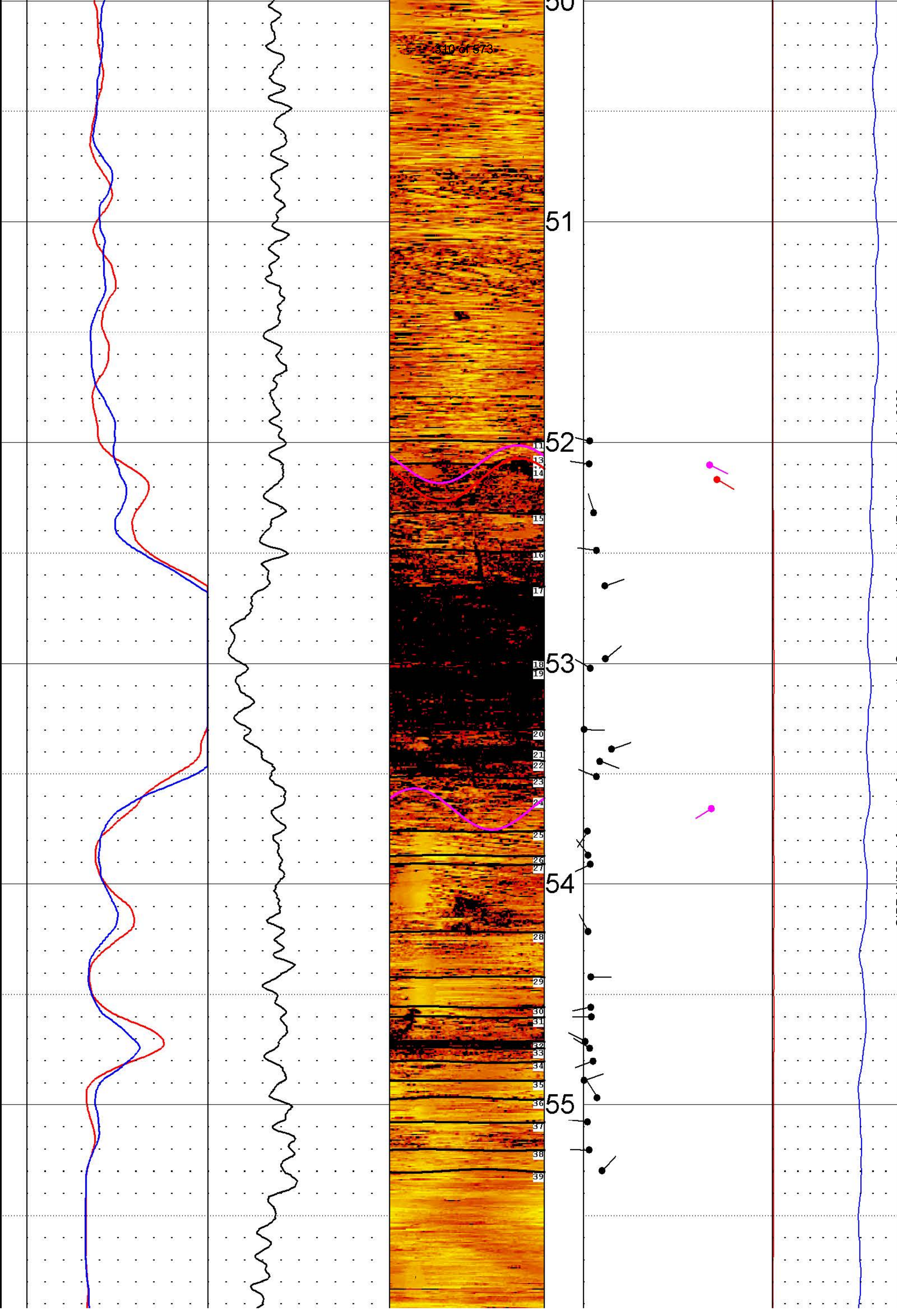
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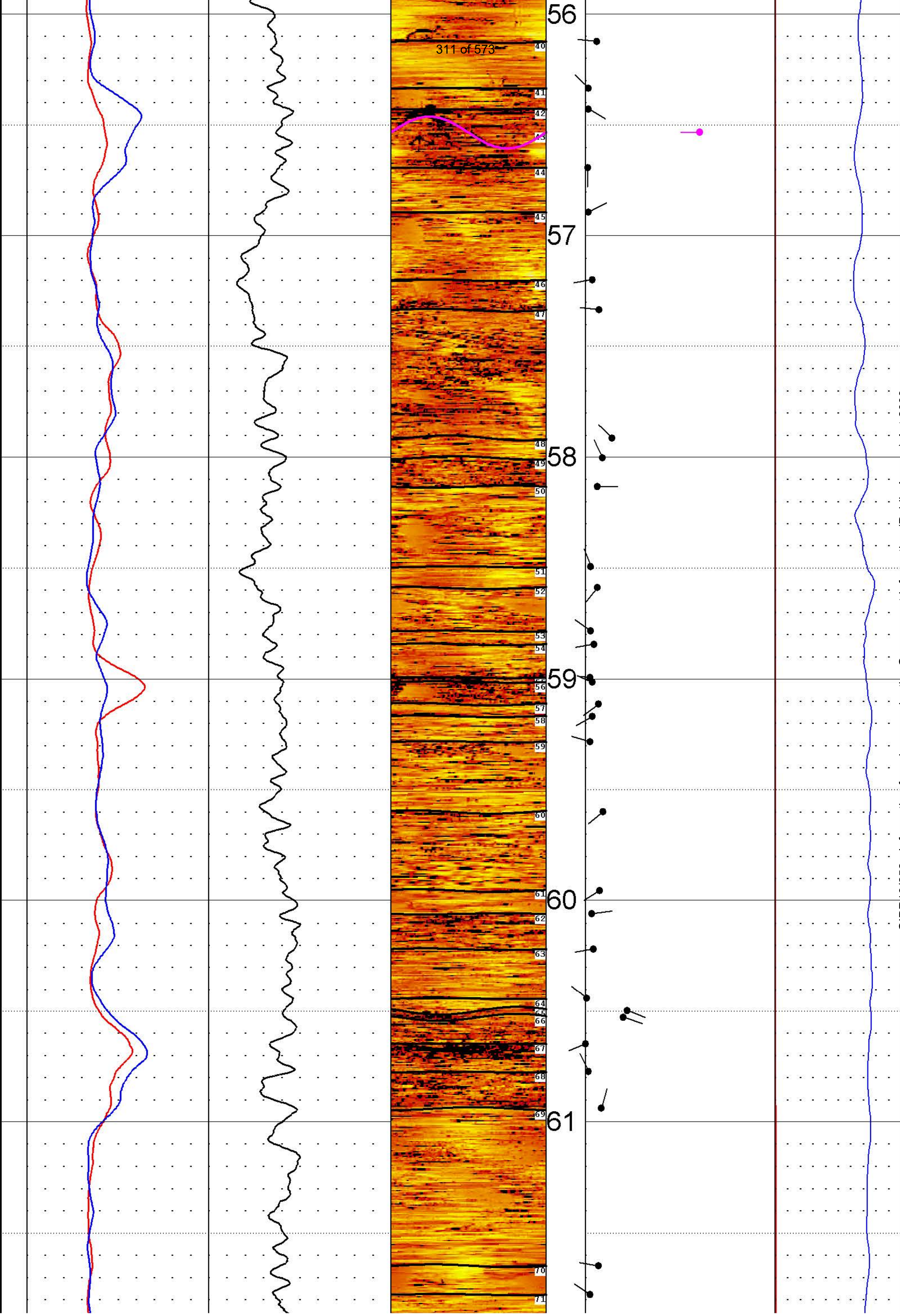
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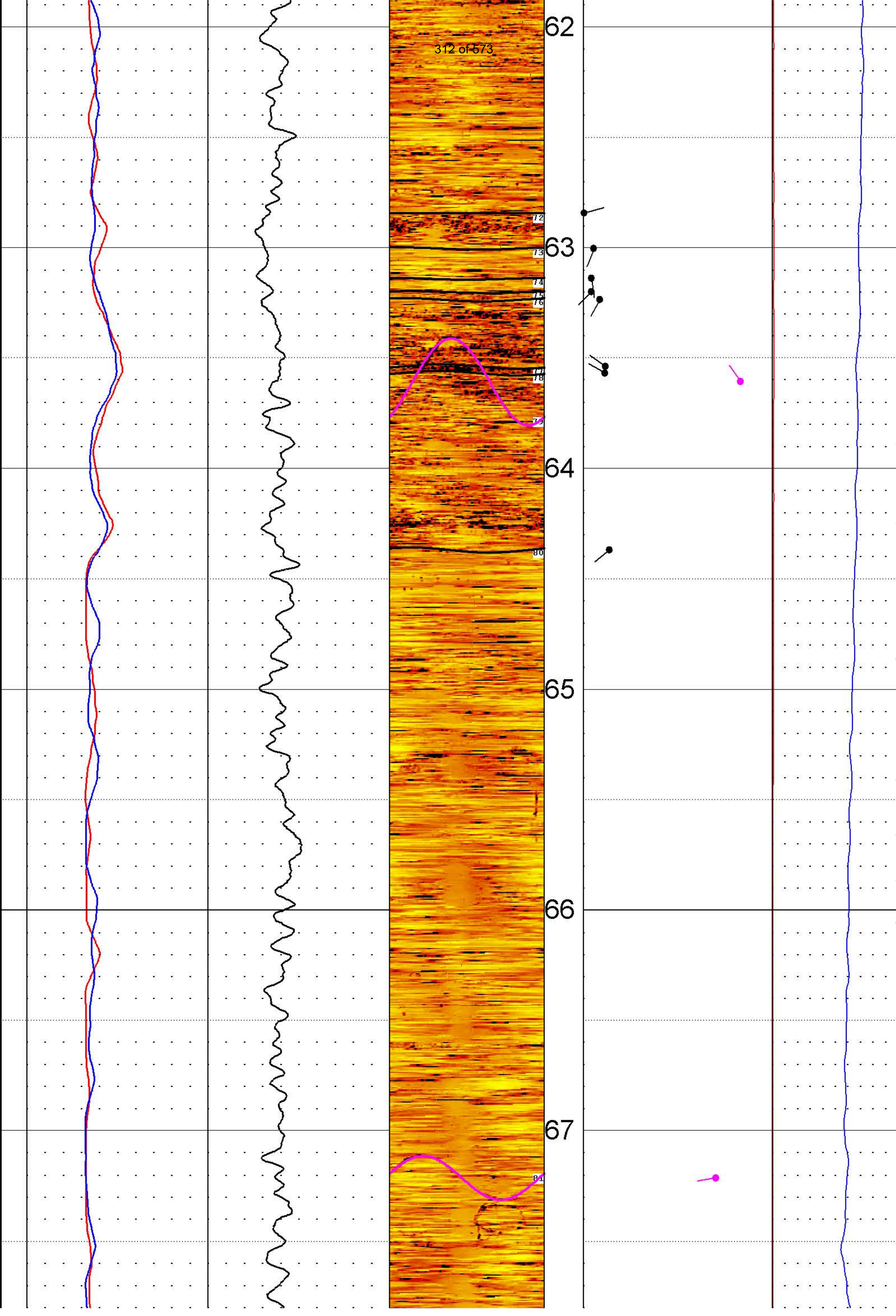
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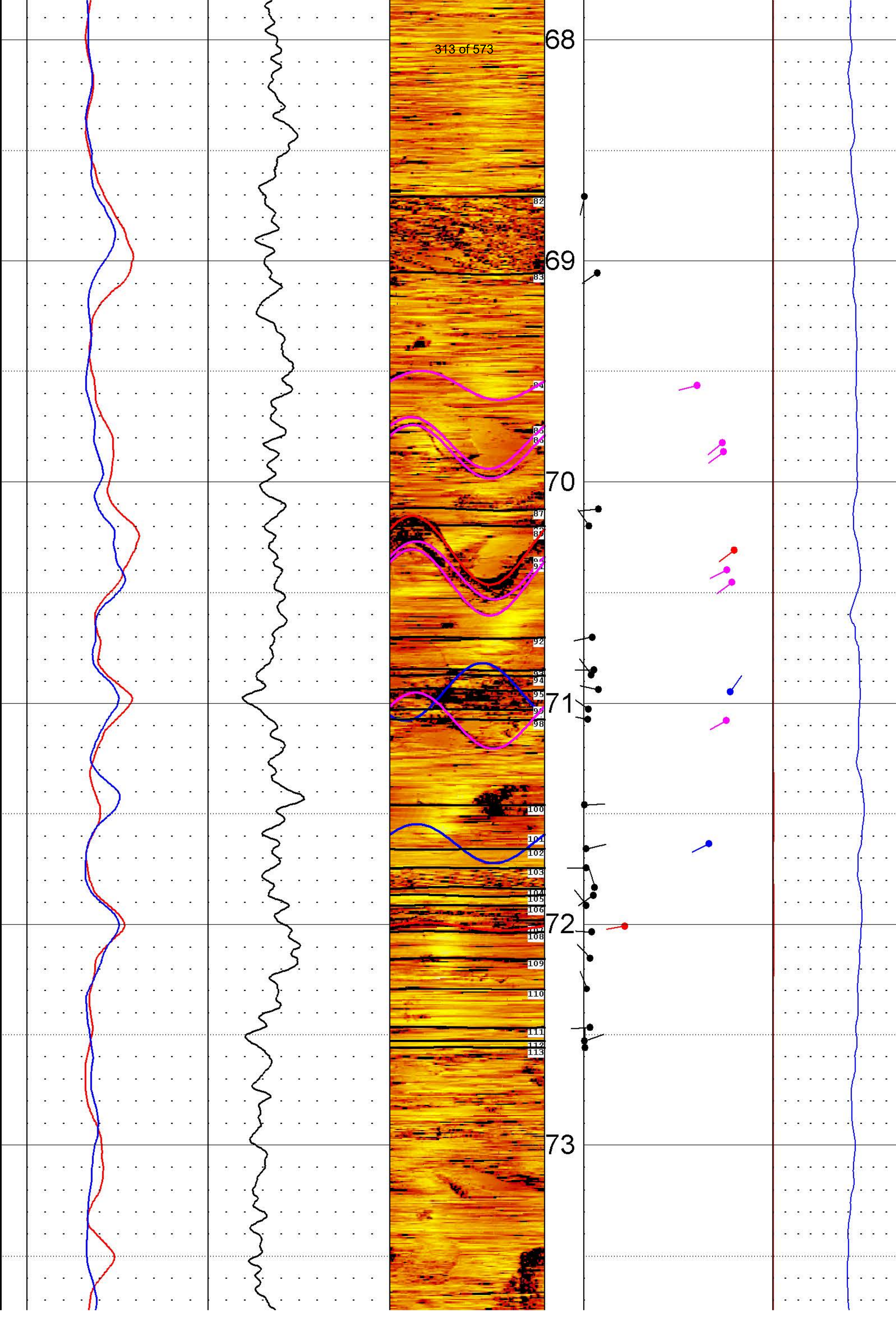
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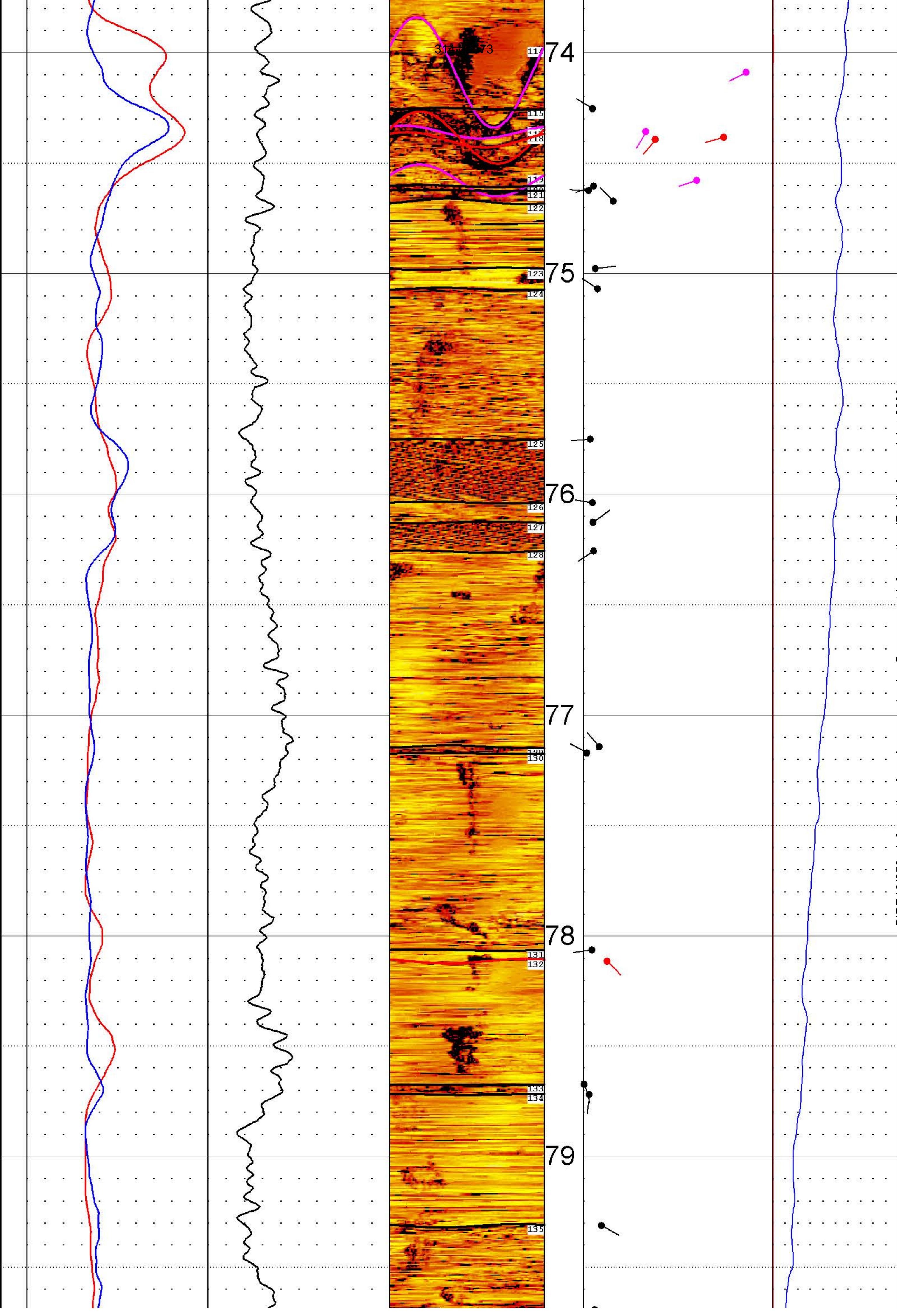
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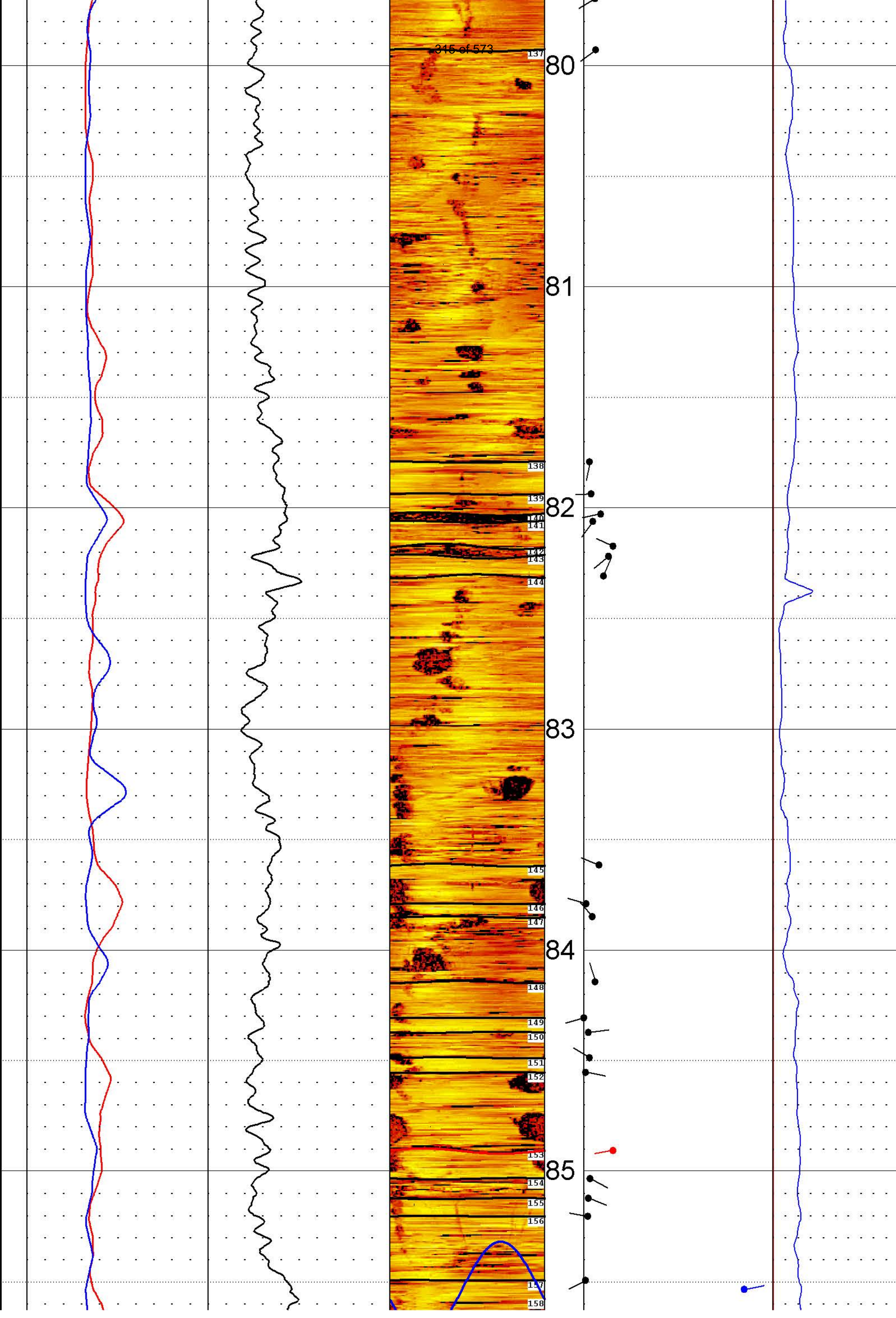
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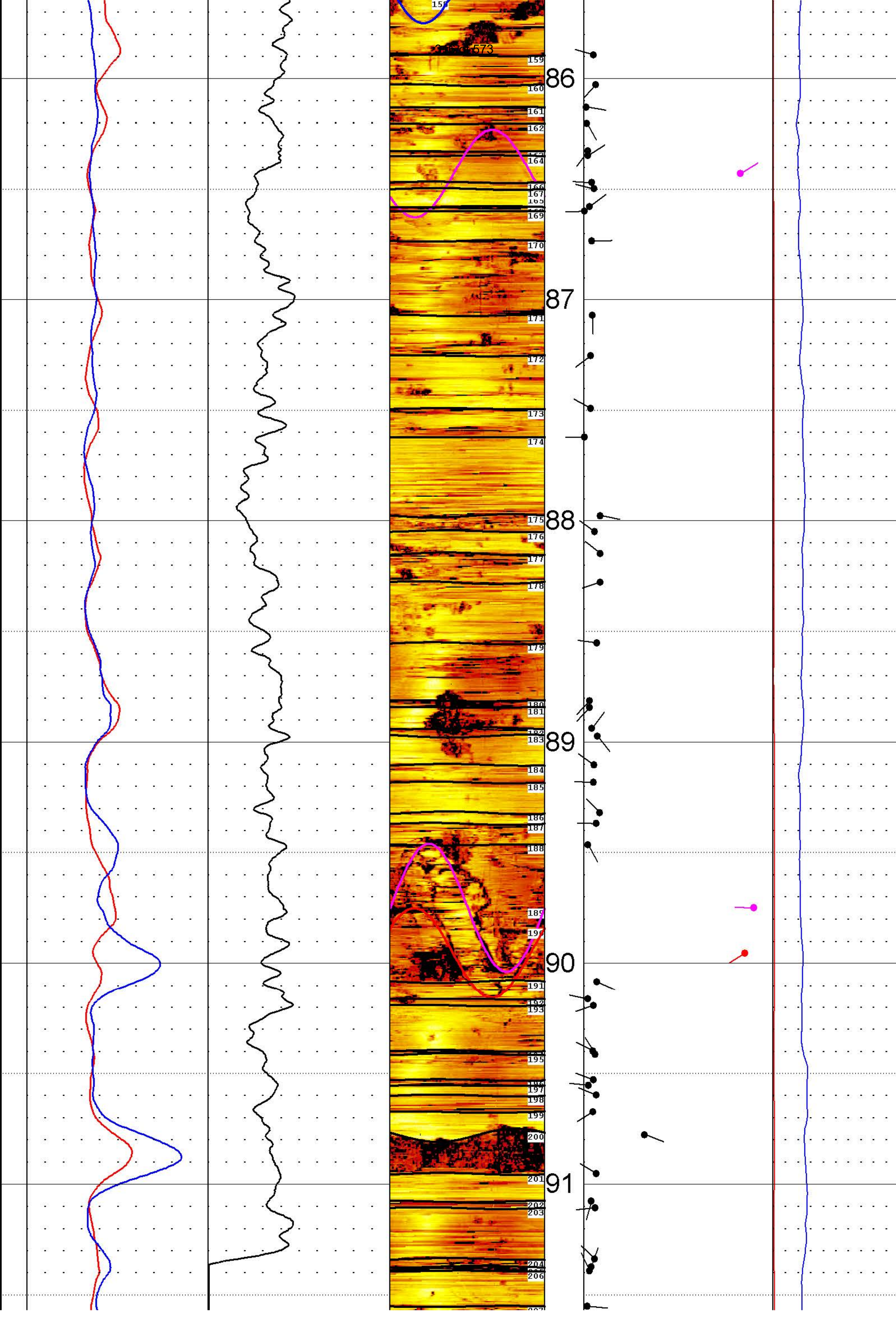
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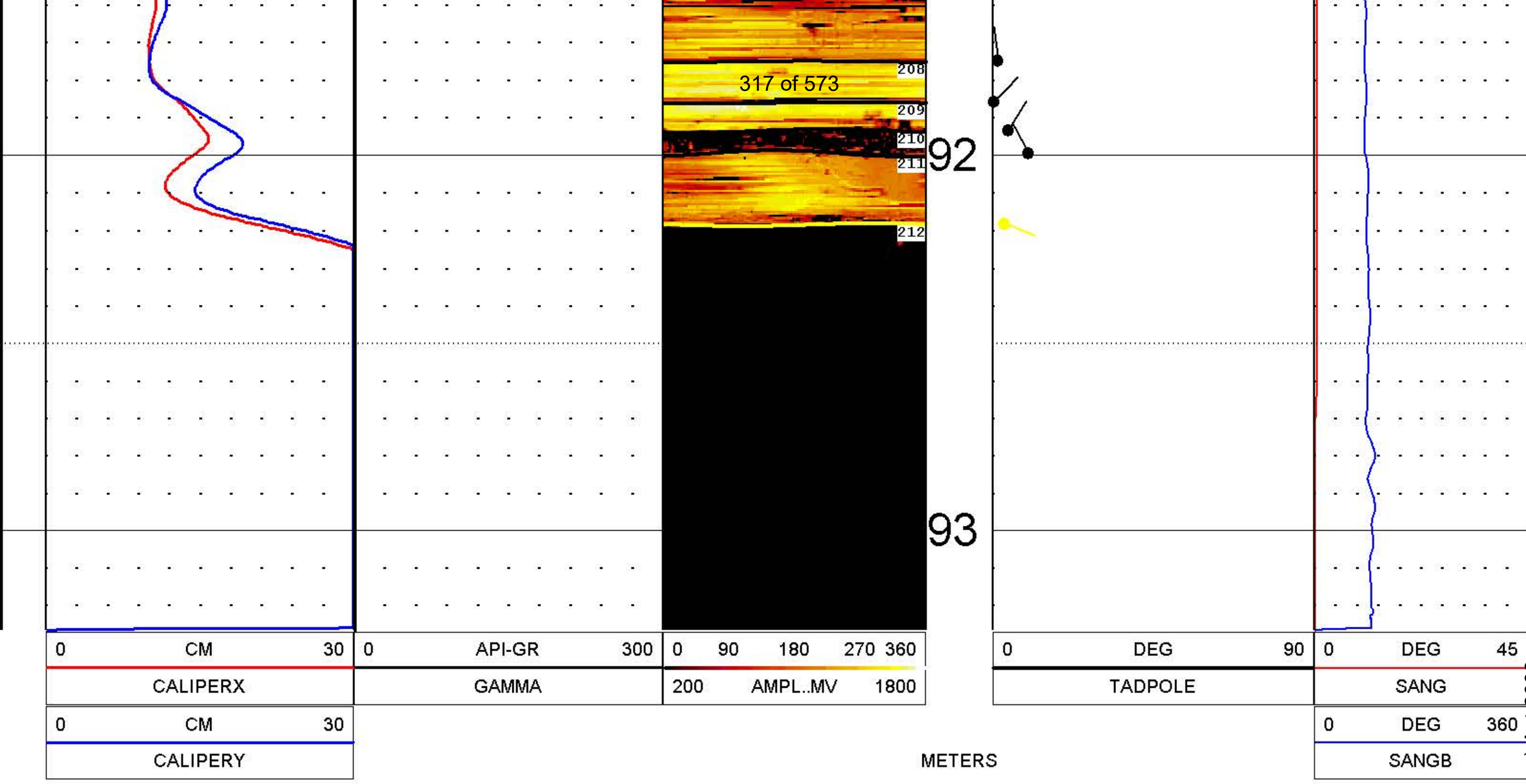
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CALIPERY
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GAMMA
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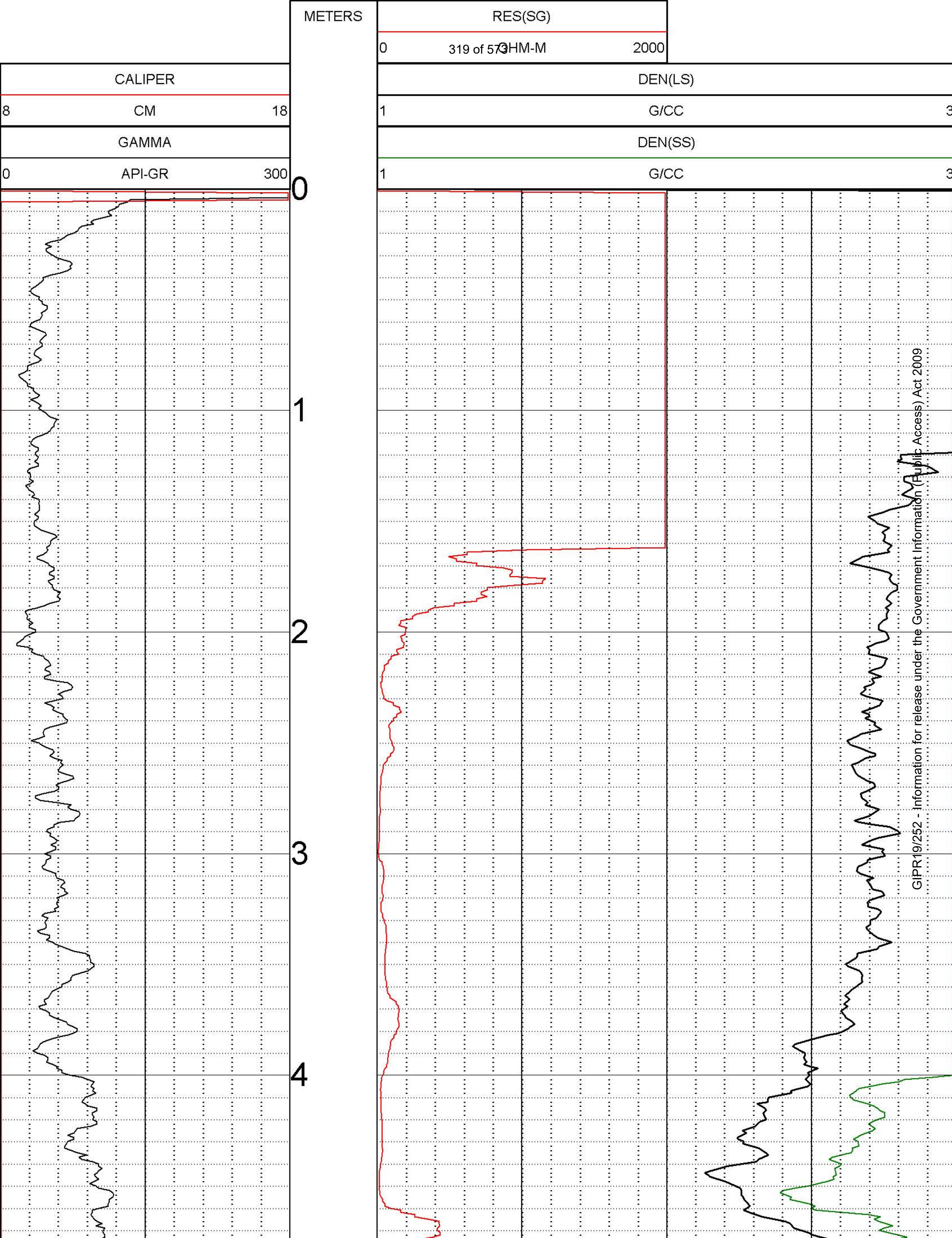
200 AMPL..MV 1800
METERS
0 DEG 90
TADPOLE
0 DEG 45
SANG
0 DEG 360
SANGB

GROUNDSEARCH AUSTRALIA

BOREHOLE04 DENSITY c 1:20

COMPANY	COFFEY GEOTECH	OTHER SERVICES:	DEN ATV		
WELL	BOREHOLE04 DENSITY c 1:20				
LOCATION/FIELD	LINGARD				
COUNTRY	AUST				
LOCATION	NEWCASTLE				
SECTION	N/A	TOWNSHIP	N/A	RANGE	N/A
DATE	09/14/18	PERMANENT DATUM	-0.9		
DEPTH DRILLER	101.6			KB	N/A
LOG BOTTOM	100.81	LOG MEASURED FROM	N/A	DF	N/A
LOG TOP	0.00	DRL MEASURED FROM	N/A	GL	NA
CASING DIAMETER	10.	LOGGING UNIT	T107		
CASING TYPE	STEEL	FIELD OFFICE	RUTHERFORD		
CASING THICKNESS	.5	RECORDED BY	P WOODWARD		
BIT SIZE	9.90	BOREHOLE FLUID	0	FILE	PROCESSED
MAGNETIC DECL.	0	RM	N/A	TYPE	9239B
MATRIX DENSITY	2.65	RM TEMPERATURE	N/A	LGDATE	09/14/18
NEUTRON MATRIX	SANDSTONE	MATRIX DELTA T	177	LGTIME	07:50:
				THRESH	99999

ALL SERVICES PROVIDED SUBJECT TO STANDARD TERMS AND CONDITIONS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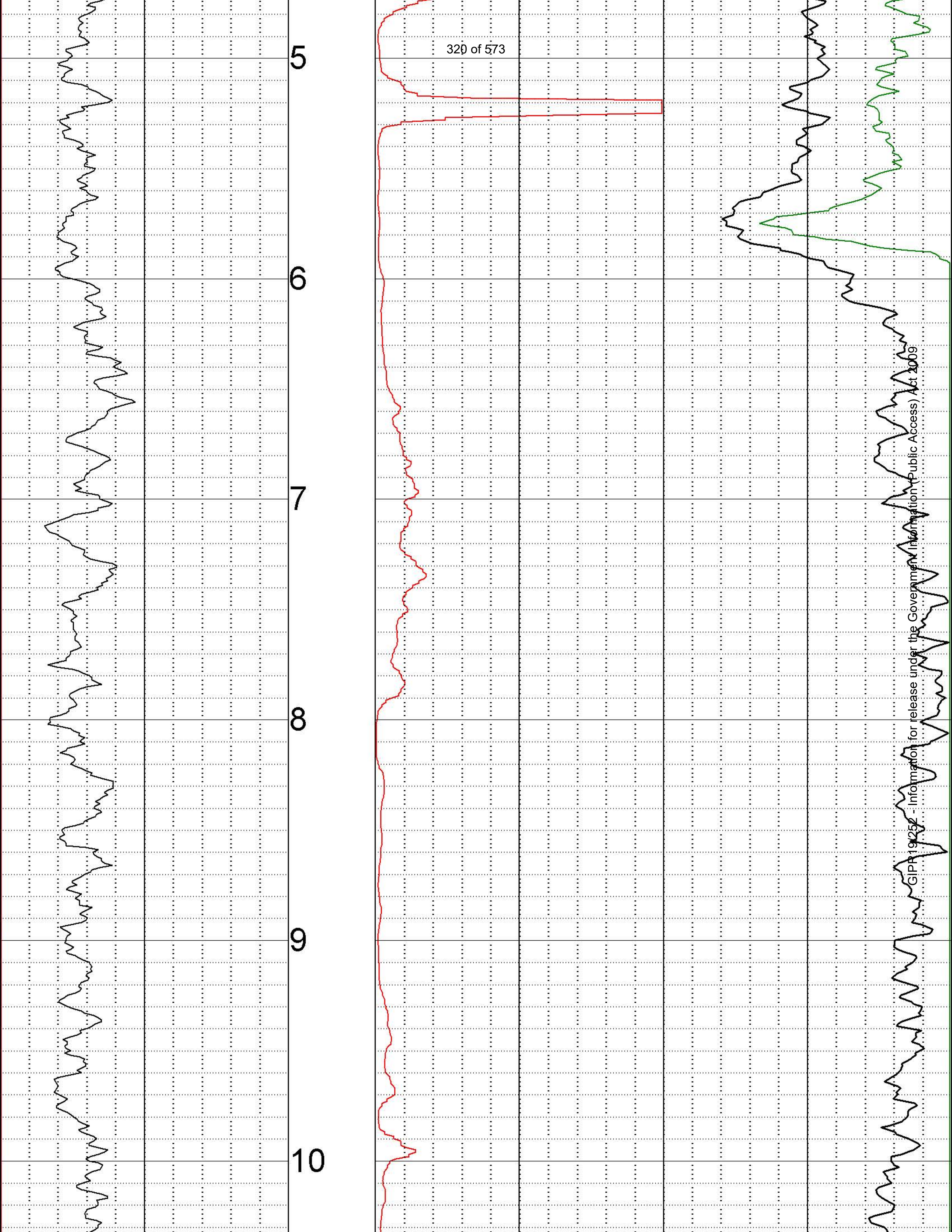

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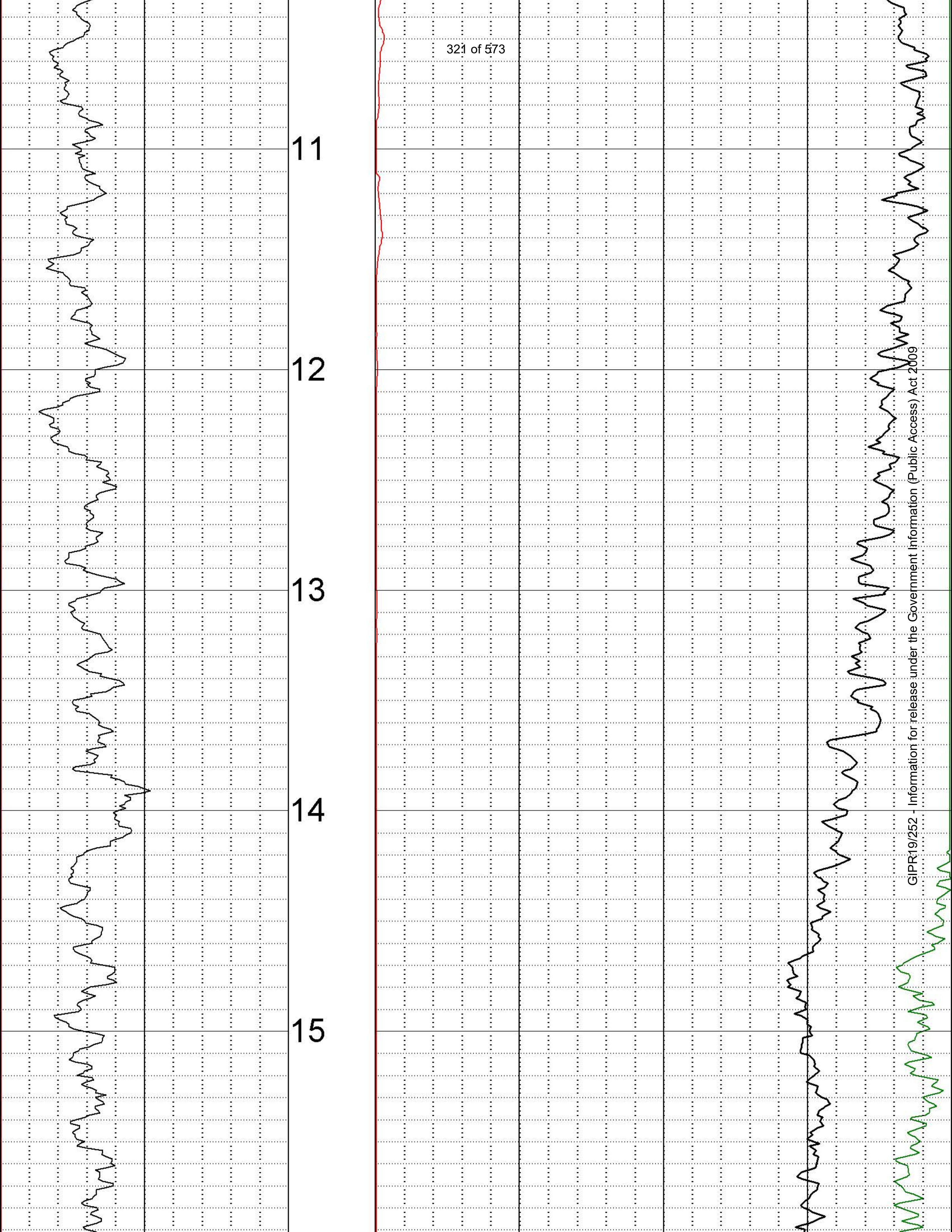
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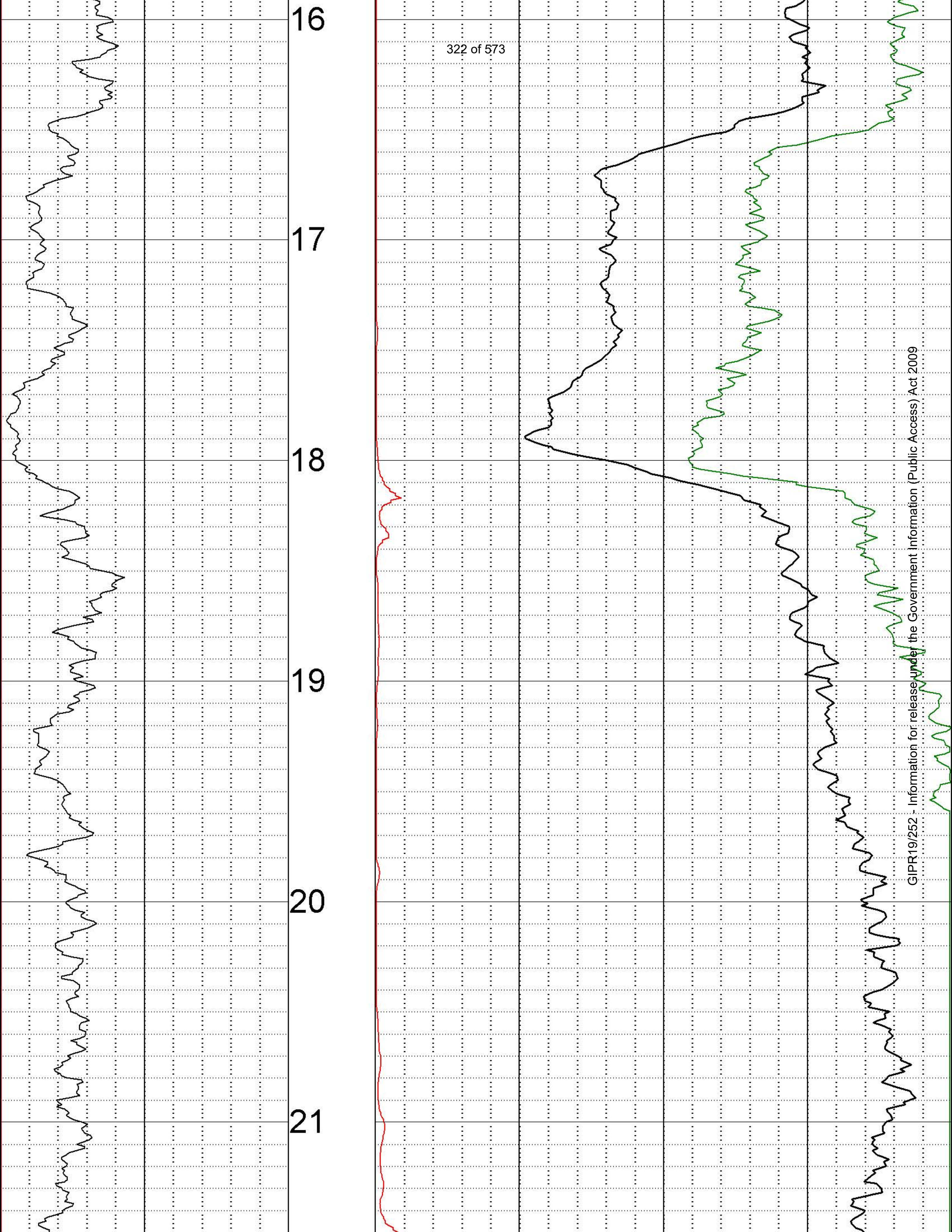
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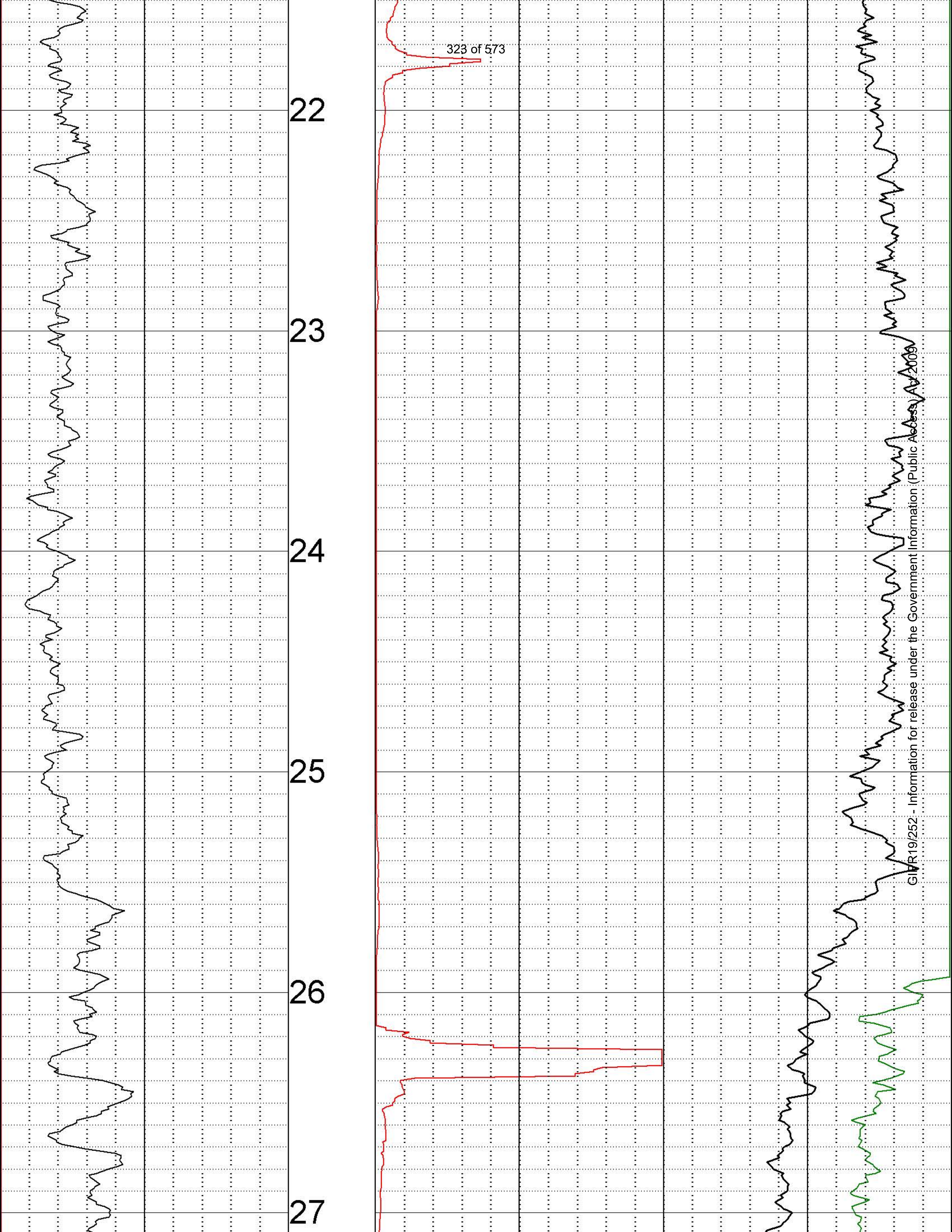
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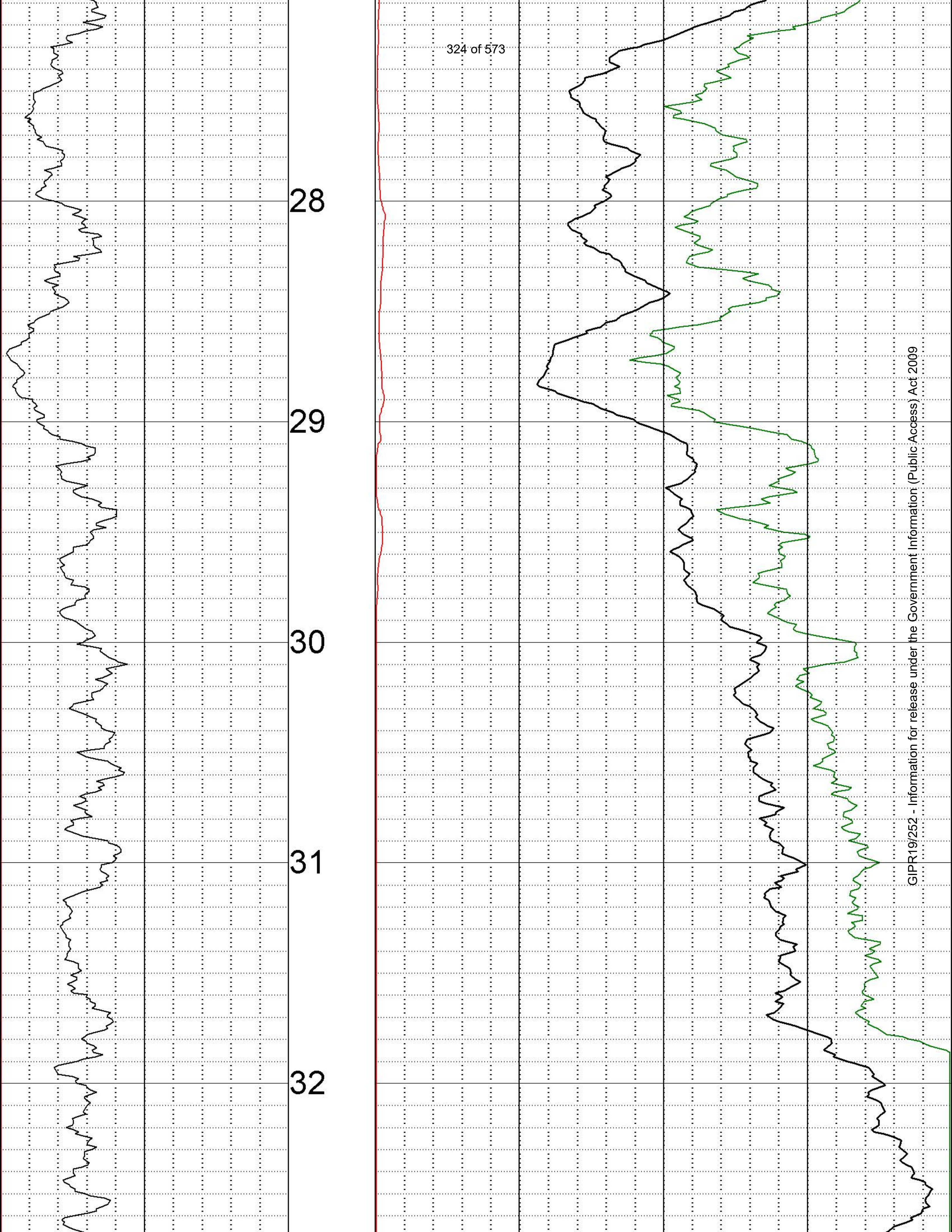
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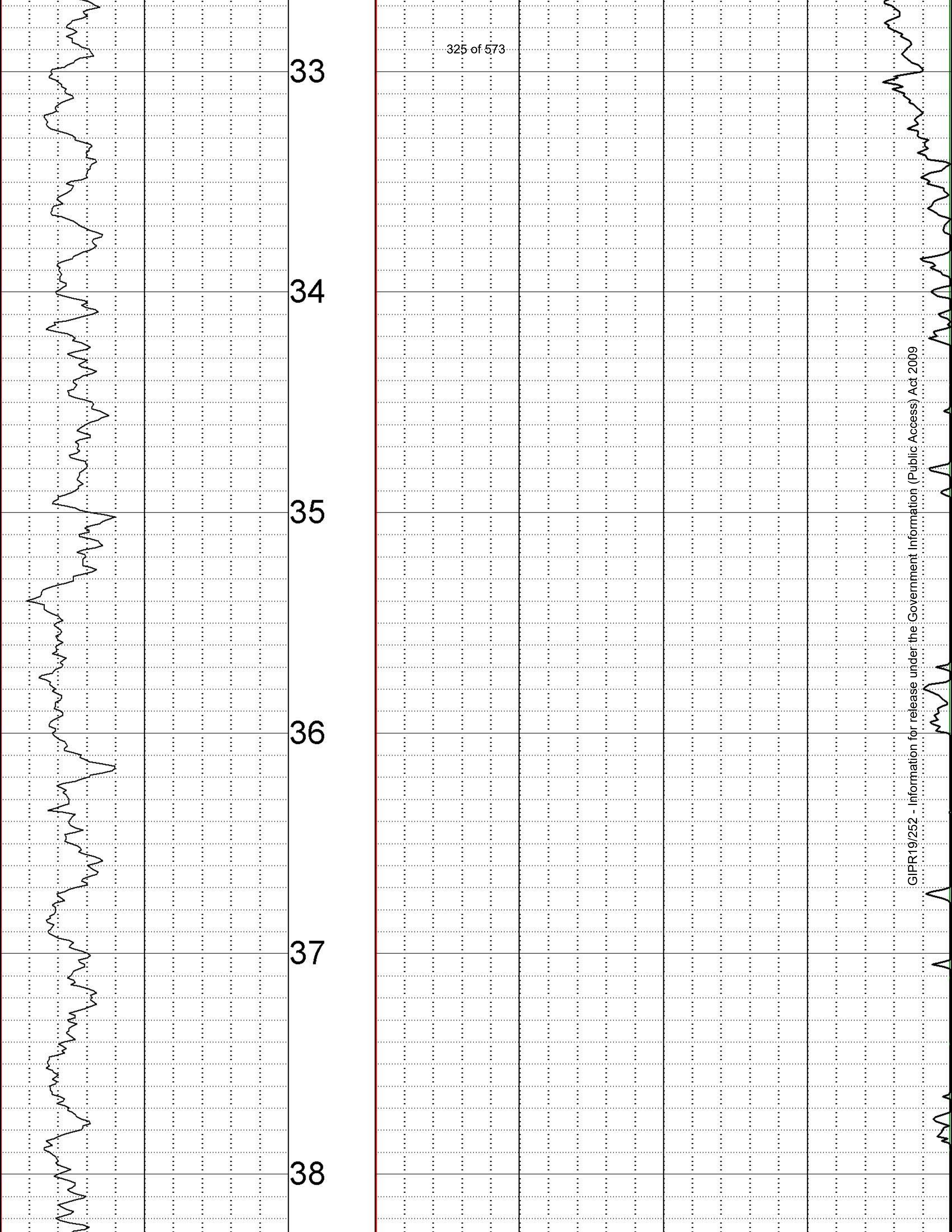
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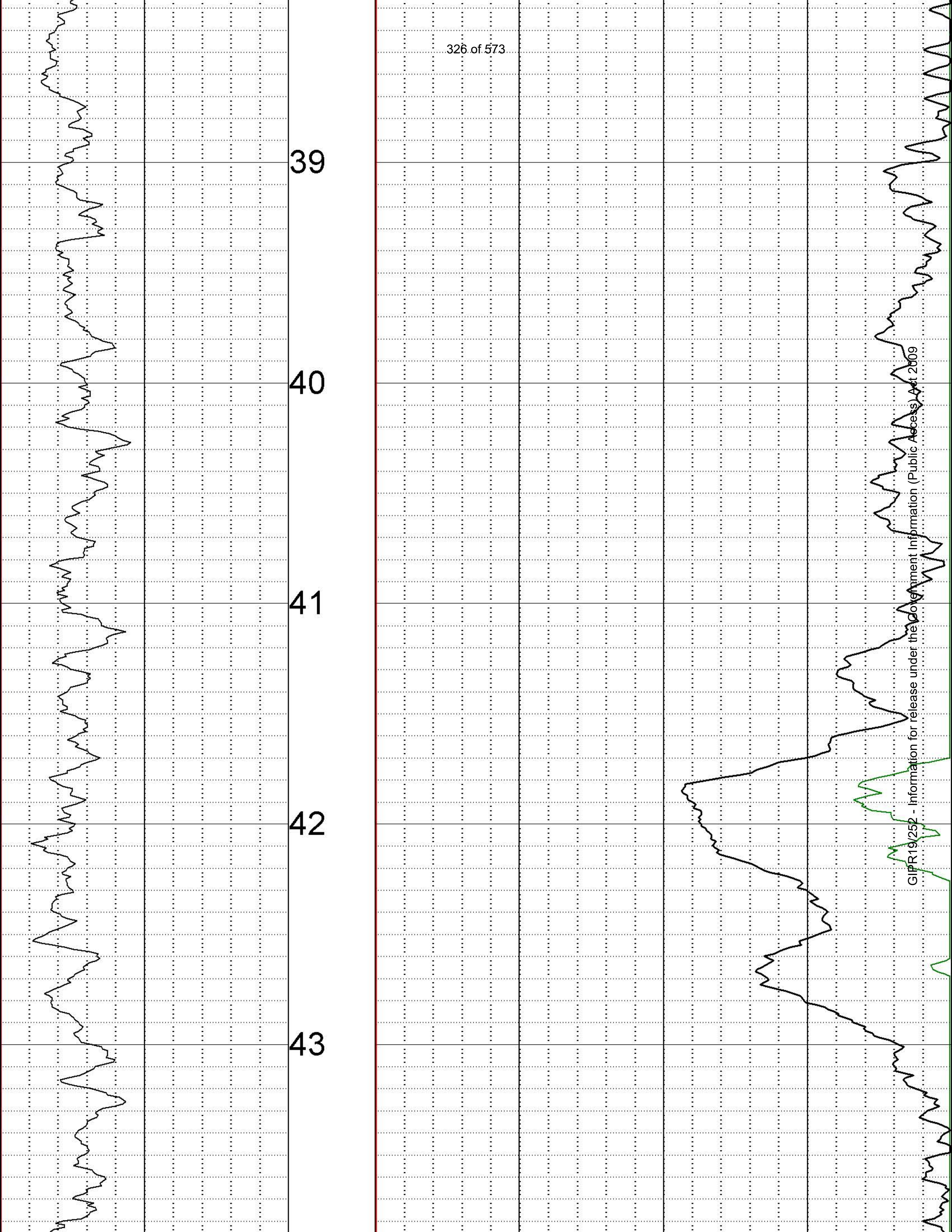
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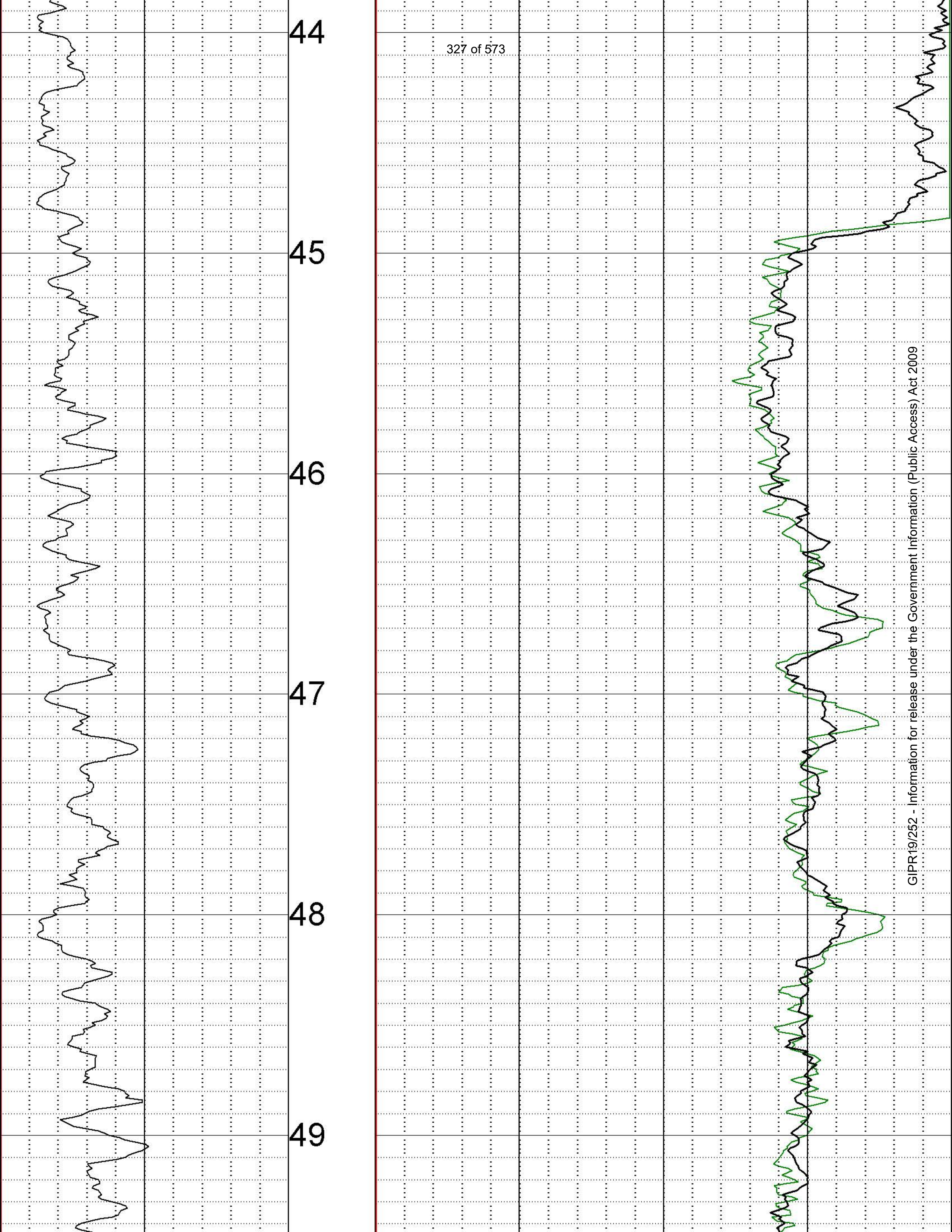
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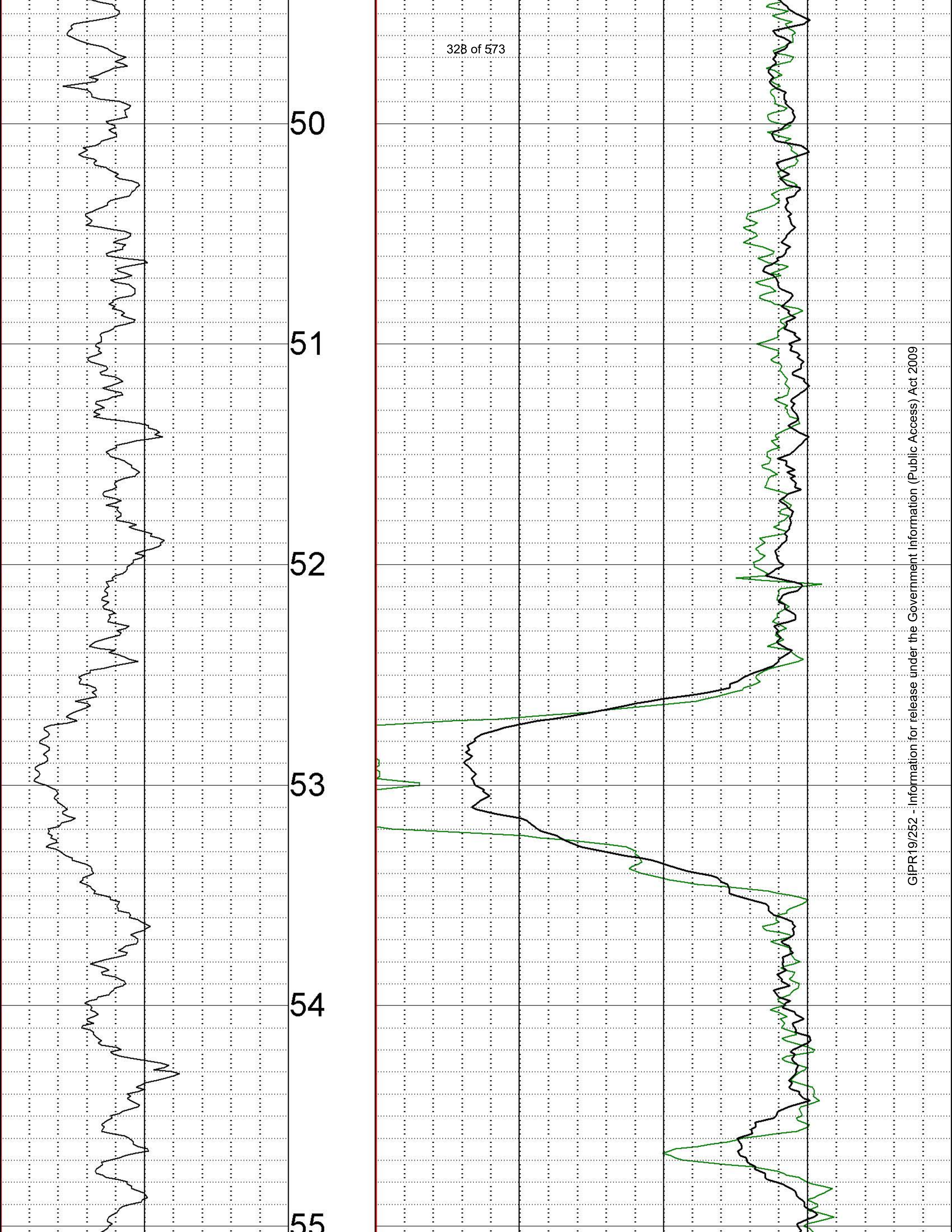
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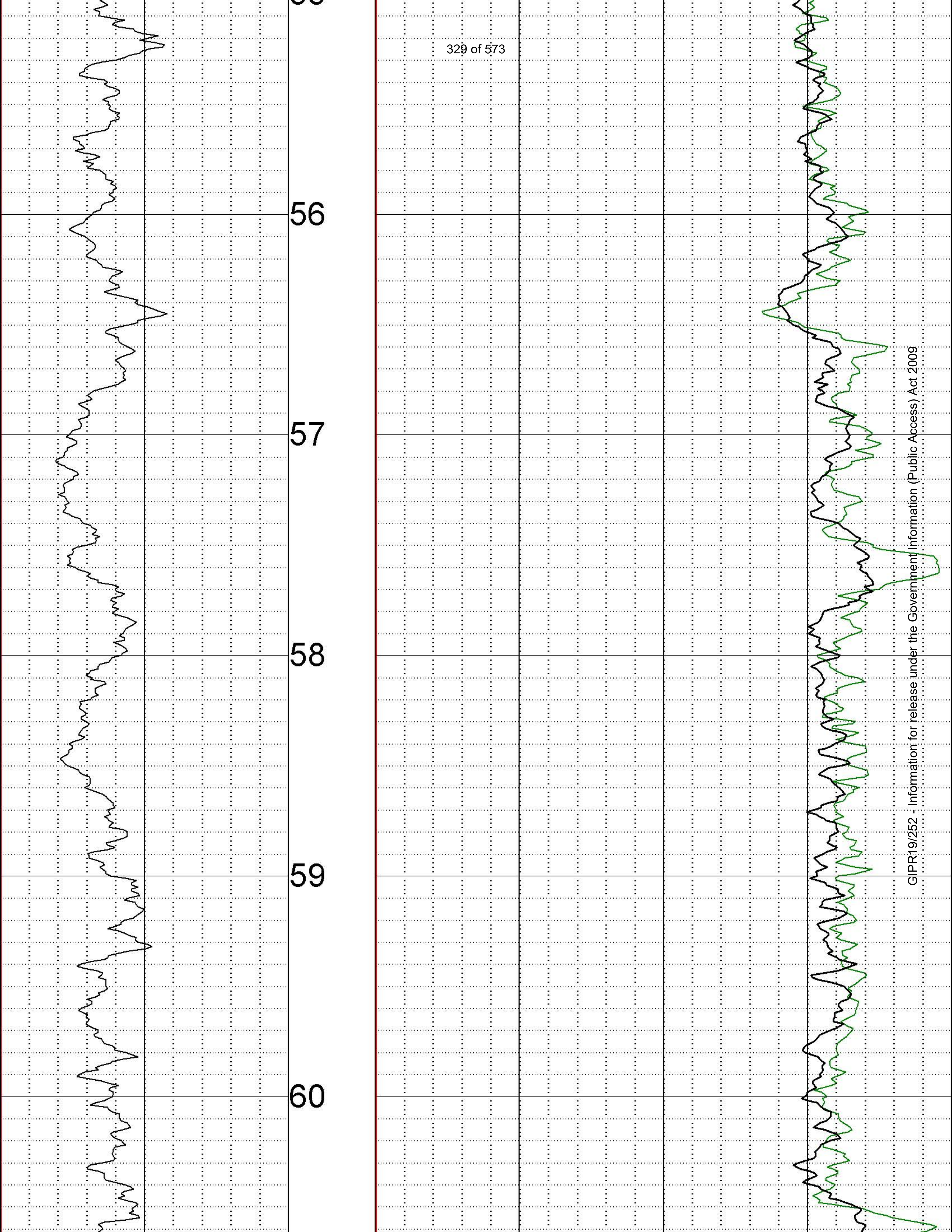
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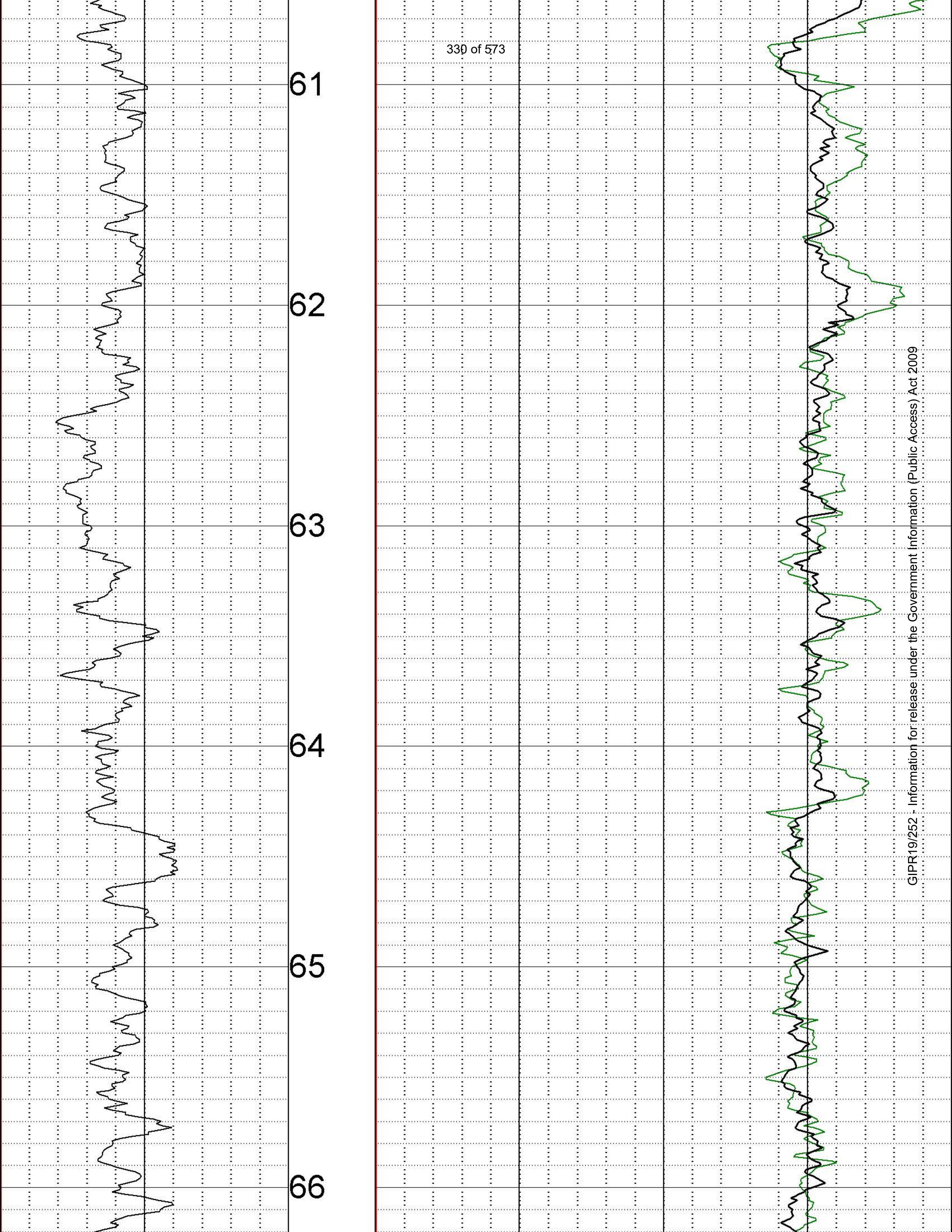
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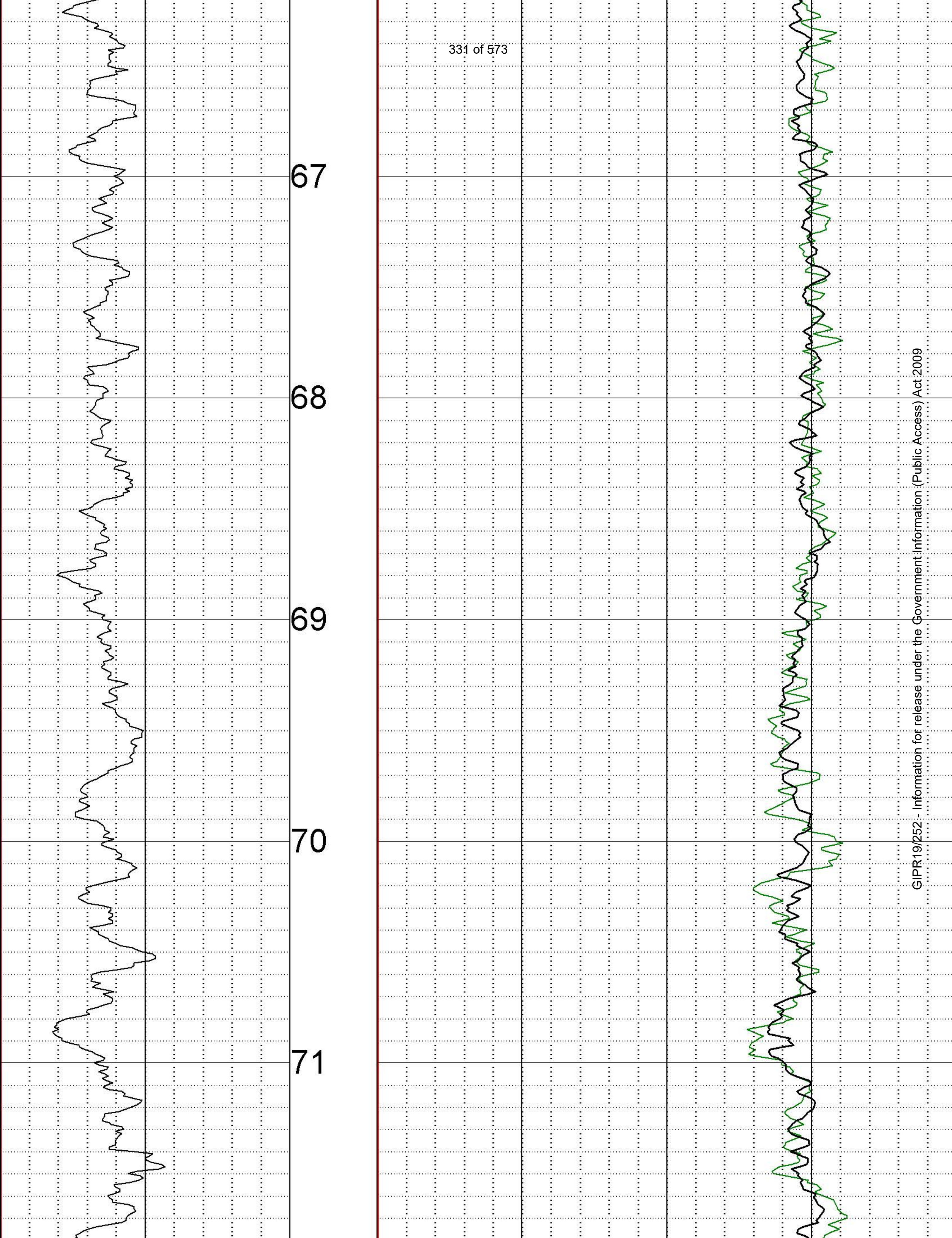
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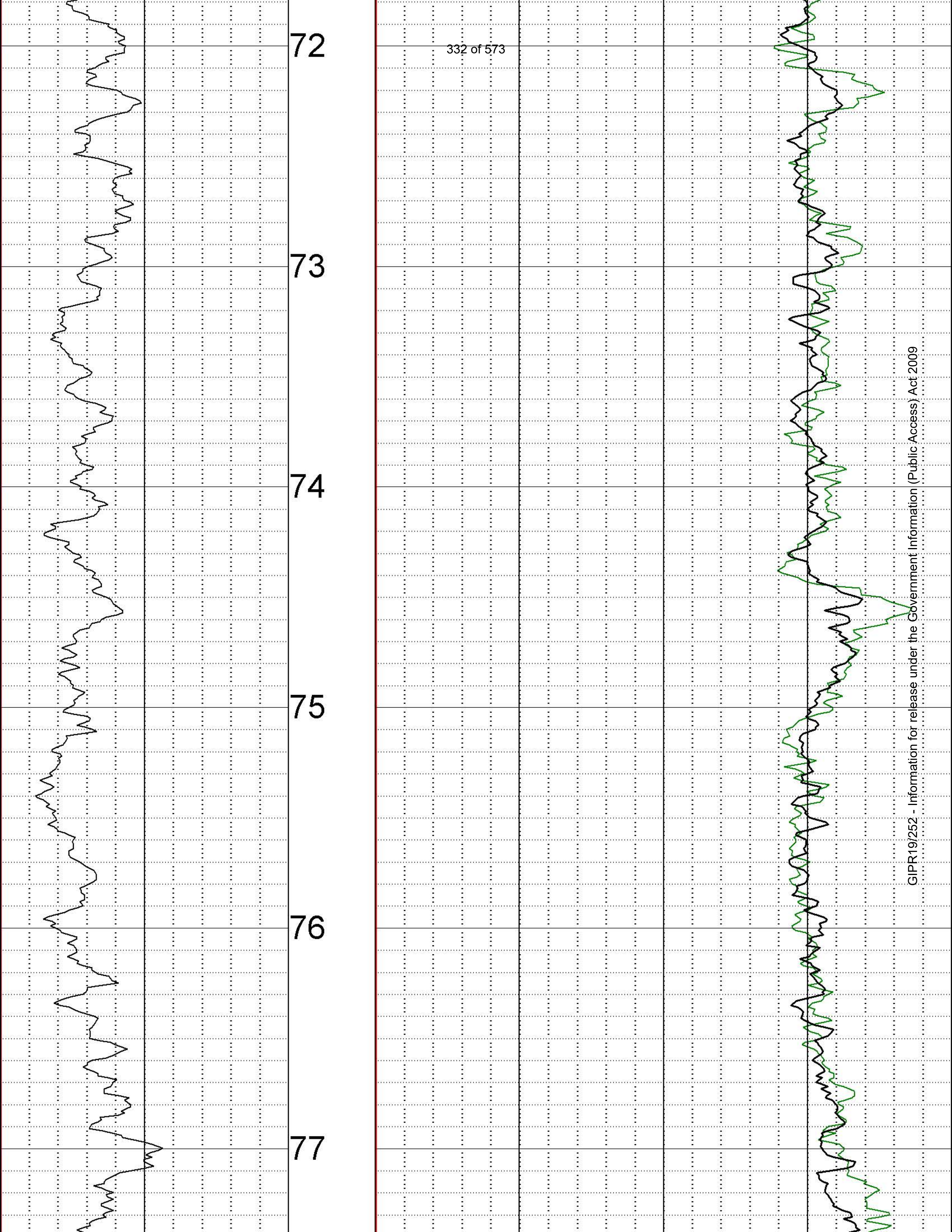
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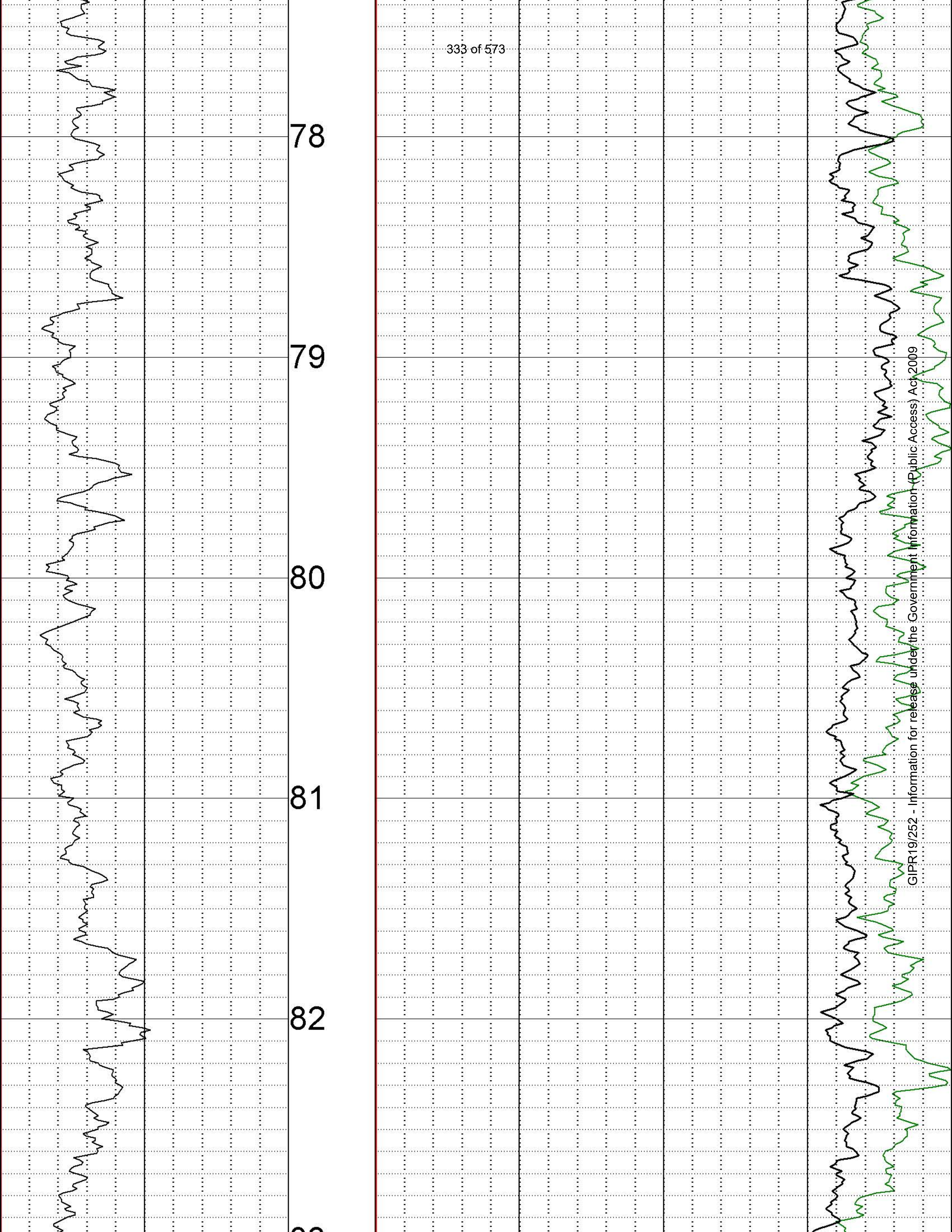
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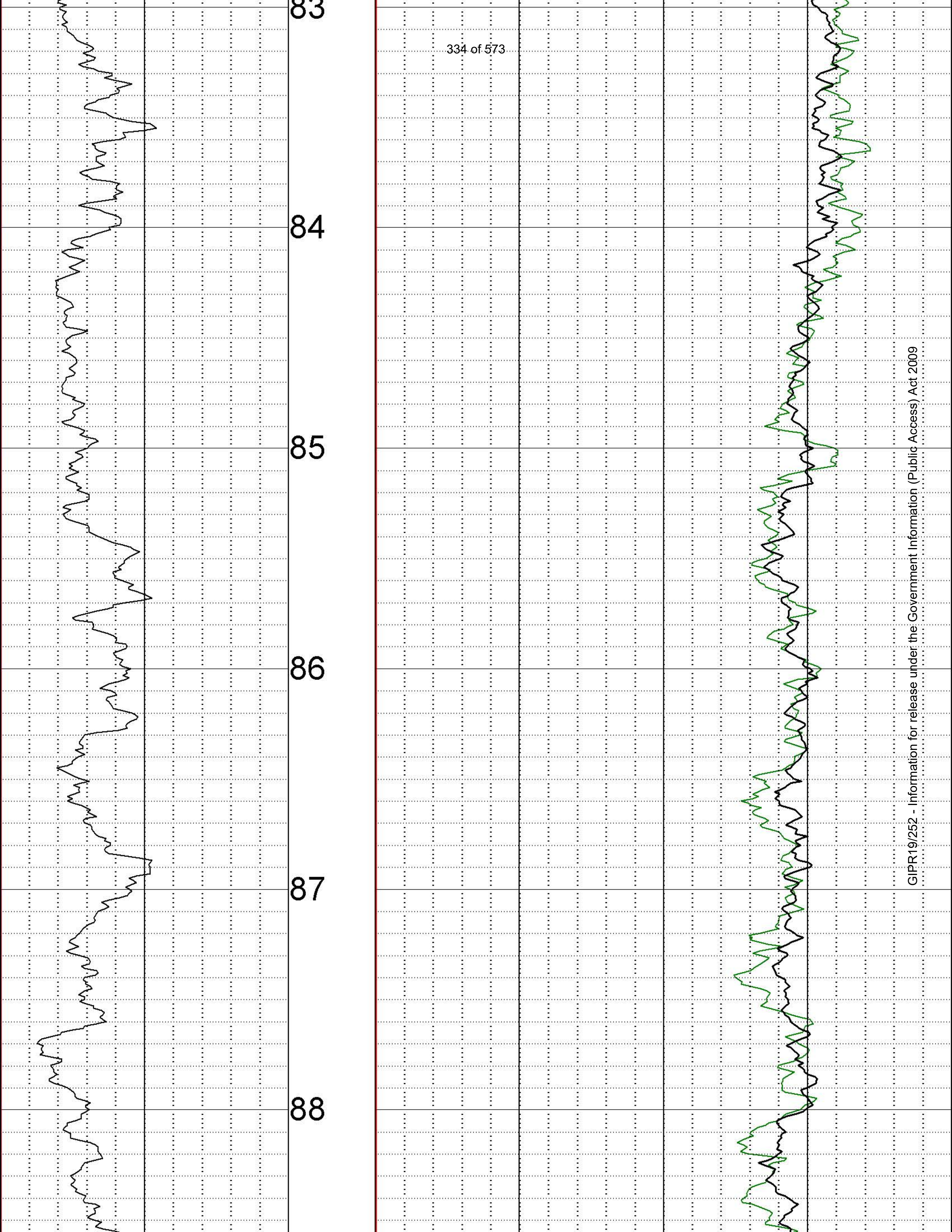
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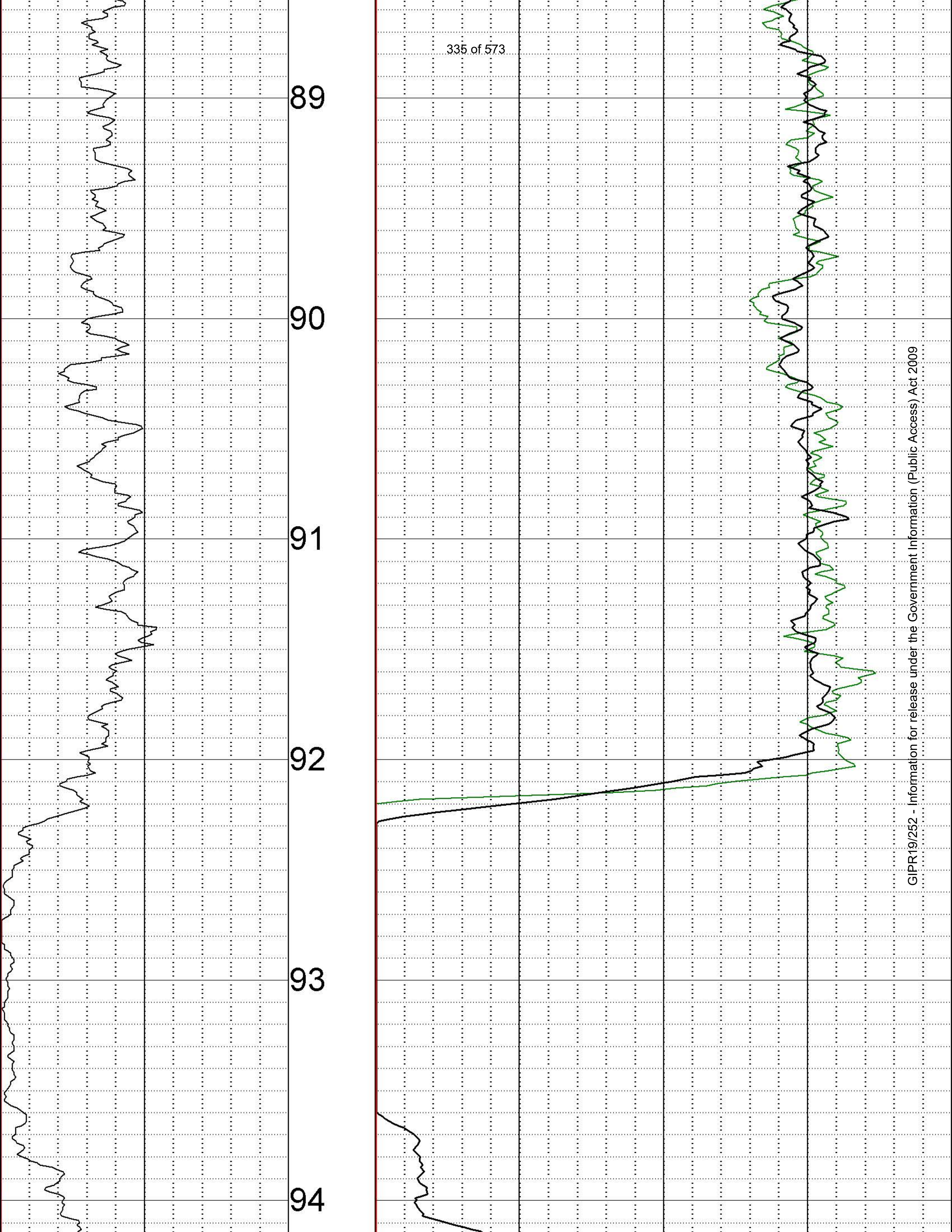
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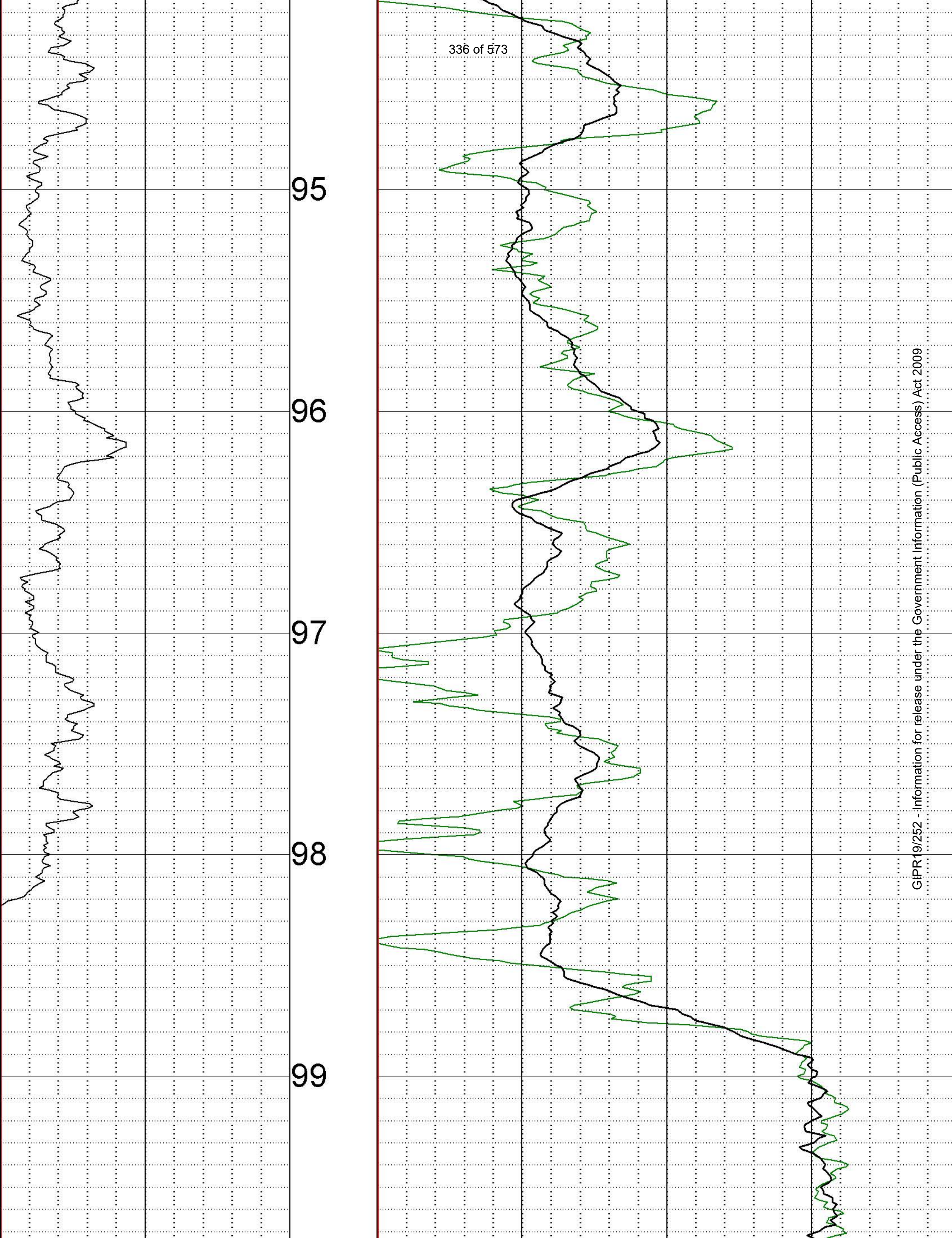
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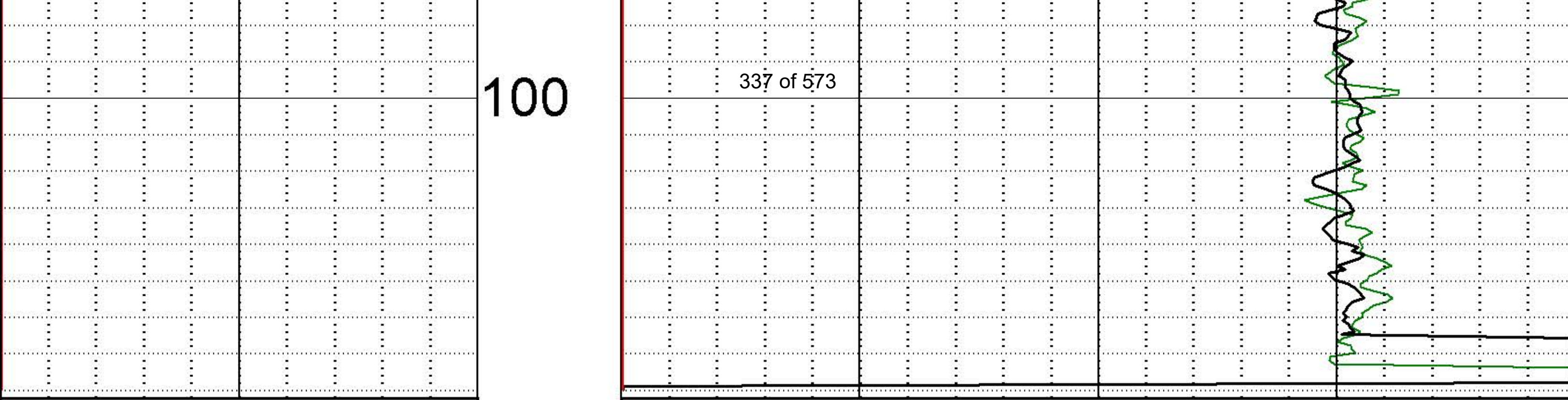

0 API-GR 300

GAMMA

8 CM 18

CALIPER

METERS

1 G/CC 3

DEN(SS)

1 G/CC 3

DEN(LS)

0 OHM-M 2000

RES(SG)

Appendix C – Downhole camera

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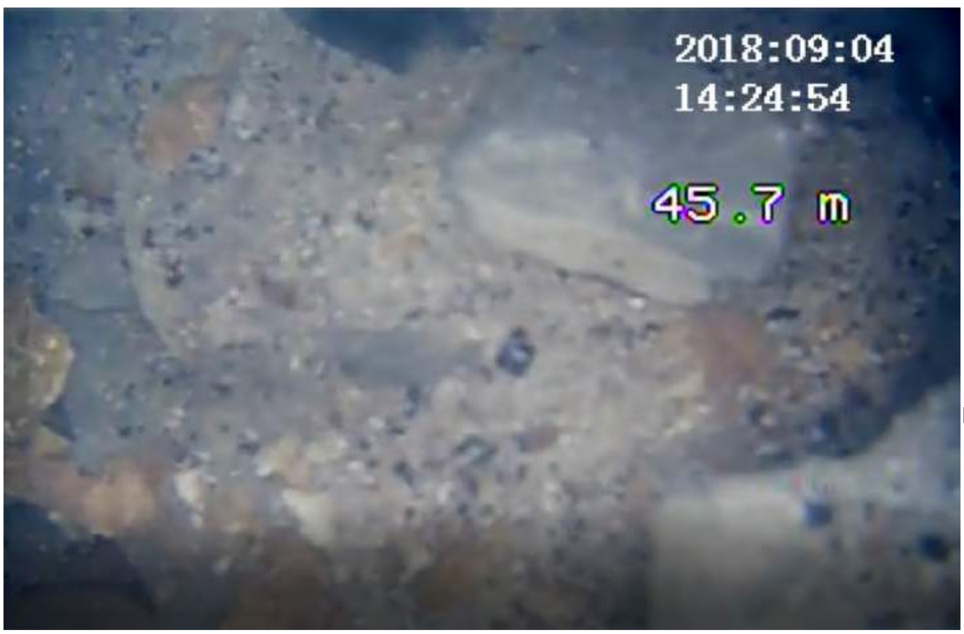
BH01 CCTV Yard Seam

Roof of void



Floor of void

Note depths are approximate only

drawn	SJB	coffey A TETRA TECH COMPANY	client:	CRESCENT NEWCASTLE PTY LTD	
approved	JD		project:	PROPOSED RESIDENTIAL DEVELOPMENT	
date	2/11/2018			11-17 MOSBRI CRESCENT THE HILL	
scale	N/A		title:	CCTV SNAPSHOTS BH01 YARD SEAM	
original size	A4		project no:	754-NTLGE220504	figure no: C-BH01 -01

BH01 CCTV Borehole Seam

Roof of void

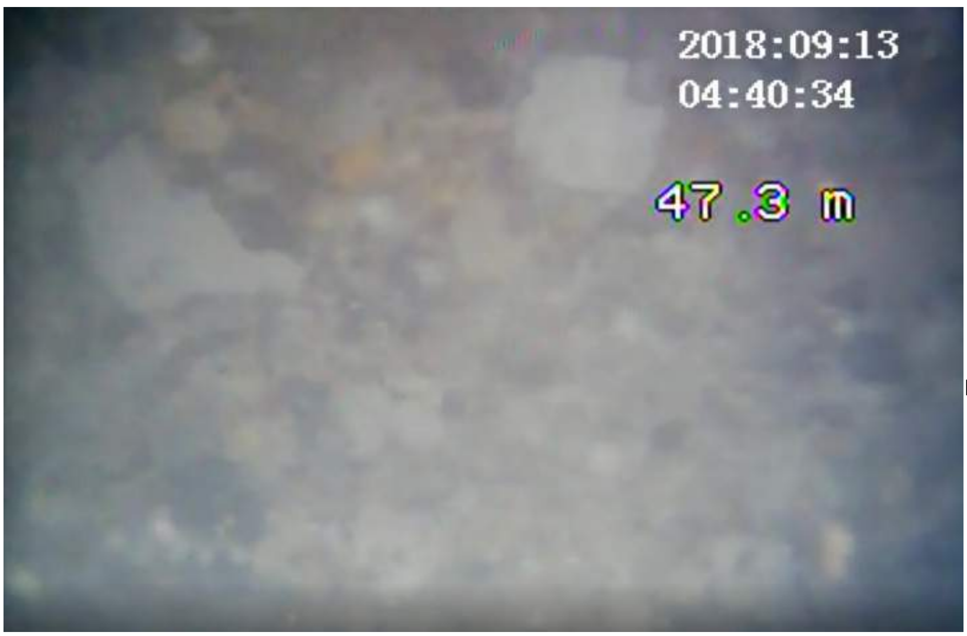
Floor of void

Note depths are approximate only

drawn	SJB	coffey A TETRA TECH COMPANY	client:	CRESCENT NEWCASTLE PTY LTD	
approved	JD		project:	PROPOSED RESIDENTIAL DEVELOPMENT	
date	2/11/2018			11-17 MOSBRI CRESCENT THE HILL	
scale	N/A		title:	CCTV SNAPSHOTS BH01 BOREHOLE SEAM	
original size	A4		project no:	754-NTLGE220504	figure no: C-BH01 -02

BH03 CCTV Yard Seam

Roof of void



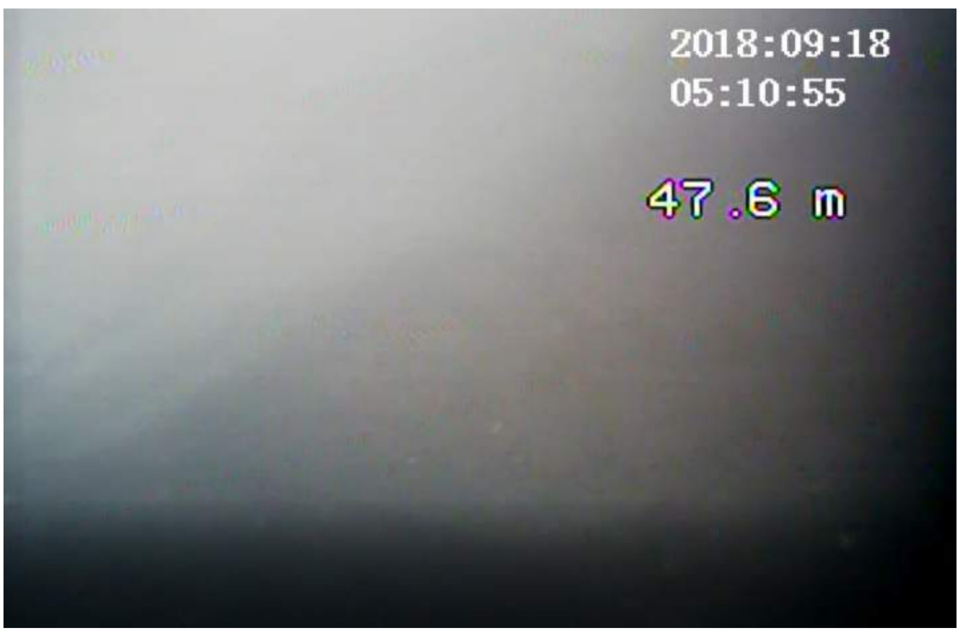
Floor of void

Note depths are approximate only

drawn	SJB	coffey A TETRA TECH COMPANY	client:	CRESCENT NEWCASTLE PTY LTD	
approved	JD		project:	PROPOSED RESIDENTIAL DEVELOPMENT	
date	2/11/2018			11-17 MOSBRI CRESCENT THE HILL	
scale	N/A		title:	CCTV SNAPSHOTS BH03 YARD SEAM	
original size	A4		project no:	754-NTLGE220504	figure no: C-BH03 -01

BH04 CCTV Yard Seam

Roof of void



Floor of void

Note depths are approximate only

drawn	SJB	coffey A TETRA TECH COMPANY	client:	CRESCENT NEWCASTLE PTY LTD	
approved	JD		project:	PROPOSED RESIDENTIAL DEVELOPMENT 11-17 MOSBRI CRESCENT THE HILL	
date	2/11/2018				
scale	N/A		title:	CCTV SNAPSHOTS BH01 YARD SEAM	
original size	A4		project no:	754-NTLGE220504	figure no: C-BH04 -01

BH04 CCTV Yard Seam

Roof of void

Floor of void

Note depths are approximate only

drawn	SJB	coffey A TETRA TECH COMPANY	client:	CRESCENT NEWCASTLE PTY LTD	
approved	JD		project:	PROPOSED RESIDENTIAL DEVELOPMENT	
date	2/11/2018			11-17 MOSBRI CRESCENT THE HILL	
scale	N/A		title:	CCTV SNAPSHOTS BH01 YARD SEAM	
original size	A4		project no:	754-NTLGE220504	figure no: C-BH04 -02

coffey
A TETRA TECH COMPANY

Crescent Newcastle Pty Ltd
Proposed Multi - Building Residential Development

754-NTLGE220504-AI

Mine Subsidence Assessment Report

18 January 2019

Technology
is the product
of intelligence
not the
cause of it

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Proposed Multi - Building Residential Development - 11-17 Mosbri Crescent, Cooks Hill, NSW 2300

Prepared for
Crescent Newcastle Pty Ltd

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18 January 2019

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Executive Summary

The Site located at 11-17 Mosbri Crescent Cooks Hill is known to be located over abandoned workings in both the Yard Seam and the Borehole Seam. The Borehole Seam is at a depth of 92m to 100m with variations due to surface topography.

Historical Creep events (i.e. crushing of the pillars) were modelled using FLAC3D to develop an understanding what may subsidence may occur should the pillars under the site weaken sufficiently. Using this model, the area should have collapsed even with a pillar height of 5.1m, less than the 6.6m present within BH04.

Coffey completed a numerical analysis to assess the effectiveness of a proposed grouting scheme for the Borehole Seam to control the risk of subsidence. The proposed grouting scheme included the grouting of two locations per bord, either side of eight coal pillars. At the two critical corners, an additional bord (i.e. three bords) was deemed necessary while within the centre of the site the grouting was reduced to only one location per bord (Refer to Drawing 4). It is noted the grouting scheme has been designed primarily to control the pattern of subsidence rather than to fully grout the site and prevent all subsidence.

Using this model, it was assessed that:

- The factor of safety of the panel of workings in their current condition is in the order of 1
- After grouting, the maximum differential subsidence that may be experienced by the site is estimated to be 160mm. Further weakening of the grouted pillars will result in less curvature due to the limited void space at mine level.
- The tilts estimated for the development are 4mm/m.
- The maximum tensile strains were assessed to be less than 0.9mm/m while the compressive strains were assessed to be up to 0.6mm/m (from the 120mm to 160mm contour only).
- The curvature has been estimated to be a minimum of 11km concave down and 16km concave up (from the 120mm to 160mm contour only on Drawing 5).

1. Introduction

Crescent Newcastle Pty Ltd (Crescent) commissioned Coffey Services Australia Pty Ltd (Coffey) to carry out a mine subsidence investigation for the proposed multi building residential development located at 11-17 Mosbri Crescent, Cooks Hill, NSW referred to hence forth as The Site.

This report addresses the scope of work outlined in our proposal referenced as 754-NTLGE220504.P01.Rev02, Section 2.2.1 *Mine subsidence numerical analysis*, dated 27 August 2018. Preliminary contamination assessment, geotechnical and mine subsidence investigations will be reported separately.

The currently proposed development at The Site will include:

- Construction of residential accommodation comprising 172 dwellings, being:
  - Eleven (11) two storey townhouse style dwellings fronting Mosbri Crescent, located above a basement car park containing 34 visitor spaces and 11 resident spaces
  - Three (3) residential flat buildings (Building A, B, and C) containing 161 dwellings, ranging from one to three bedrooms; being:
    - Building A including a nine (9) storey east wing and six (6) storey west wing
    - Building B comprising seven (7) storeys and a roof top communal open space, with (9) town house style dwellings facing the internal courtyard
    - Building C comprising five (5) levels
- Interconnected car parking for Building A, B & C located on the ground floor and first level, contains 1 visitor spaces and 196 resident spaces
- Pedestrian path, providing connection from Mosbri Crescent to Kitchener Parade
- Associated landscaping, communal open space, services and site infrastructure.

The Site is sloping south westerly towards Mosbri Crescent Reserve and existing ground RLs within the footprint of the Building A, B and C varies between RL 36m AHD and RL 38.00m AHD. The combined basement levels will require excavation of approximately 8.5m to 9.5m below existing ground level (RL 28.10m AHD and RL 29.60m AHD) at the rear (eastern) side of the property although the proposed excavation is generally less than 4m.

Two storey townhouses are proposed along Mosbri Crescent with single basement level. Maximum excavation required for the proposed townhouses will be approximately 4.5m below ground level (basement RL 25.40m AHD to RL 27.40m AHD).

Vehicular access to the proposed development is via ramp from Mosbri Crescent connecting with proposed basements driveways, located next to apartment building located at 9 Mosbri Crescent, north western side of site.

Prior to this report Coffey was given following documents:

- Site Survey Plan prepared by Monteath & Powys Pty Ltd, titled as “Detail Survey Over Lot 1 DP204077, NBN Studios, Mosbri Crescent, The Hill”, referenced as 15/047 and dated 10/4/15, inclusive
- Preliminary Architectural Drawings prepared by Marchese Partners International Pty Ltd, titled as “11-17 Mosbri Crescent, The Hill NSW 2300”, referenced as job 171114 and comprises of drawing from DA2.01 to DA2.11, dated as 10/10/2018, water marked as work in progress

The Site is known to be located over abandoned workings in both the Yard Seam and the Borehole Seam.

This report aims to:

- Assess the factor of safety of the mine workings beneath The Site

- Assess the potential maximum subsidence that may be experienced at The Site
- Assess subsidence parameters applicable to proposed developments in the area given the current grouting works completed in the area

This report presents in the results of a numerical modelling phase using FLAC3D.

The following report presents the steps followed in the numerical analysis of the mine workings, the data used in this assessment, and the resultant findings and recommendations for design. This report does not include assessment of potential movements from the construction of the building itself (i.e. consolidation of soil layers) and does not address footing design parameters.

2. Background

Coffey completed a mine subsidence investigation to assess the condition of the mine workings and overburden, Coffey Report 754-NTLGE220504-AH.Rev2 dated 17 December 2018. This report should be read in conjunction with the above report although a brief summary is provided below. Mine workings exist under The Site within the Borehole Seam at a depth of 92m to 100m below ground level by the AACo from their New Winnings Pit (also known as Sea Pit). These workings are shown Record Tracing RT566, Sheet 4 (completed in 1906, reproduced on Drawing 3) and Record Tracing RT566, Sheet 8 (showing extent at abandonment in 1916, reproduced on Drawing 2.) Mine workings also exist within the Yard Seam, however as they are unmapped an accurate numerical model of these workings is not possible without extensive drilling. Hence this report focuses on the lower Borehole Seam.

From the borehole log on RT566, Sheet 8, the working zone from the Borehole Seam ranged from 267’ 0” to 284’ 0” (81.4m to 86.6m) or 5.2m. The general workings comprised bords 6 yards wide (5.4m) and 33 yards long (30.2m) and pillars were 12 yards wide (11m) (Power 1912). This means the mine workings under The Site have a width to mined height ratio of approximately 2. These dimensions were not increased even under The Hill where the overburden load is substantially higher. This resulted in the failure of the coal pillars causing Creep 1 on 15 May 1906, Creep 2 on 17 October 1907 and Creep 3 on 17 January 1908. These events are recorded on RT566, Sheet 4 (refer to Drawing 4).

While areas outside the Creep events have been shown to have crushed elsewhere (Coffey report 754-NTLGE211941-AD May 2018), rock core samples and downhole logging of the coal pillars under The Site did not show evidence of crushing.

Since the time of mining, the roof of the workings has started to collapse over the bords where wider mined widths are present. This has resulted in a significant amount of rubble/ loose material on the floor of the workings (up to 5m in BH04).

3. Methodology for numerical modelling

3.1. Approach

This assessment included the following steps:

- Development of a large scale numerical model with the geological features of the area, including ground elevation and mine workings based on RT566 Sheet 8
- Trigger pillar collapses and assess paths of pillar creeps, recalibrate as necessary
- Add grout to selected pillar in the model and assessment of the consequent ground deformations at different strength reduction of the coal material
- Assessment of consequent ground deformations caused by pillar collapse.

To assess the FOS of the workings and resultant surface deflection, the three-dimensional numerical analyses proprietary software FLAC3D was used to simulate a pillar collapse of the workings. This simulation included attempts to model the pattern of previous crush events known to have already occurred within and around The Site.

The model was returned to previous state, grout was added to selected locations on both sides of pillars with the crush events trigged again, with a final phase of slowly degrading coal within the remaining standing pillars.

3.2. Geometry and mesh

A pillar run that impacts The Site may be initiated from weaker pillars outside of the immediate area. As such, a large area of mine workings was modelled to assess potential surface response behaviours at The Site and to reduce the impact of edge effects in the model affecting the ground response assessed at The Site.

For The Site, the model extended an area of 800m by 800m. This elemental 'mesh' adopted extends sufficiently broadly to recognise and reduce the impact of enable boundary fixities at The Site. This included:

- Surrounding The Hill which generally meant extending the whole of Creep 2 as well as large portions of Creeps 1 and 3.
- Having all model limits more than 200m from the site (i.e. boundaries at least twice the depth to workings around The Site).

The outlines of pillars within the workings were first digitised using polylines in AutoCAD based on the layout of pillars from RT566 Sheet 8 which is generally similar to the version on RT Sheet 4, except with the additional mining completed after 1906. The workings were rotated so that a principal stress corresponded with the x axis (generally along the pillars). The digitised geometry of the pillars was imported into FLAC3D, with the remaining irregular shapes converted to primitives before subdivision into pillars with four elements across and eight to twelve elements along the length to create generally squarish shaped elements.

To allow for easier identification in later stages, primitives of similar units were grouped together.

- Group 1 - Full height bords
- Group 2 - AACo standard coal pillars
- Group 3 - Fault coal
- Group 4 - Fault bord

Figure 1 shows this layout.

A slight fold in the linen map is observable on the RT566 Sheet 8 images, which decreased the apparent width of the pillars by an estimated 2m. As such, the pillar layout was completed with two parts, the zone above and below the fold on the linen map.

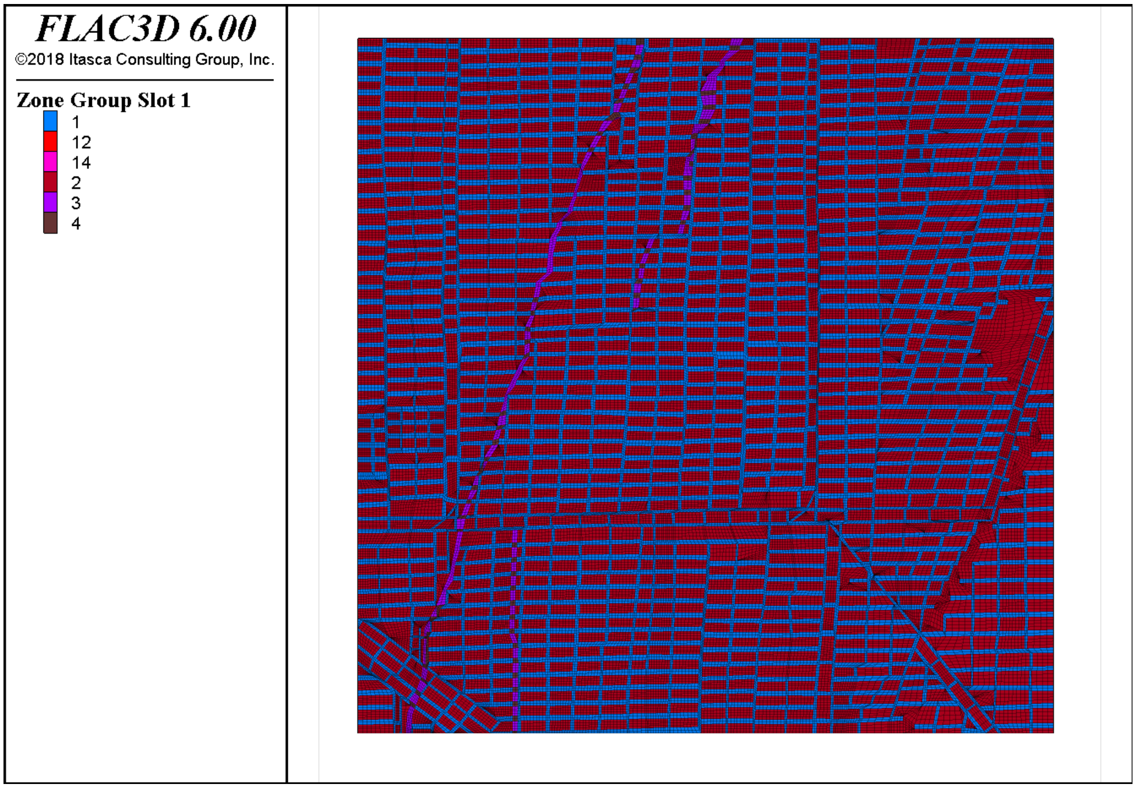

Figure 1: Mesh at Borehole Seam level

To build the vertical depth to the model, the Borehole Seam was assumed to be horizontal with the surface modified to resemble the additional overburden; the depth of the model was developed using surface contours and the seam dip of 1 in 90 for the Borehole Seam identified on Record Tracing Sheet 8.

The grid was then extruded in three stages, with the mesh refined at each stage to reduce the total number of elements to z equals 20m (i.e. where the surface topography changes means the unit no longer covered the whole model). To simulate topographic variation at the surface, above 20m, parts of the main grid were deleted with each layer extruded in 1 layer of 5m thick elements based on the third level of mesh elements. Slight adjustments were made to reduce numerical instability around cliff edges where cliffs are present. Figure 2 shows and example of this for 40m to 45m.

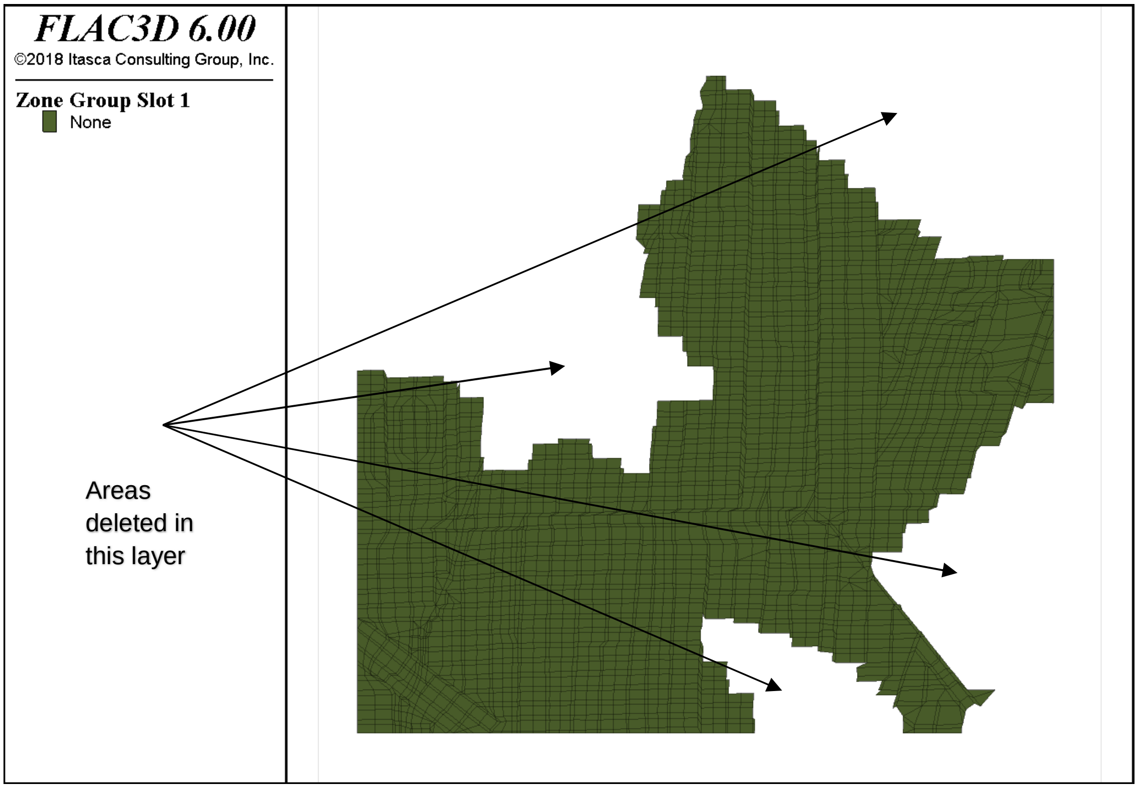

Figure 2: Example of mesh with cut outs for 40m to 45m

The resultant numerical model has approximately 1,100,000 quadrilateral elements. Around the pillars, these are generally 2m to 3m in width, increasing in size away from the pillar. The zones above and below the workings were regrouped as follows:

- Group 11 - Above workings
- Group 12 - Below workings
- Group 13 - Above workings fault zone
- Group 14 - Below workings fault zone

Figure 3 shows the final model.

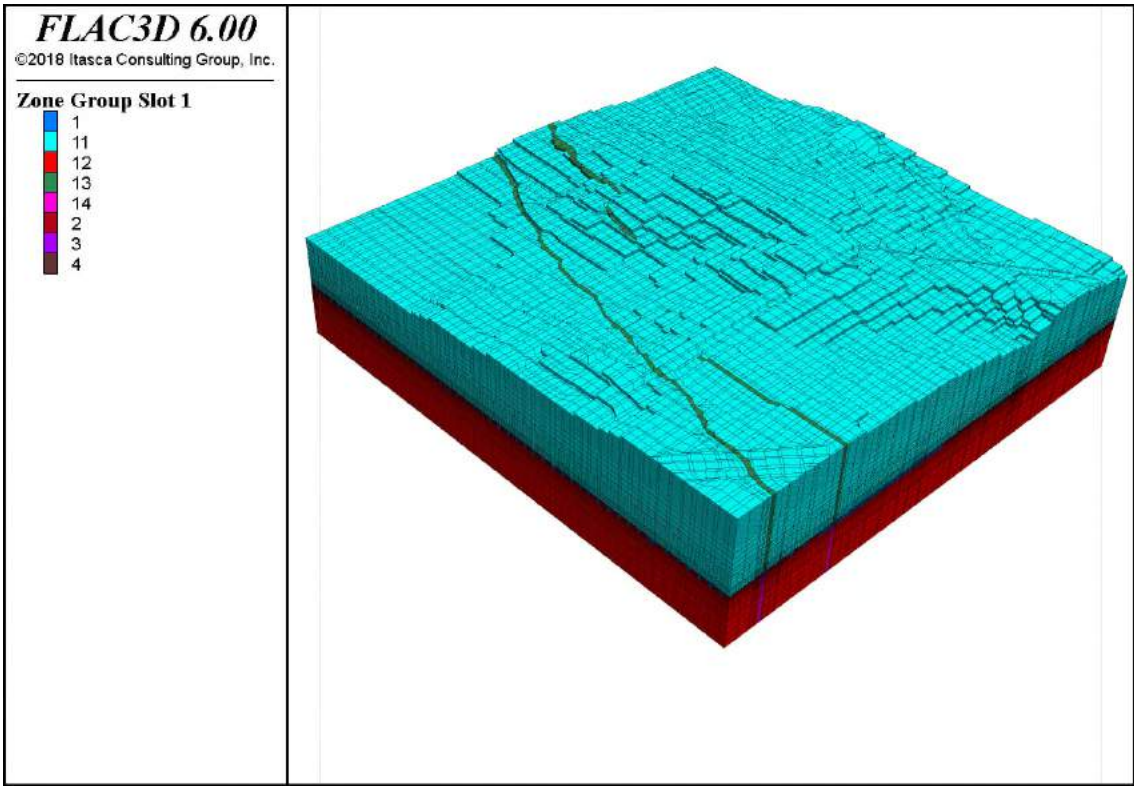

Figure 3: Complete model

3.3. Geotechnical model

The FLAC3D strain hardening/softening model with a Mohr-Coulomb failure criterion was adopted for the analyses. This model allows different cohesion values to be used depending on the strain. For the overburden rock, the FLAC3D strain hardening/softening ubiquitous joint model with a Mohr-Coulomb failure criterion was adopted to allow for planes of weakness into the rock mass to simulate bedding and allow some separation along these joints. Initial values of material parameters are based on approximations of borehole data using RocLab software and compared to published data. Table 1 has the adopted parameters for the general rock mass.

Table 1: Geotechnical model of layers used for 3 dimensional FLAC3D analyses

Material	Low to medium strength interbedded siltstone sandstone coal and tuff	High to very high strength interbedded siltstone and sandstone	Waratah Sandstone
Elevation (z) (m)	65 to -12	-12 to -55	-63 to -140
Density (γ kN/m3)	24	25.5	25.5
Youngs Modulus (E GPa)	0.15	1.7	4
Poisson's Ratio (ν)	0.25	0.25	0.25
Effective Cohesion (c'_{peak} kPa)	100	700	1200
Friction Angle (ϕ °)	30	45	45
Dilation Angle (ψ °)	5	10	10
Tension (kPa)	0.5	25	150
Bedding plane tension (kPa)	0	0	N/A
Bedding plane friction (°)	35	35	N/A
Bedding plane cohesion (kPa)	20	20	N/A

The effective cohesion was modelled to soften to 10% of the peak value at approximately 4% strain.

The ground is conservatively assumed to be drained with total stress (i.e. water level below mine level) despite the fact that the workings are flooded. This assumption causes the load applied to the mine pillars to be greater than possible because the effect of buoyancy on the effective weight of the ground has not been taken into account. This more closely resembles the loading at the end of mining.

Boundaries of the stratigraphic units were modelled using the drilling data at four general locations:

- VH01 (754-NTLGE206228-AG, 19 February 2018) (at the next-door site near the centre of the model)
- BH01 and BH02 (GEOTWARA22556AB-ACRev1, 13 March 2016 north western side of model)
- BH1C, BH1D, BH2A and BH2B (N8788-01-AH, 5 July 2004 south eastern corner of model)
- BH1 to BH3 (N7013-01-AE. dated 8 September 1998 north eastern corner of model)

The Borehole Seam in the area has a dip locally of up to 1 in 90. To simplify the construction of the model, the seam was assumed to be level, with the additional thickness of units included in the surface levels of each of the unit boundaries.

Only one significant fault was shown on the mine plans. The fault material was assumed to have the same strength of the respective surrounding rock of the same unit, however it was assumed to have reached its residual strength state (i.e. effective cohesion approximately 10% of peak strength (i.e. $c'_{fault} = c'_{residual} = 0.1 \times c'_{peak}$).

Material parameters for the coal pillars were calibrated to published empirical data and derivation of these parameters is presented in Section 3.4.

For the model, the horizontal stress in the major principal direction (i.e 'x' or north east to south west or along the pillars) has been assumed to be equivalent to a coefficient of earth pressure at rest (k_0) (i.e. (i.e.$\frac{\sigma_{h\,soil}}{k_0} = 1$)) for the soil zone and increasing at rock level at a similar rate similar to ¾ of vertical stress (i.e. $\Delta\sigma_{hx\,rock} = \frac{3}{4}\Delta\sigma_v$). Similarly, in the minor direction (i.e. 'y' or north west to south east or across the pillars) the horizontal stress was also taken as k_0. While within the rock zone the rate of increase in stress was taken as ½ of the vertical rate of change (i.e. $\Delta\sigma_{hy\,rock} = \frac{1}{2}\Delta\sigma_v$).

This means within the soil zone, the horizontal pressure is approximately 9kPa times the depth while in the rock zone the horizontal pressure is approximately 9kPa times depth of soil plus 18.75kPa times depth within rock in the x direction (principal) and approximately 9kPa times depth of soil plus 12.5kPa times depth within rock in the y direction (minor).

Although no pillars were modelled within the Yard Seam, an interface was allowed for. Table 2 provides properties of this failure plane.

Table 2: Failure properties of Yard Seam interface

Unit	Peak Effective Cohesion (c' MPa)	Peak Friction Angle Adopted (ϕ°)	Residual Effective Cohesion (c' MPa)	Residual Friction Angle Adopted (ϕ°)	Tension (kPa)	Stiffness Normal (E GPa)	Stiffness Shear (E GPa)
Yard Seam	0.2	16	0.05	15	1	60	30

3.4. Calibration of coal pillar strength

A critical factor in understanding the stability of the workings is the strength of the coal pillars. The strength of a coal pillar relies on three aspects:

- The intact coal strength
- The effect of discontinuities controlling the rock mass behaviour
- The coal pillar geometry, affecting the degree of confinement within the coal pillar core
- Confinement at the top and bottom of coal pillars

The intact coal strength of a seam will be dependent on the 'quality' of the coal. 'Dull' or silty coal will typically have a greater strength than the higher quality 'bright' or clean coal. The latter has predefined face cleats (essentially cleavage) aligned perpendicular to the primary regional stress direction. Within a seam, the overall seam strength will tend to vary depending on the variation of the distribution of the different quality layers within the coal.

The strength of the coal pillars was calibrated using a pillar height of 6.5m (the approximate height of the Borehole Seam less 0.2m for inferior coal left at floor of mine). The upper shale zone within the coal pillars was assumed to be 1.5 x the strength of the coal.

$$Sp = 8.6 \text{ x } \frac{w^{0.51}}{h^{0.84}} \qquad (1)$$

Where Sp = pillar strength, w = width and h = height in metres.

Sp = $8.6 \text{ x } 10.5^{0.51}/6.5^{0.84}$ = 5.9MPa for the 10.5m wide pillar, (general seam in area)

The coal pillars have been modelled with:

- A peak strength as per Equation 1 above, before crushing of the pillar.
- A plastic phase that decreases in strength due to plastic deformation. Once the load on the pillar reaches its ultimate strength a strain softening phase is implemented at a volumetric plastic shear strain of 0.005 (0.5%) to 0.04 (4%).
- An after-crush phase where the rubble within the bord (combination of roof fall, expanded coal pillar and poor coal) provides confinement of the pillar. The amount of crush aimed for, for each of the individual pillars, at the site-specific pillar stress is estimated to be 0.5m.

The result of the pillar calibrations, with a course mesh similar to that used for the pillars within the model, are shown below in Figure 4 with the final parameters given in Tables 3 and 4.

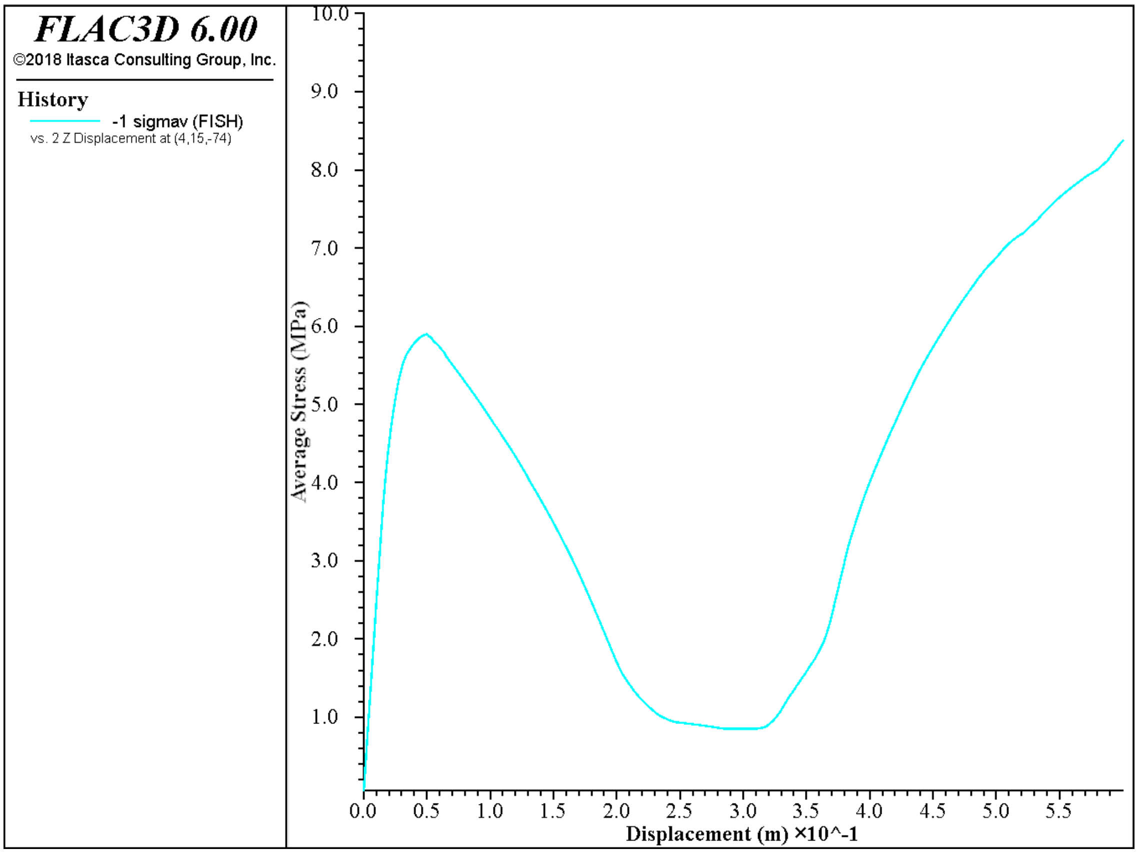

Figure 4: Original pillar calibration for the 10.5m coal pillars assuming a 6.5m height

Table 3: Summary of pillar calibration

Unit	Calibrated Effective Cohesion (c' MPa)	Friction Angle Adopted (ϕ°)	Tension (kPa)	Young's Modulus (E GPa)	Poisson's Ratio (ν)
10.5m pillar coal (6.5m high)	0.96	28	10	2	0.3
10.5m pillar siltstone high (6.5m high)	1.44	30	40	3	0.3

A series of two interfaces were adopted one at the top and one at the bottom of the coal pillars.

Table 4: Geotechnical model of interfaces within coal pillars used for the three-dimensional FLAC3D analysis

Unit	Peak Effective Cohesion (c' MPa)	Peak Friction Angle Adopted (ϕ°)	Residual Effective Cohesion (c' MPa)	Residual Friction Angle Adopted (ϕ°)	Tension (kPa)	Stiffness Normal (E GPa)	Stiffness Shear (E GPa)
Top Pillar	0.2	16	0.05	15	1	60	30
Bottom Pillar	0.2	16	0.05	15	1	40	20

4. Stages of calculation

The following stages were adopted in the calculations:

- Construct the x-y (flat) plane of the model, based on of mine workings.
- Extrude main section body of model reducing the elements in the x-y plane in three stages.
- Deleting elements from the x-y plane before ‘extruding’ to account for surface topography
- Calibrate ground parameters with collected and inferred field data relevant to the area, including historical records and previous empirical relationships of pillar width and height to pillar strength.
- Apply the geostatic initial stresses to the model. For conservatism with respect to pillar stresses, the ground water has been assumed to be below mine level.
- Progressively excavate the mining voids (bords and headings) to simulate the condition after mining was completed (although at the current bord height of 8m).
- Trigger pillar run without modifying the strength of coal pillars and watch path of conceptual ‘creep’. The overburden stresses are distributed according to relative stiffness of the coal in each area and amount of collapse of pillars in the area. The degree of deformation (to a condition of collapse) is assessed, including how that deformation transpires to potential surface movement.
- Modify pillar parameters to get behaviour representative of the historic ‘creep’ events and repeat previous step.
- Add grout to select mine voids retrigger pillar run
- Progressively reduce strength and tension parameters of remaining pillars to assess conceptual reductions in strength required for pillar failure and resulting ground subsidence in different areas.
- This report was then developed.

5. Results and discussion

5.1. Excavation of bords

After application of in situ field stresses, the bords were excavated in stages in the model, as is required to prevent numerical instability during the analyses.

An output that summarises the final vertical stress after excavation (at completion of initial mining) is given below in Figure 5. This provides an image of the layout of workings, showing overburden stress being distributed between pillars’ cores and the extent of mining.

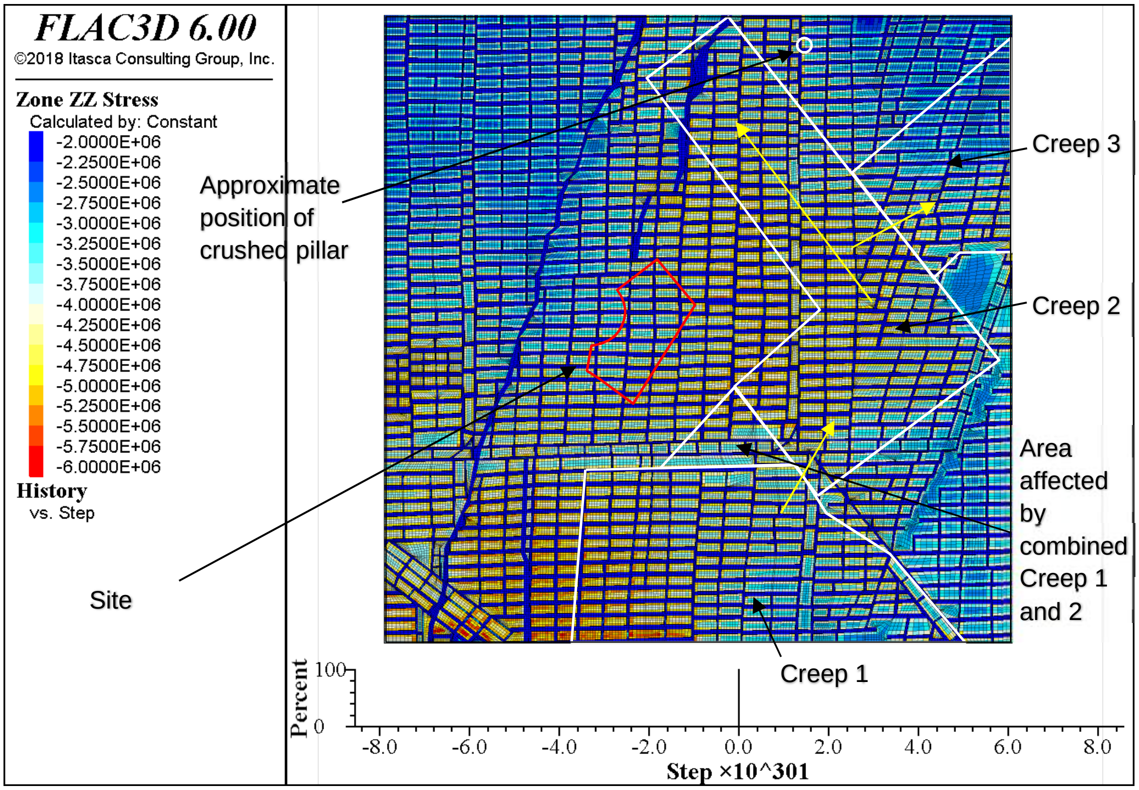

Figure 5: Vertical stress at Borehole Seam level before collapse with historical 'Creeps' shown

Figure 5 shows the variation in stress at the end of mining before the historical creep events (Creeps 1 to 3). It is noted the pillars around Creep 2 appear to behave elastically (i.e. load higher around the outside of the pillar 5MPa to the core of 4MPa) while in the western portion of the Creep 1 area, the highly stressed pillars are starting to behave plastically with over 5MPa though out. It is noted that the vertical depth to the mine workings and or thickness of workings near Creep 1 may have some inconsistencies to the actual conditions as the higher loaded area is west of the Creep 1 and a natural valley is present over the eastern portion of Creep 1 reducing the overburden. This is not deemed to substantially affect the results of the modelled ground behaviour at the location of The Site.

The assumed path of the 'Creeps' is shown by the yellow arrows. Of note is the low stress in the area of Creep 3. In this area the additional historical creep may be the result of the thicker Borehole Seam. Conversely, pillars around The Site although subjected to high overburden stresses have not apparently failed as a part of the historical creep events may be due to lower mined heights and or Borehole Seam thickness.

5.2. Modelling historical creep events

5.2.1. Similar properties through all coal pillars

Initially the model was set up with similar properties for all coal pillars. To observe the path of the modelled creep event (pillar failure), a small zone of pillars was weakened at the edge of the model within the Creep 1 area. Screen images were taken regular intervals within solving phase following the path of the modelled creep event. These images are shown in Figures 6 to Figure 13 (refer to Figure 5 for labels of each area).

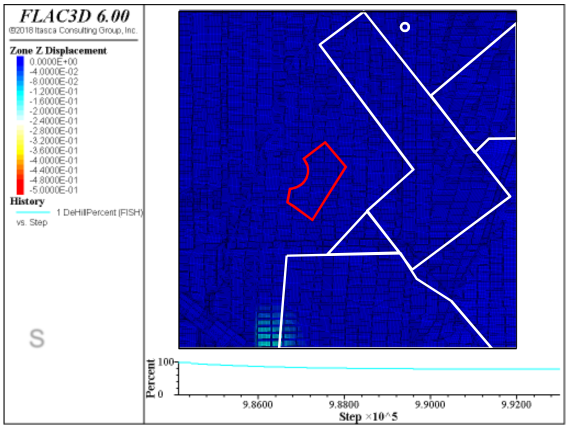

Figure 6: Screen shot one of modelled creep all same strength

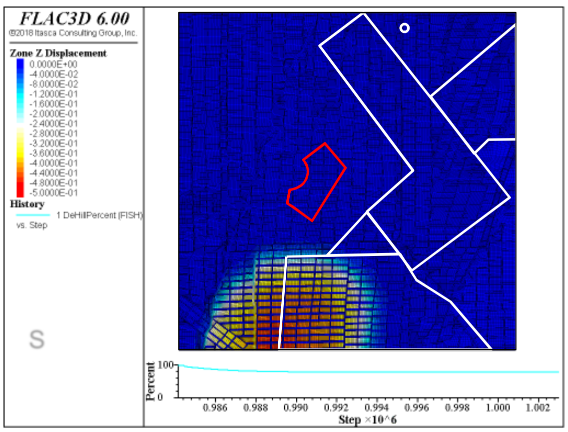

Figure 7: Screen shot two of modelled creep all same strength

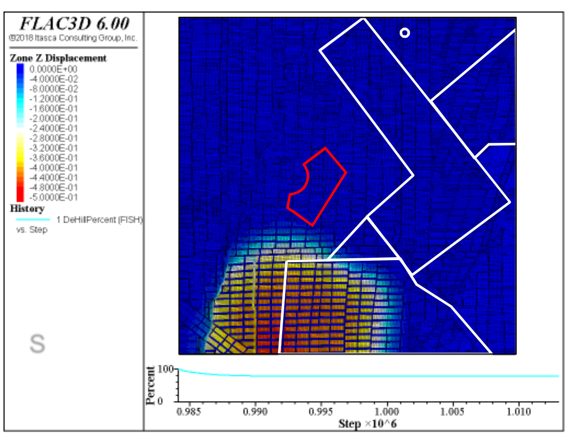

Figure 8: Screen shot three of modelled creep all same strength

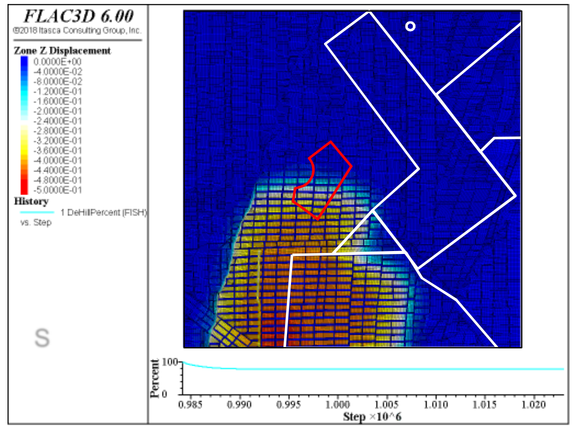

Figure 9: Screen shot four of modelled creep all same strength

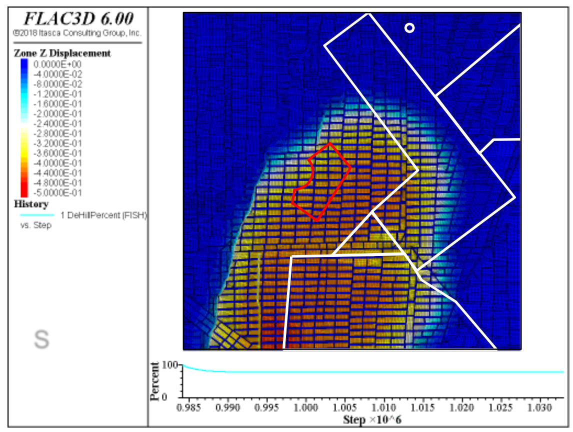

Figure 10: Screen shot five of modelled creep all same strength

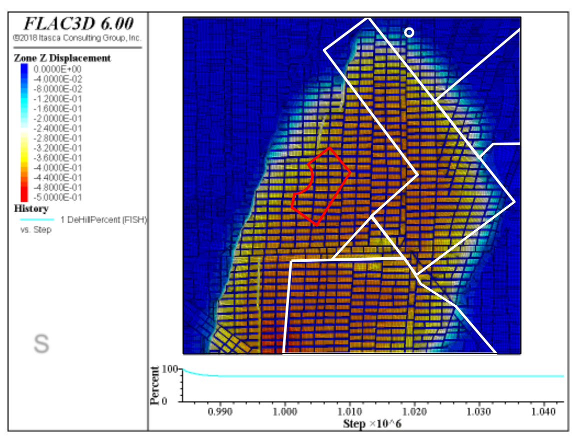

Figure 11: Screen shot six of modelled creep all same strength

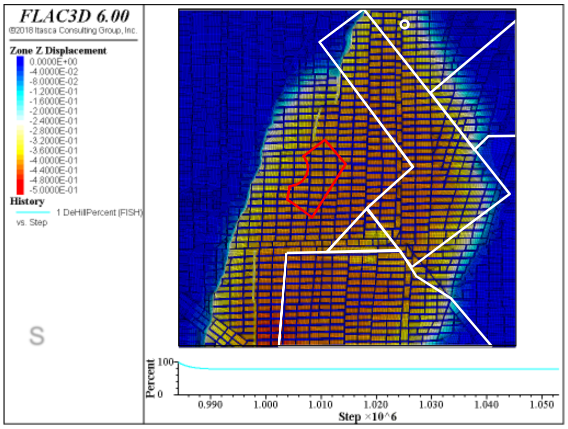

Figure 12: Screen shot seven of modelled creep all same strength

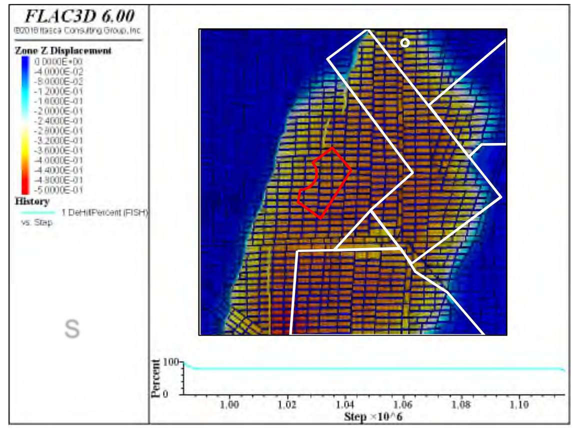

Figure 13: Screen shot eight of modelled creep all same strength

This resulted in a creep pattern that is inconsistent with the pattern of the actual historical creep events. As can be seen in the above, once the creep event is initiated, the creep event would be expected to progress through the whole area if the mining height was equal. However, it is known the heading south of The Site stopped the progression of historical Creep 1. A variation in mined heights or other variable must be considered to account for this discrepancy between the initially modelled creep and the known progression of the actual historical creep events.

5.2.2. Recalibration of coal strength at site

Even though the thickness of the coal seam at The Site was only 6m, the coal pillars appear to have not been crushed by past creep events (Coffey Report 754-NTLGE220504-AH.Rev2 dated 17 December 2018). As such, the strength of the coal around the site must be higher than the surrounding area. To more closely resemble the historical Creep events, the coal strength around The Site was increased in stages in order to simulate the historical creep events in the remodel. This was simulated by increasing c' to 1.03MPa (similar to 6.0m high coal pillars), then to 1.1MPa, and finally 1.2MPa (similar to 5.1m high coal pillars.) Coal strength recalibration is shown in Figures 14 and 15. Figure 16 shows the area to recalibrated coal strengths are modelled.

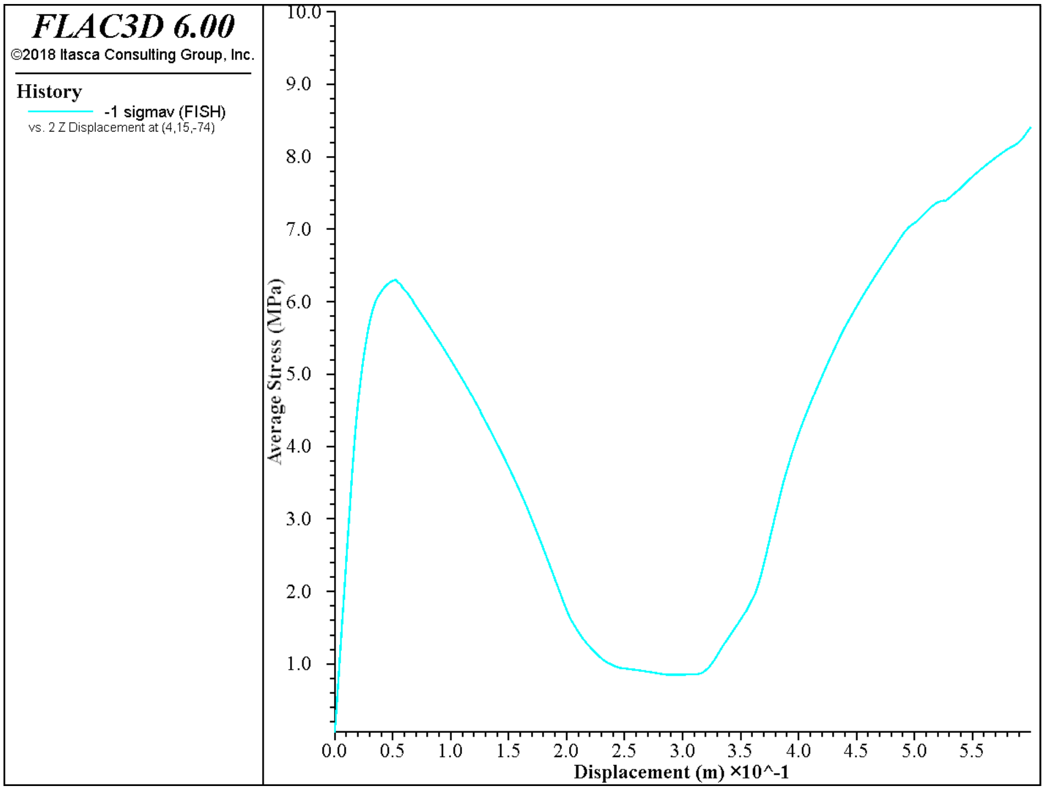

Figure 14: Recalibration curve with c' assumed to be 1.03MPa

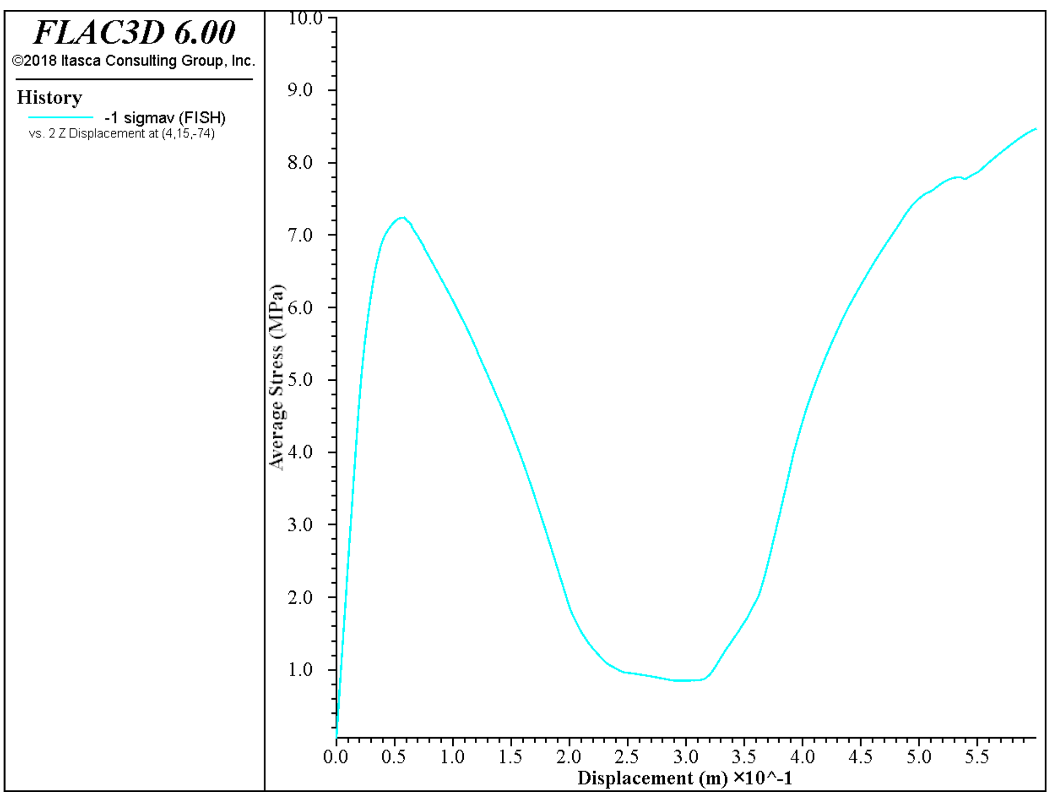

Figure 15: Recalibration curve with c' assumed to be 1.2MPa

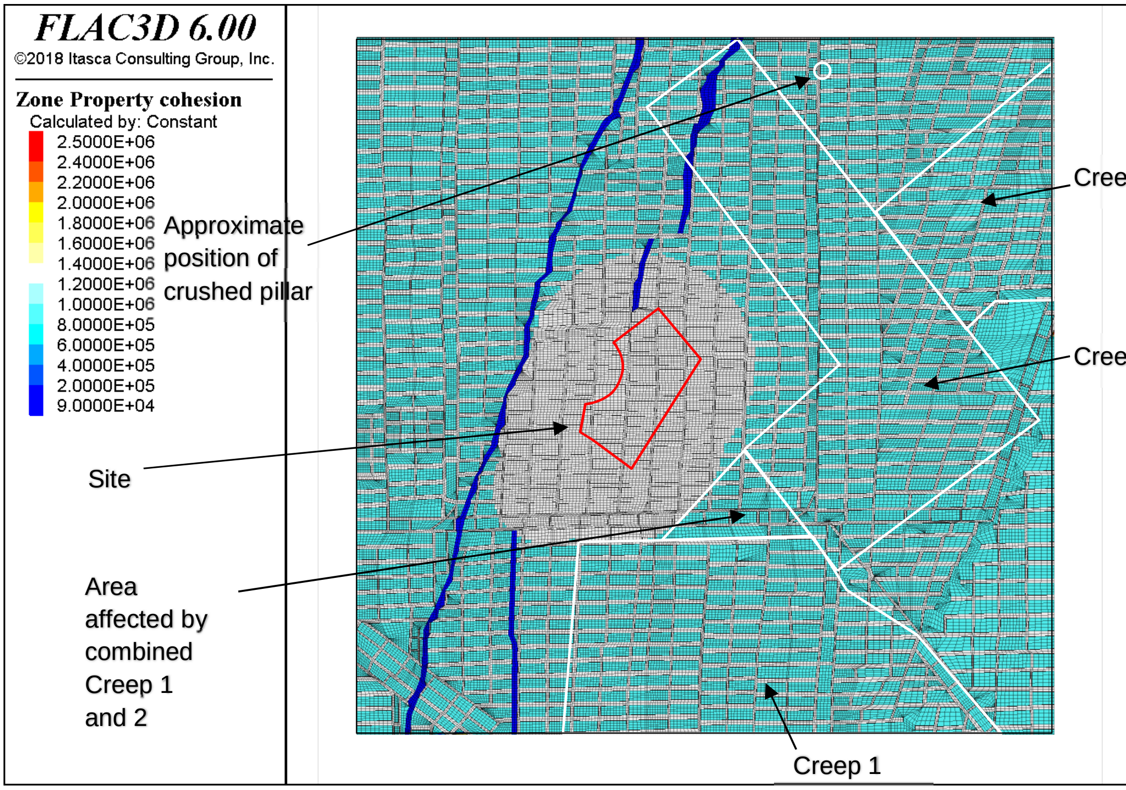

Figure 16: Area with higher cohesion in each reiteration

Figures 17 to 25 shows the sequence of image stills showing the path of the modelled creep assuming coal strength c'=1.03MPa (note the c' of the upper 2m roof collapse shale and silty coal is assumed to be 1.5 times higher).

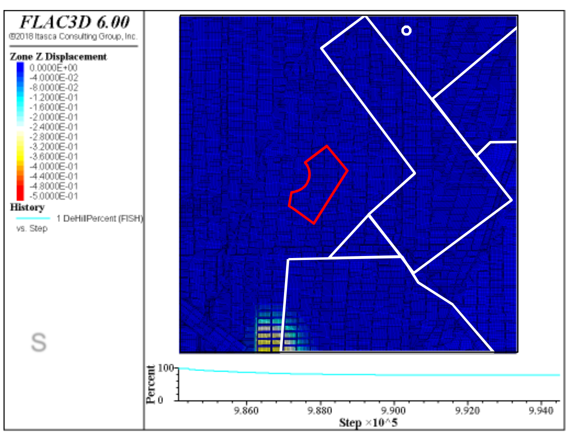

Figure 17: Screen shot one of modelled creep c' = 1.03MPa

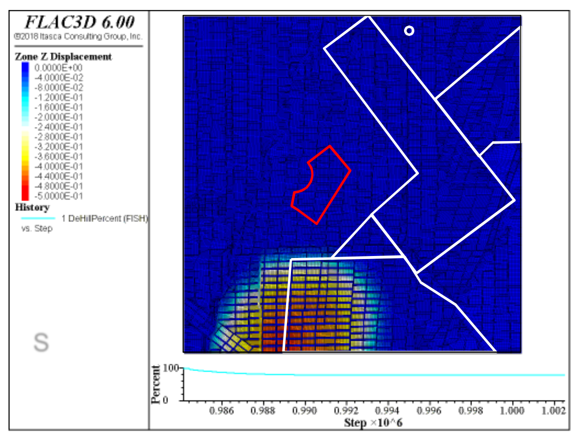

Figure 18: Screen shot two of modelled creep c' = 1.03MPa

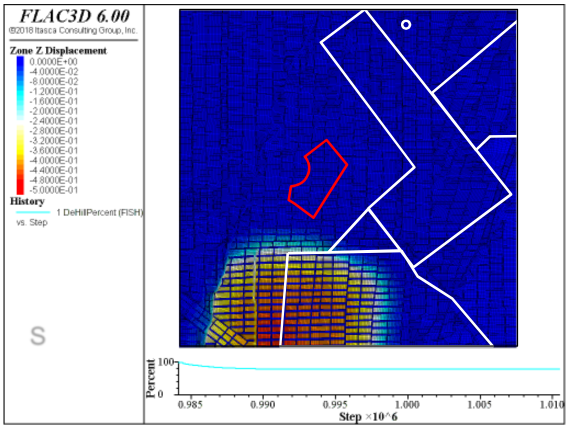

Figure 19: Screen shot three of modelled creep c' = 1.03MPa

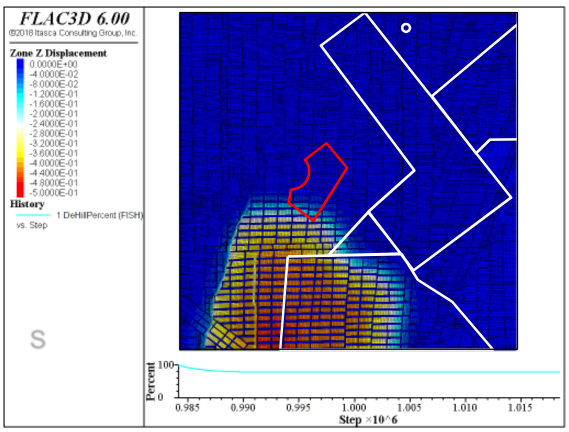

Figure 20: Screen shot four of modelled creep c' = 1.03MPa

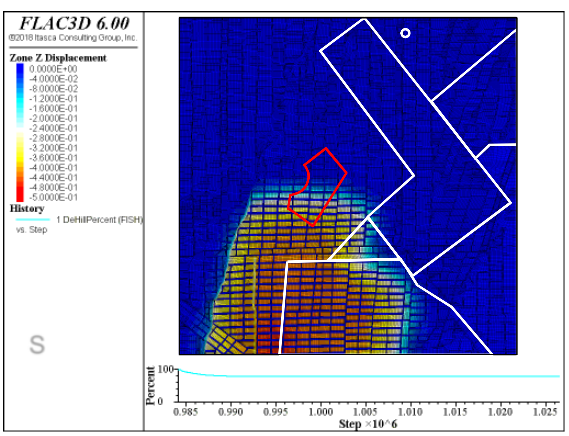

Figure 21: Screen shot five of modelled creep c' = 1.03MPa

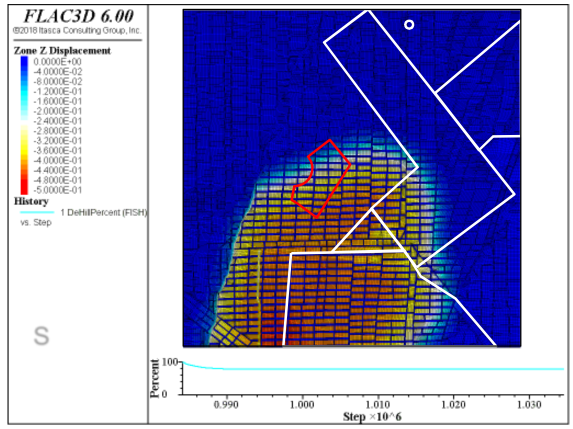

Figure 22: Screen shot six of modelled creep c' = 1.03MPa

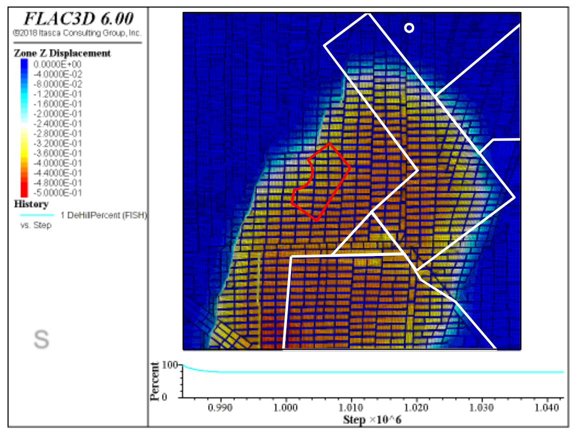

Figure 23: Screen shot seven of modelled creep c' = 1.03MPa

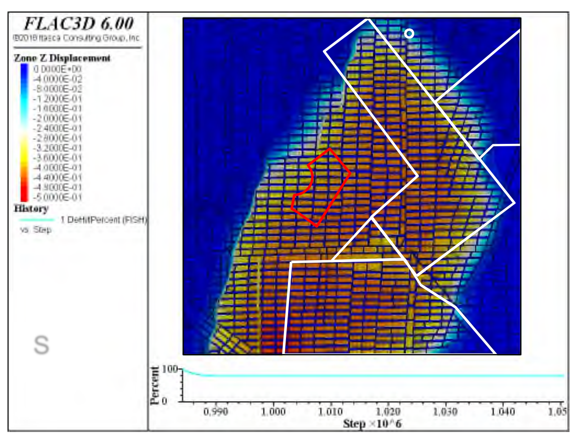

Figure 24: Screen shot eight of modelled creep c' = 1.03MPa

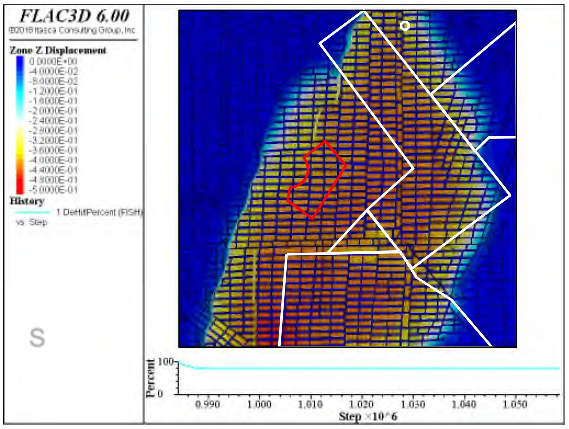

Figure 25: Screen shot nine of modelled creep c' = 1.03MPa

As the modelled creep path still appears inconsistent with that followed by the historical creep events, the coal strength c' around The Site was increased again, this time to 1.1MPa.

Figures 26 to 35 shows the sequence of image stills showing the path of the modelled creep assuming coal strength c'=1.1MPa (note the c' of the upper 2m roof collapse shale and silty coal is assumed to be 1.5 times higher)

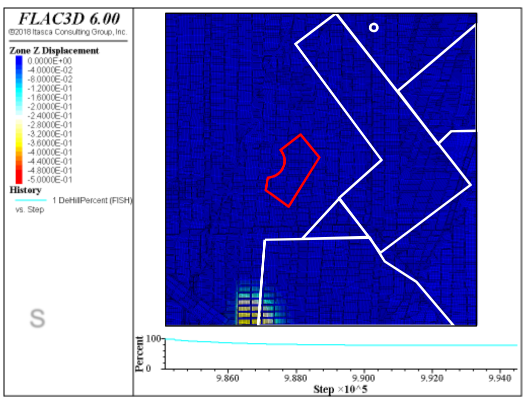

Figure 26: Screen shot one of modelled creep c' = 1.1MPa

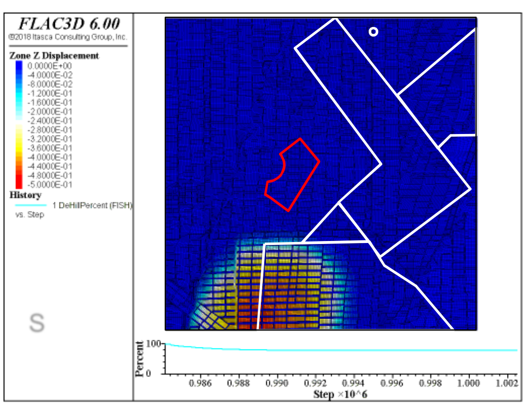

Figure 27: Screen shot two of modelled creep c' = 1.1MPa

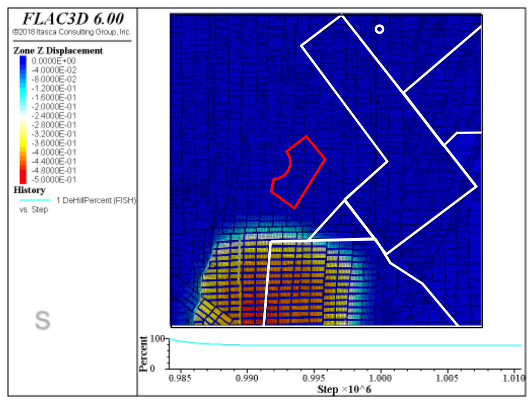

Figure 28: Screen shot three of modelled creep c' = 1.1MPa

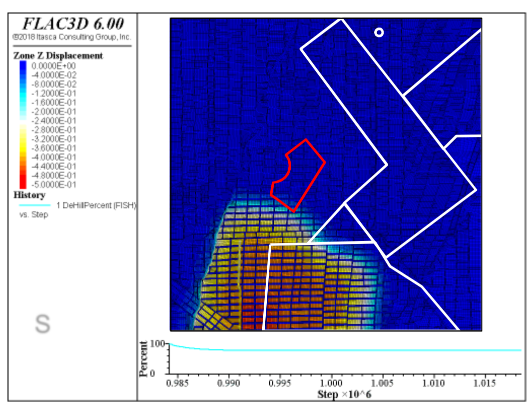

Figure 29: Screen shot four of modelled creep c' = 1.1MPa

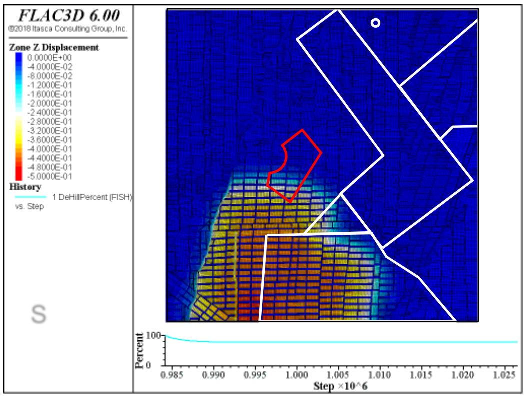

Figure 30: Screen shot five of modelled creep c' = 1.1MPa

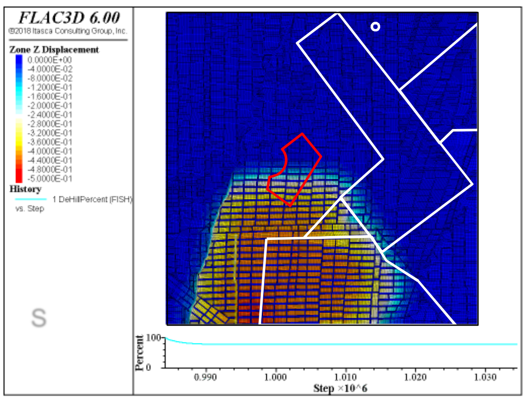

Figure 31: Screen shot six of modelled creep c' = 1.1MPa

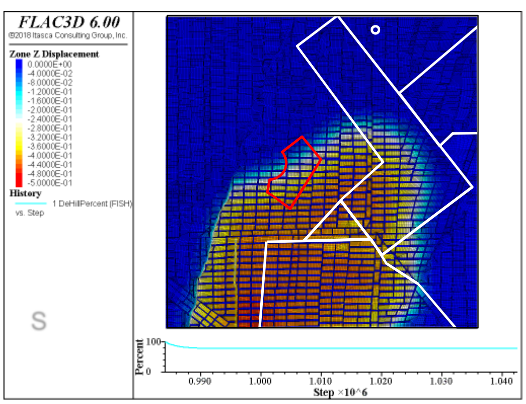

Figure 32: Screen shot seven of modelled creep c' = 1.1MPa

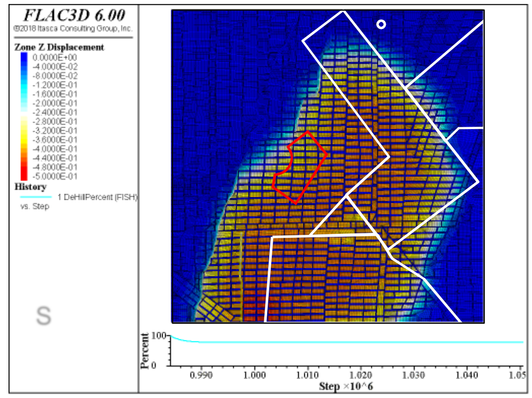

Figure 33: Screen shot eight of modelled creep c' = 1.1MPa

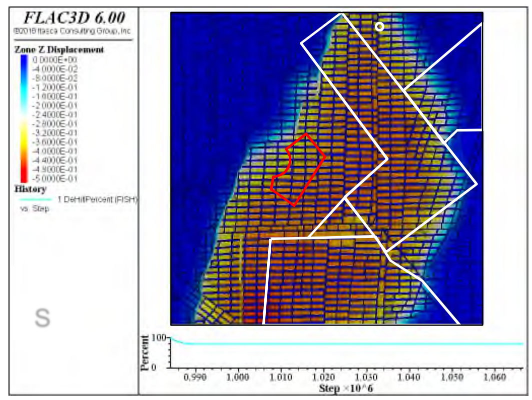

Figure 34: Screen shot nine of modelled creep c' = 1.1MPa

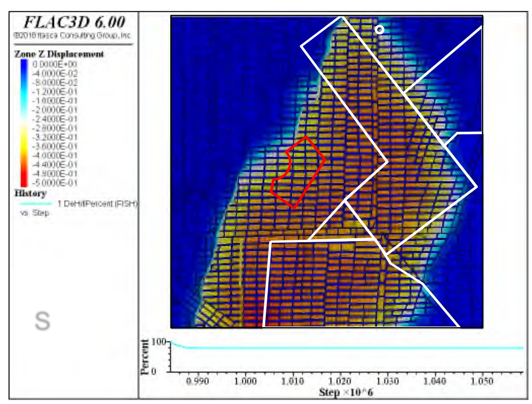

Figure 35: Screen shot ten of modelled creep c' = 1.1MPa

As the modelled creep path still appears inconsistent with that followed by the historical creep events, the coal strength c' around The Site was increased again, this time to 1.2MPa.

Figures 36 to 51 shows the sequence of image stills showing the path of the modelled creep assuming coal strength c'=1.2MPa (note the c' of the upper 2m roof collapse shale and silty coal is assumed to be 1.5 times higher)

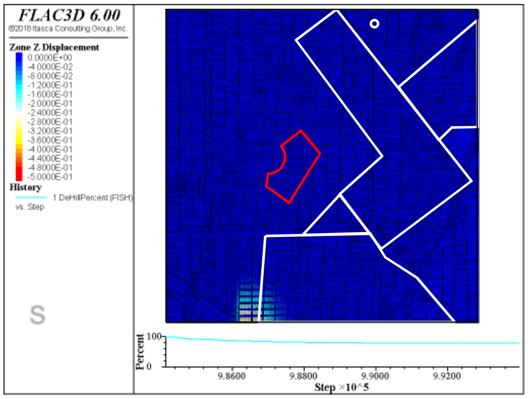

Figure 36: Screen shot ten of modelled creep c' = 1.2MPa

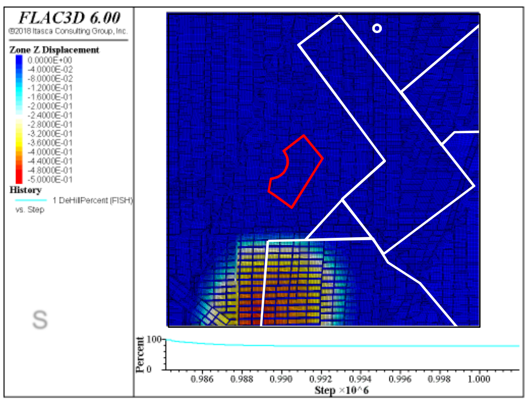

Figure 37: Screen shot two of modelled creep c' = 1.2MPa

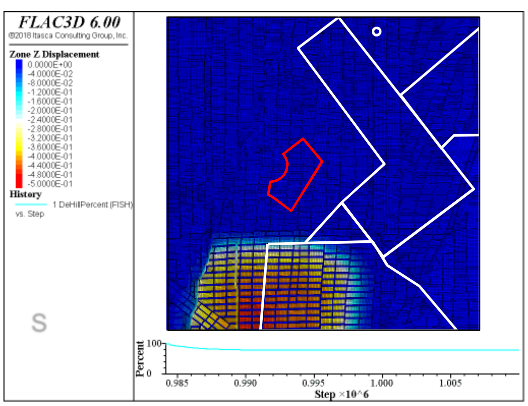

Figure 38: Screen shot three of modelled creep c' = 1.2MPa

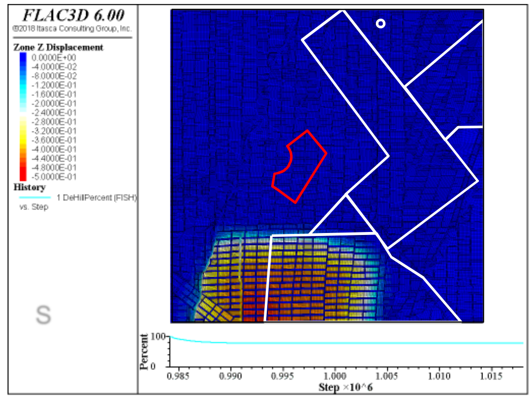

Figure 39: Screen shot four of modelled creep c' = 1.2MPa

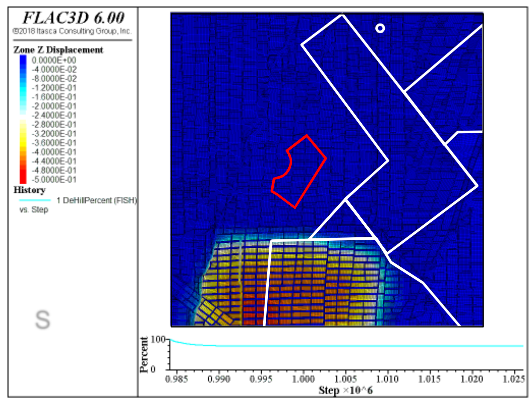

Figure 40: Screen shot five of modelled creep c' = 1.2MPa

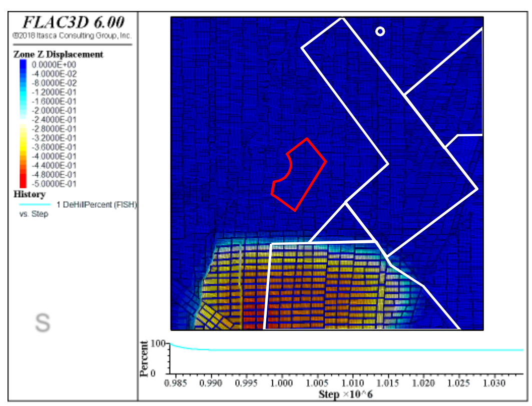

Figure 41: Screen shot six of modelled creep c' = 1.2MPa

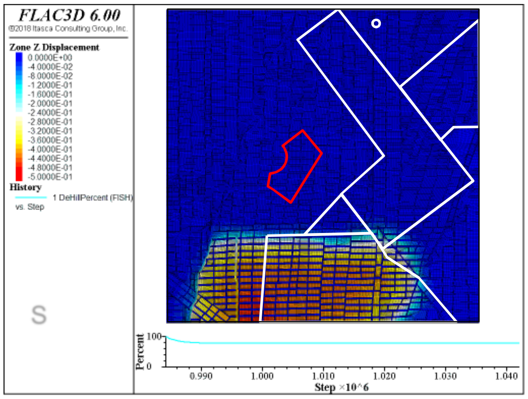

Figure 42: Screen shot seven of modelled creep c' = 1.2MPa

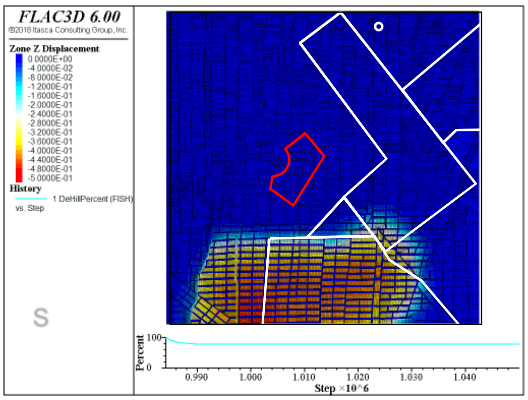

Figure 43: Screen shot eight of modelled creep c' = 1.2MPa

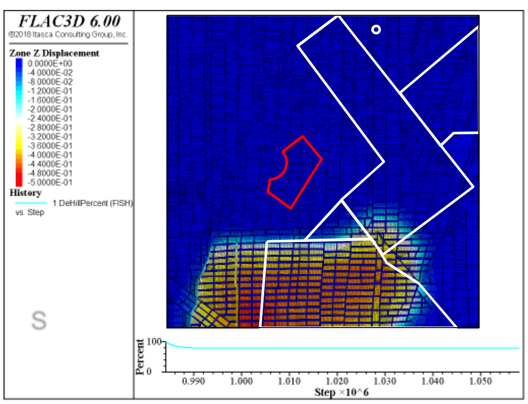

Figure 44: Screen shot nine of modelled creep c' = 1.2MPa

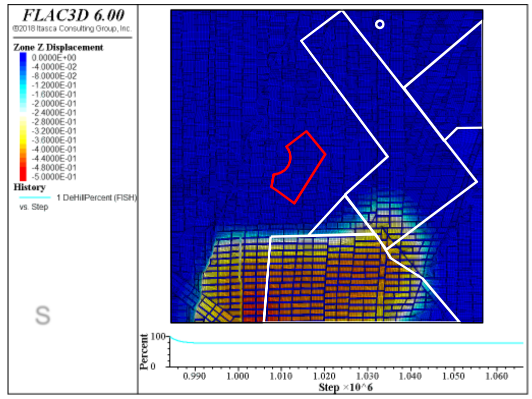

Figure 45: Screen shot ten of modelled creep c' = 1.2MPa

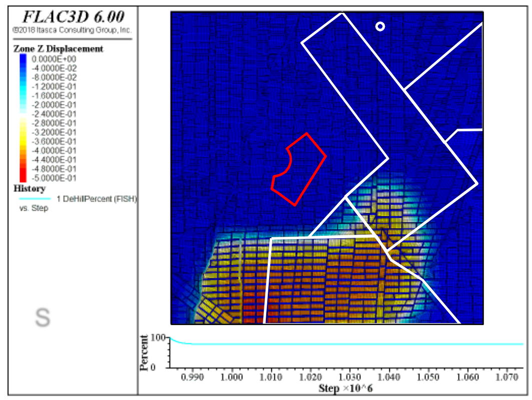

Figure 46: Screen shot eleven of modelled creep c' = 1.2MPa

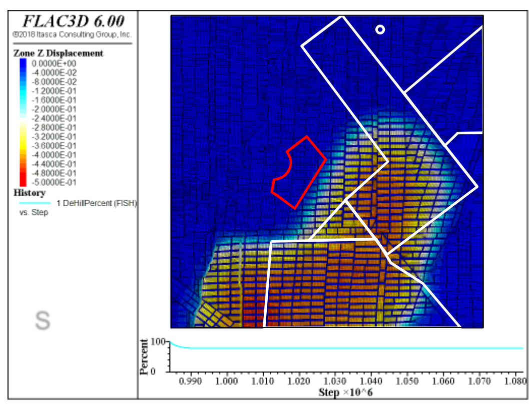

Figure 47: Screen shot twelve of modelled creep c' = 1.2MPa

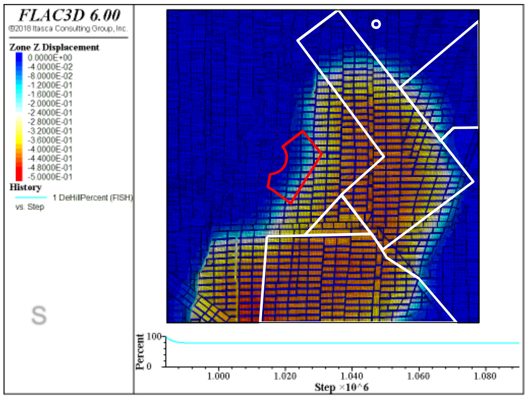

Figure 48: Screen shot thirteen of modelled creep c' = 1.2MPa

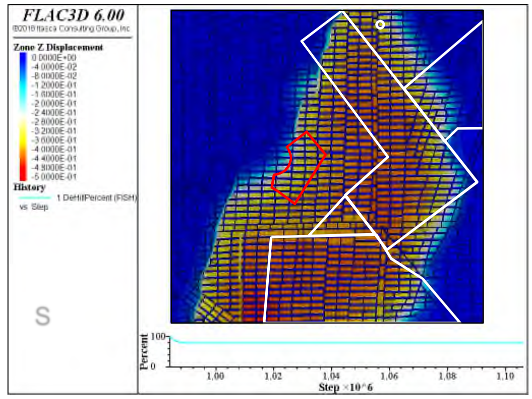

Figure 50: Screen shot fifteen of modelled creep c' = 1.2MPa

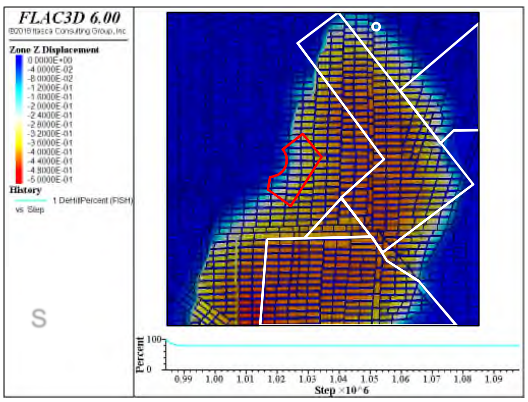

Figure 49: Screen shot fourteen of modelled creep c' = 1.2MPa

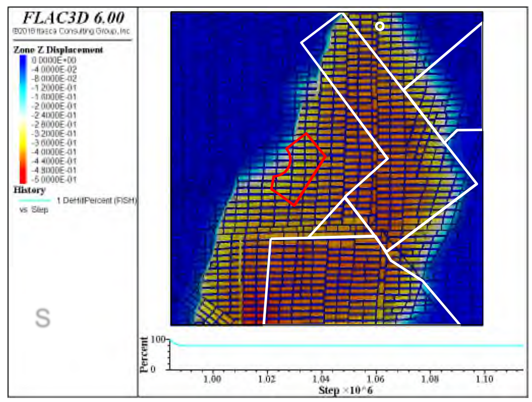

Figure 51: Screen shot sixteen of modelled creep c' = 1.2MPa

Although the model still has pillars under The Site failing at the new assumed coal strength, the path now appears to be more consistent with the historical creeps and as such further increase in coal strength for the coal pillars under The Site was not carried out. This allows for some conservatism.

5.3. Addition of grout to selected bords

To assess a suitable grouting strategy for the site, the model was reset back to the uncrushed state before adding grout to selected bords. The grout was generally added in groups of four, two per bord either side of eight coal pillars. At the two critical corners, an additional bord (i.e. three bords) was deemed necessary, while within the centre of the site the grouting was reduced to only one location per bord. The grouting strategy was developed to control the behaviour of the subsidence profile rather than to fill the whole area to eliminate all subsidence.

Due to the height of overburden and the low factor of safety of the area, the proposed grout strength is 5MPa for the Site. With reference ACARP 2001, the modulus of flyash grout may be expected to be 300 x the UCS strength. Allowing for some conservatism, a base modulus of 1,000MPa was adopted, reducing within the bord depending on the position within the rubble. The final adopted values for grout strength are shown in Table 5.

Table 5: Parameters for grout locations

Unit	Effective Cohesion (c' kPa)	Friction Angle Adopted (ϕ°)	Youngs Modulus (E MPa)	Poisson's Ratio (ν)
Proposed grout bottom 2m (i.e. significant rubble with poor permeation)	5	29	120	0.3
Proposed grout 2m to 6m (i.e. significant rubble with ok permeation)	250	29	500	0.3
Proposed grout upper 2m (i.e. Solid grout	500	29	1000	0.3

Grout locations were chosen to be generally within 0.5 x the depth to workings around the boundaries of proposed buildings. Figure 52 shows proposed grout locations with ground slopes visible in Figure 53.

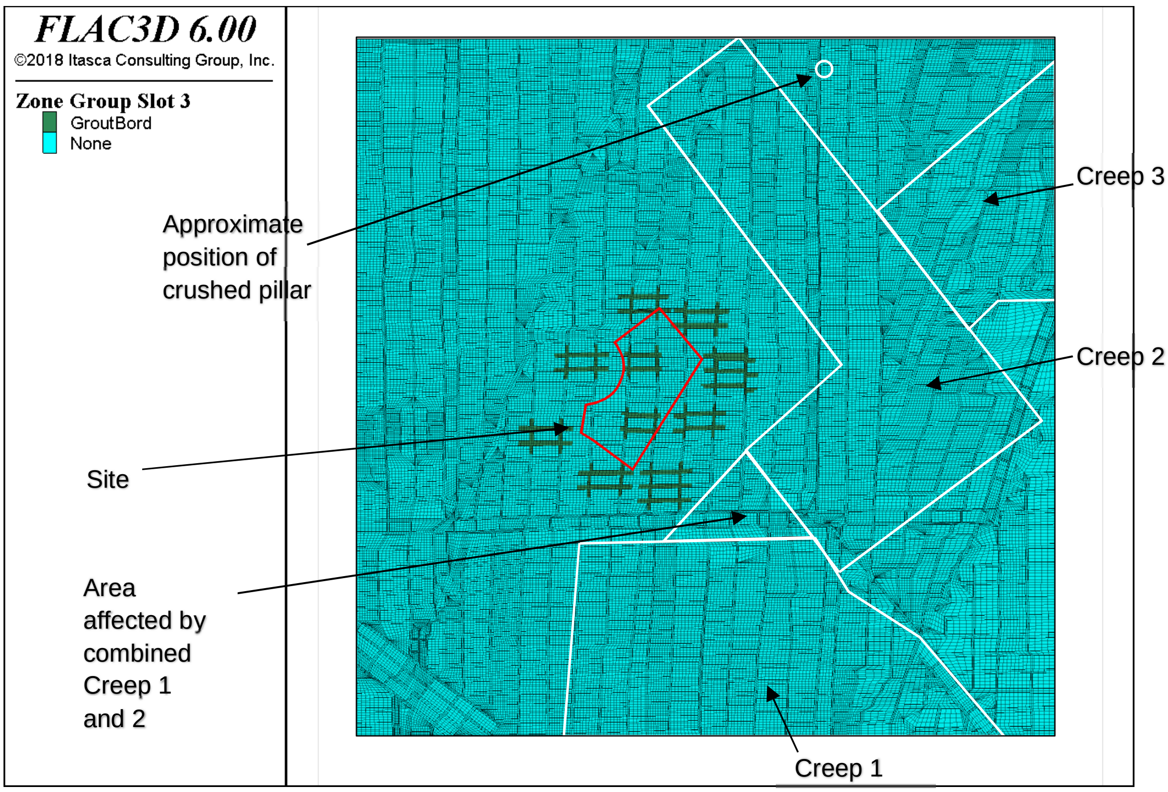

Figure 52: Proposed grout layout

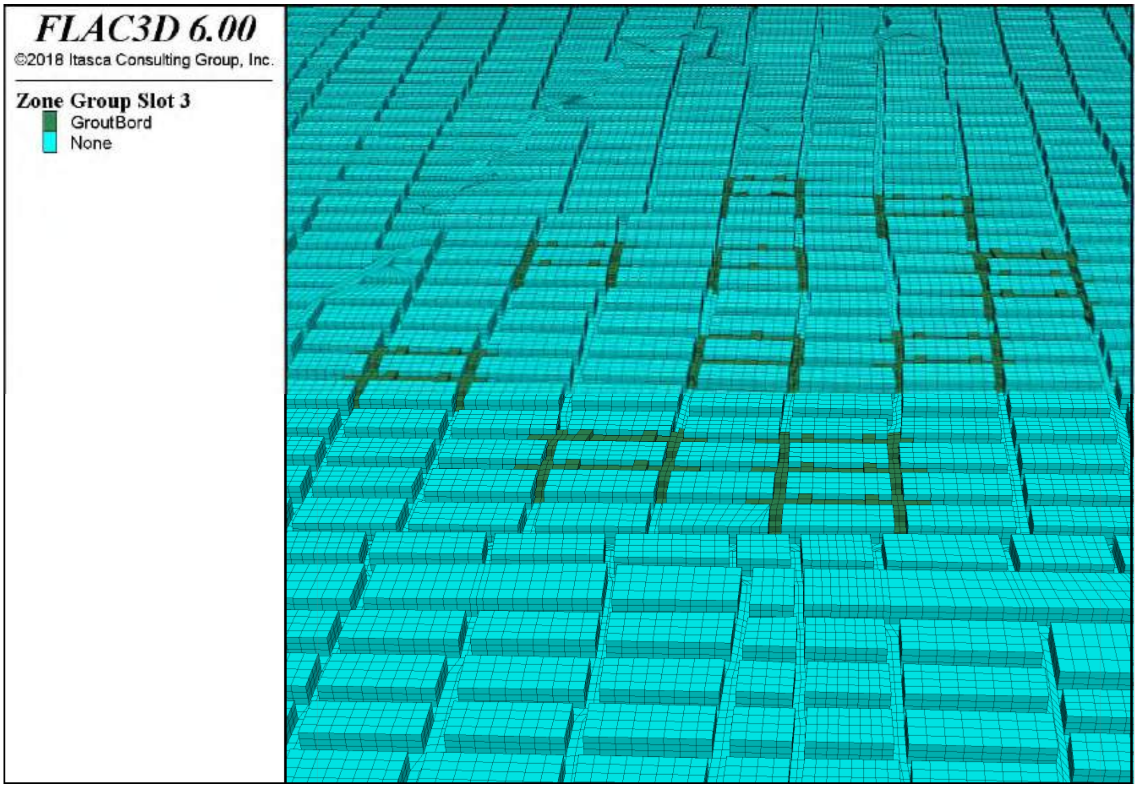

Figure 53: Closeup of grout locations with grout surface visible (i.e. cones of grout with a small 2m width zone connected to the roof with remaining grout 2m from roof)

5.4. Gradual degradation of coal strength methodology

To allow for the possible/conceivable slow degradation of coal strength, the coal strength in the numerical model was reduced by approximately 5% for each stage solved by the modelling. The resultant condition for generally every five increments is then saved for later examination as well as at increment two. This results in the following reduction of coal strength:

- $0.95^{2} = 0.90$
- $0.95^{5} = 0.77$
- $0.95^{10} = 0.60$
- $0.95^{15} = 0.46$
- $0.95^{20} = 0.36$
- $0.95^{25} = 0.28$
- $0.95^{27} = 0.25$

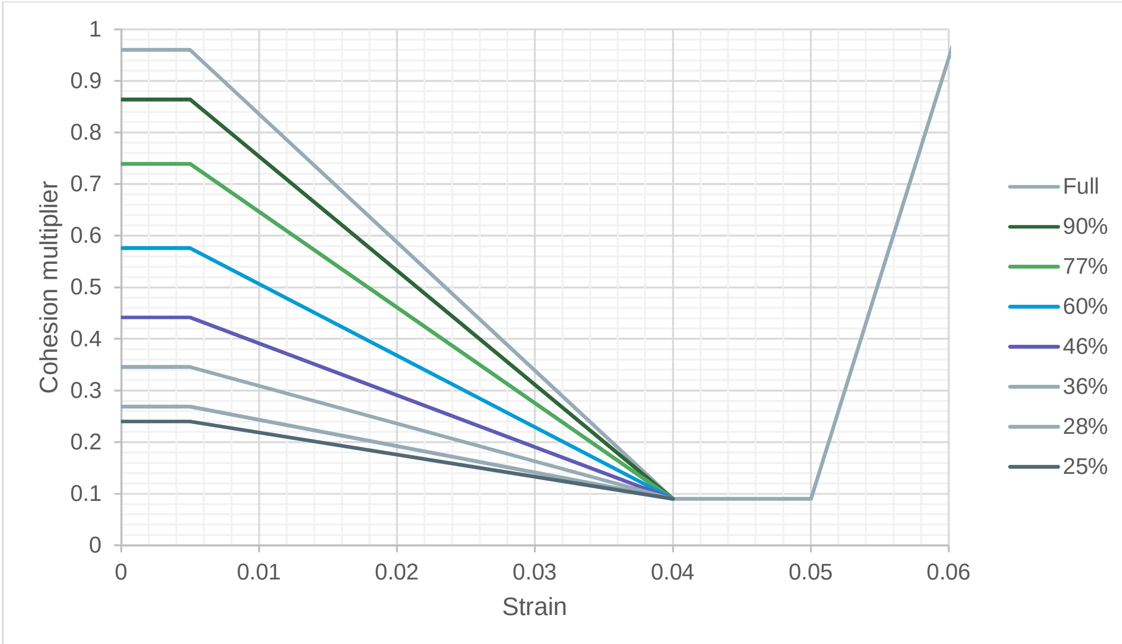

Figure 54: Degradation of peak coal strength

5.5. Output of results

Although the modelling of the pillar crushing causes several forms of displacements, we have chosen to output the conceptual vertical displacement (settlement) at surface level and its distribution at the surface to demonstrate the effect of potential future pillar crushing/convergence at surface level.

5.5.1. Retrigger of modelled creep with grout in place

After the addition of grout, the pillar run was retriggered similar to as described above at the edge of historical Creep 1 in the most highly stressed pillars in the model. This settlement is shown in Figure 55. It is noted that with the addition of remedial grouting, the modelled creep and settlement did not extend to The Site as previously illustrated in figures 44 to 51.

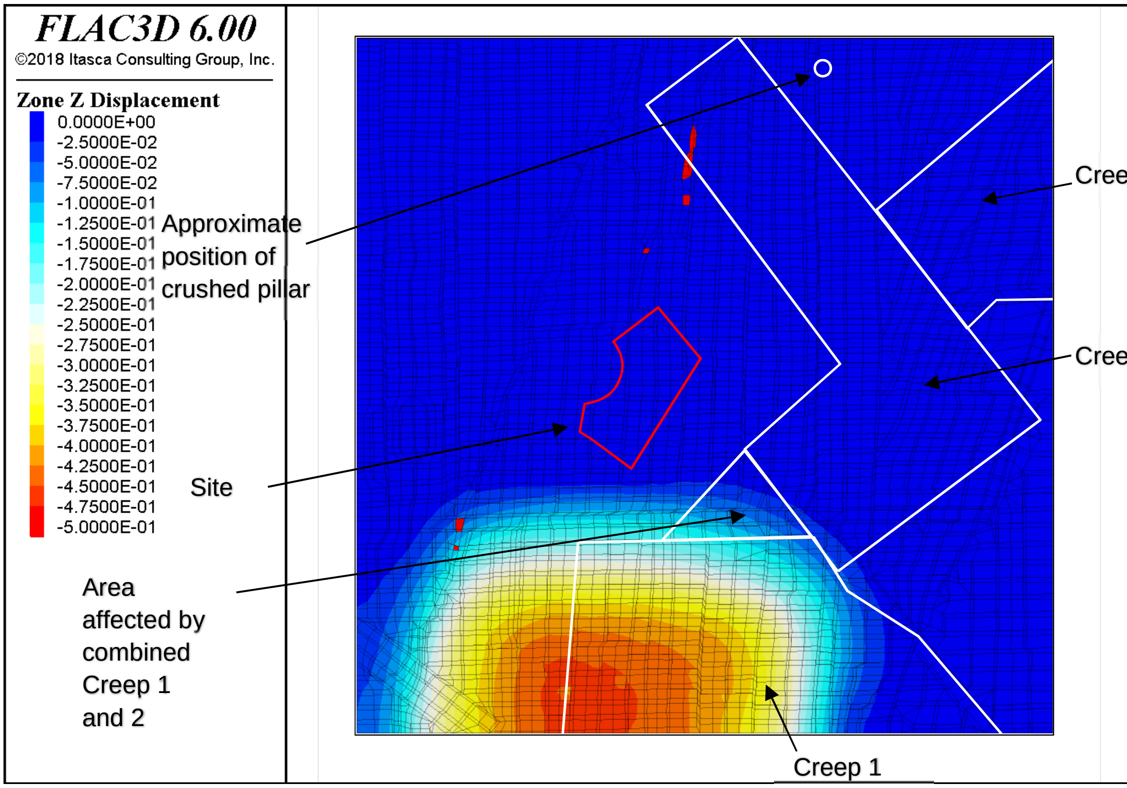

Figure 55: Modelled creep event conceptual surface displacement.

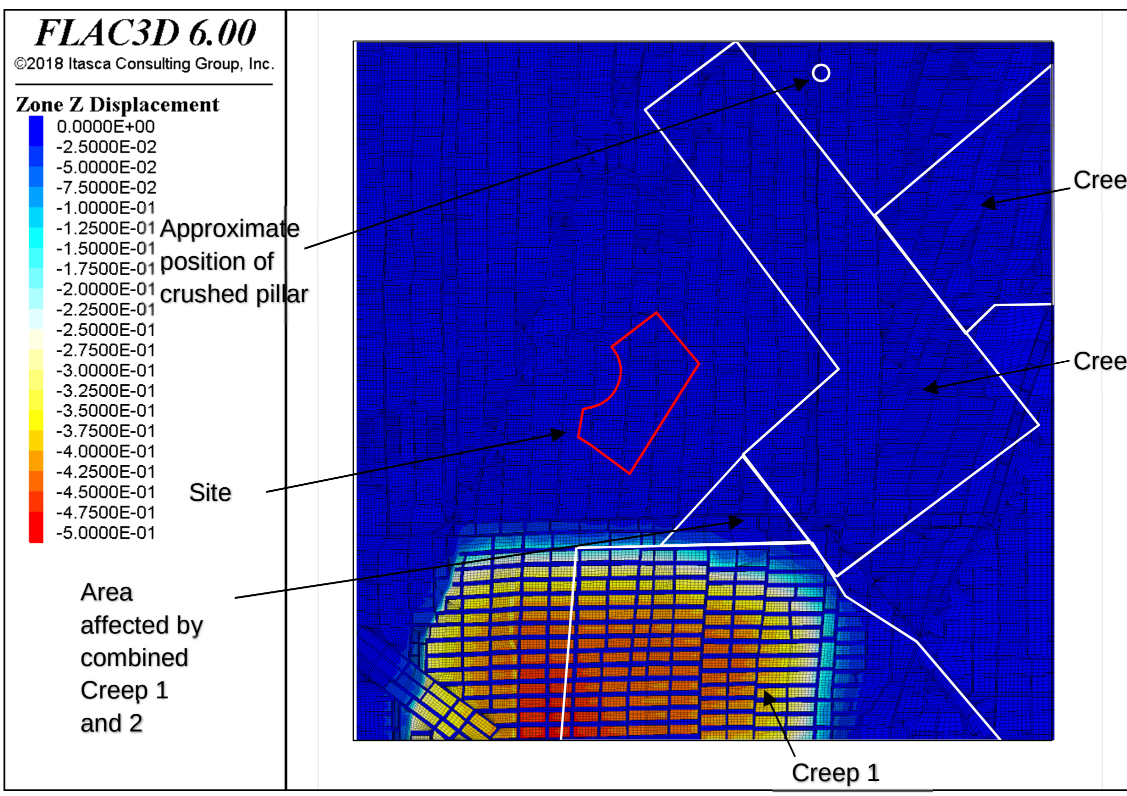

Figure 56: Borehole Seam crush after modelled creep

5.5.2. Degradation phase

Figures 57 to 63 show the change in the crush front at strengths of 90%, 77%, 60%, 46%, 36%, 28% and 25%.

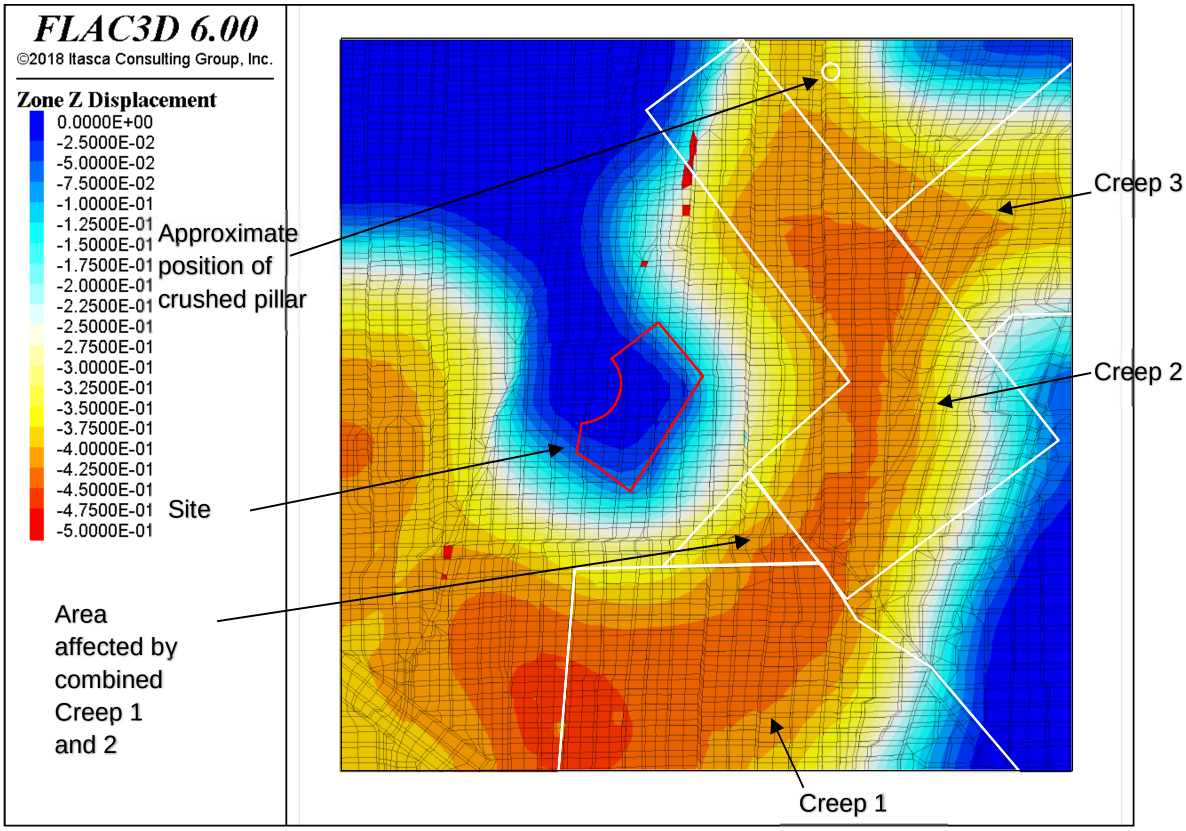

Figure 57: Conceptual vertical displacement with pillar coal at 90% strength with proposed grout

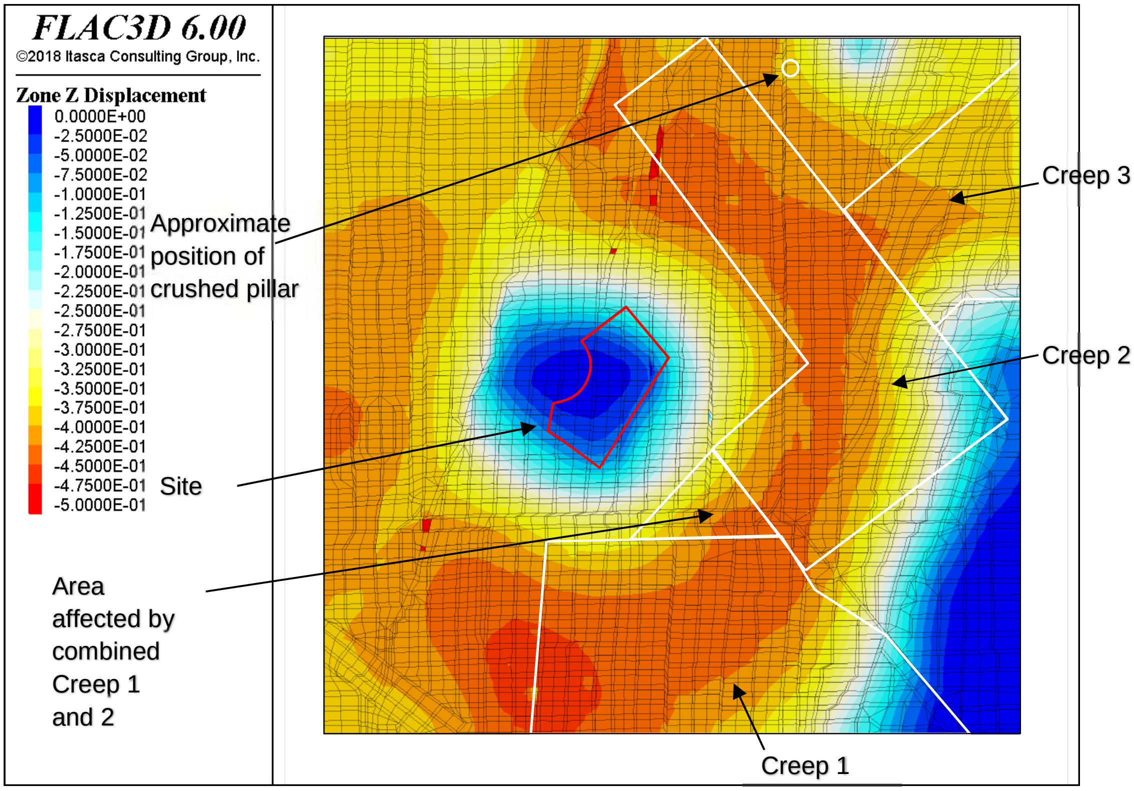

Figure 58: Conceptual vertical displacement with pillar coal at 77% strength with proposed grout

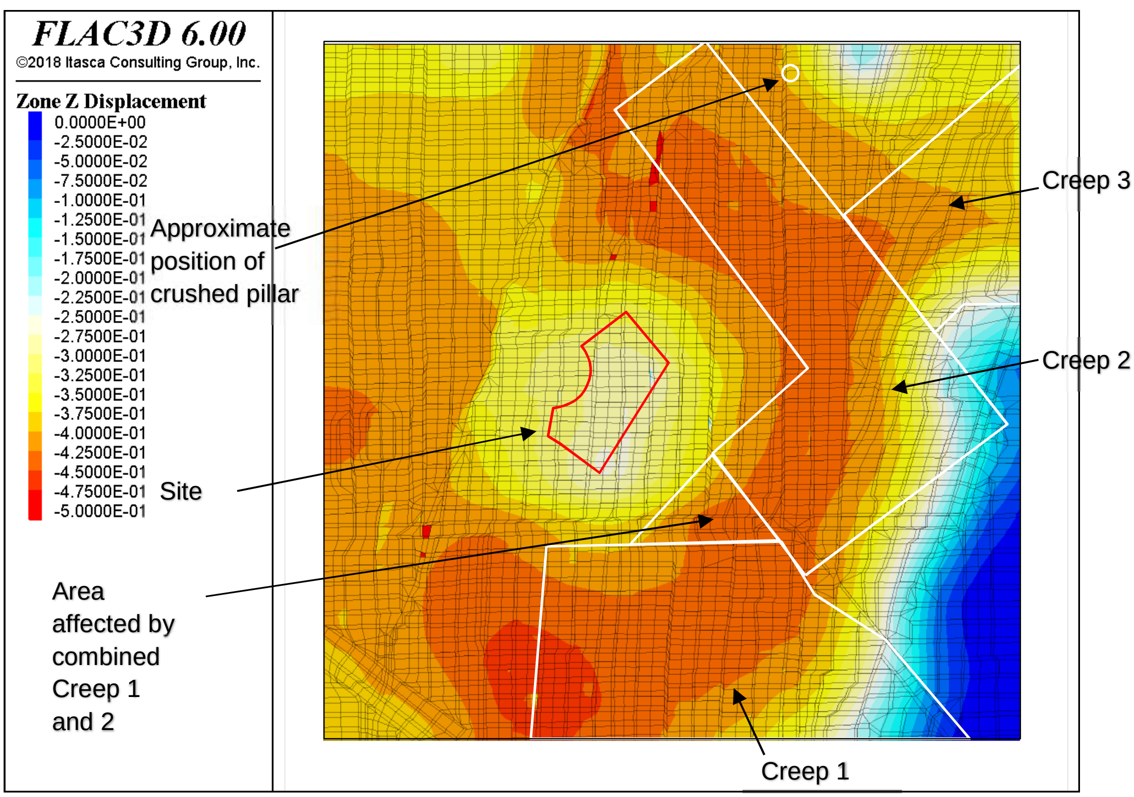

Figure 59: Conceptual vertical displacement with pillar coal at 60% strength with proposed grout

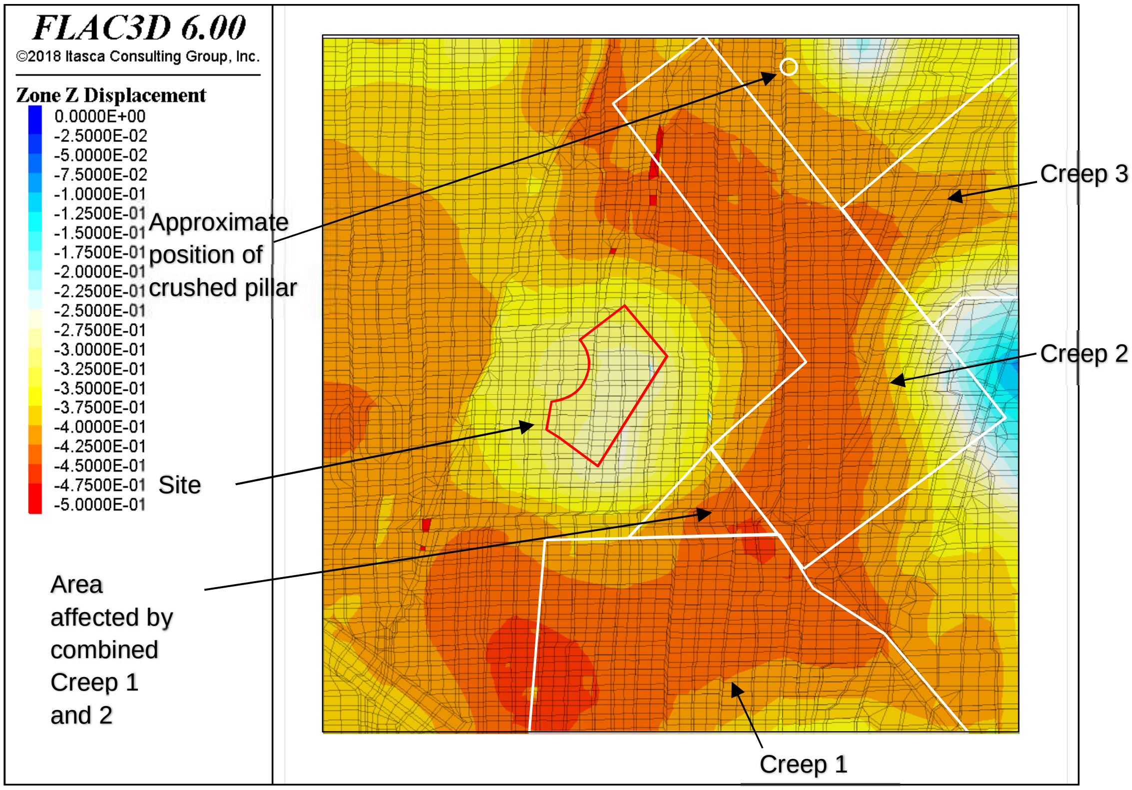

Figure 60: Conceptual vertical displacement with pillar coal at 46% strength with proposed grout

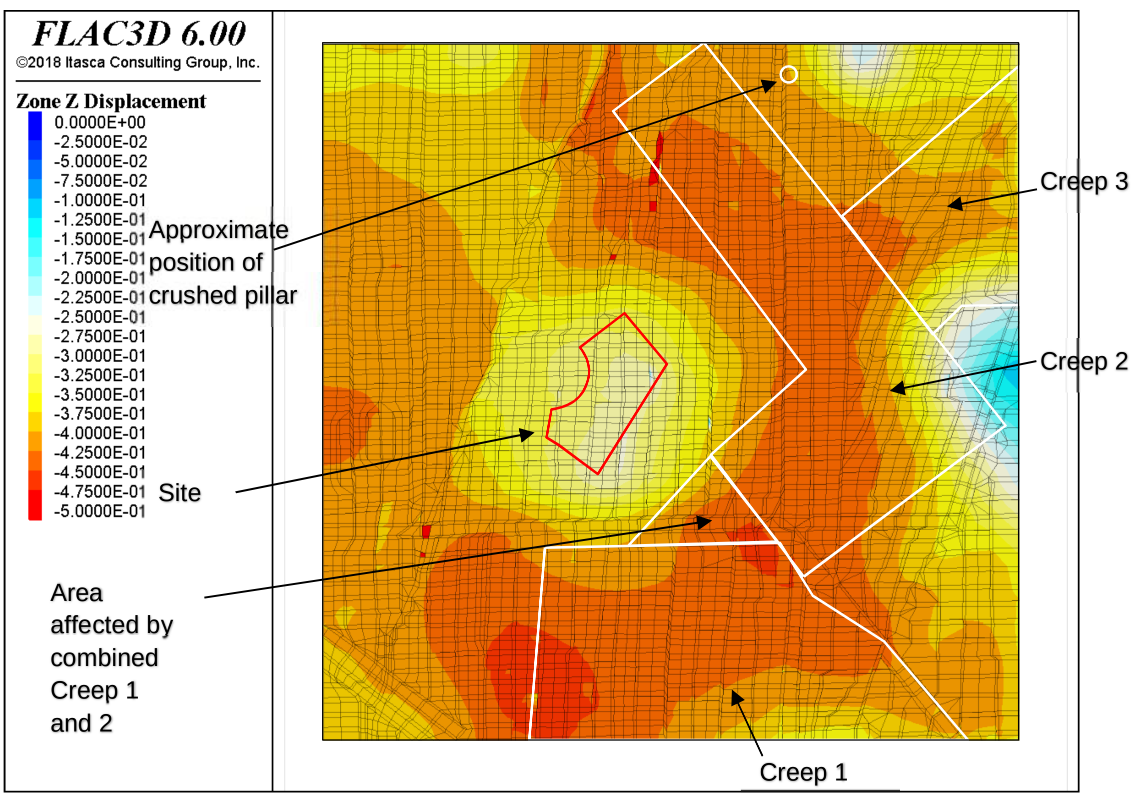

Figure 61: Conceptual vertical displacement with pillar coal at 36% strength with proposed grout

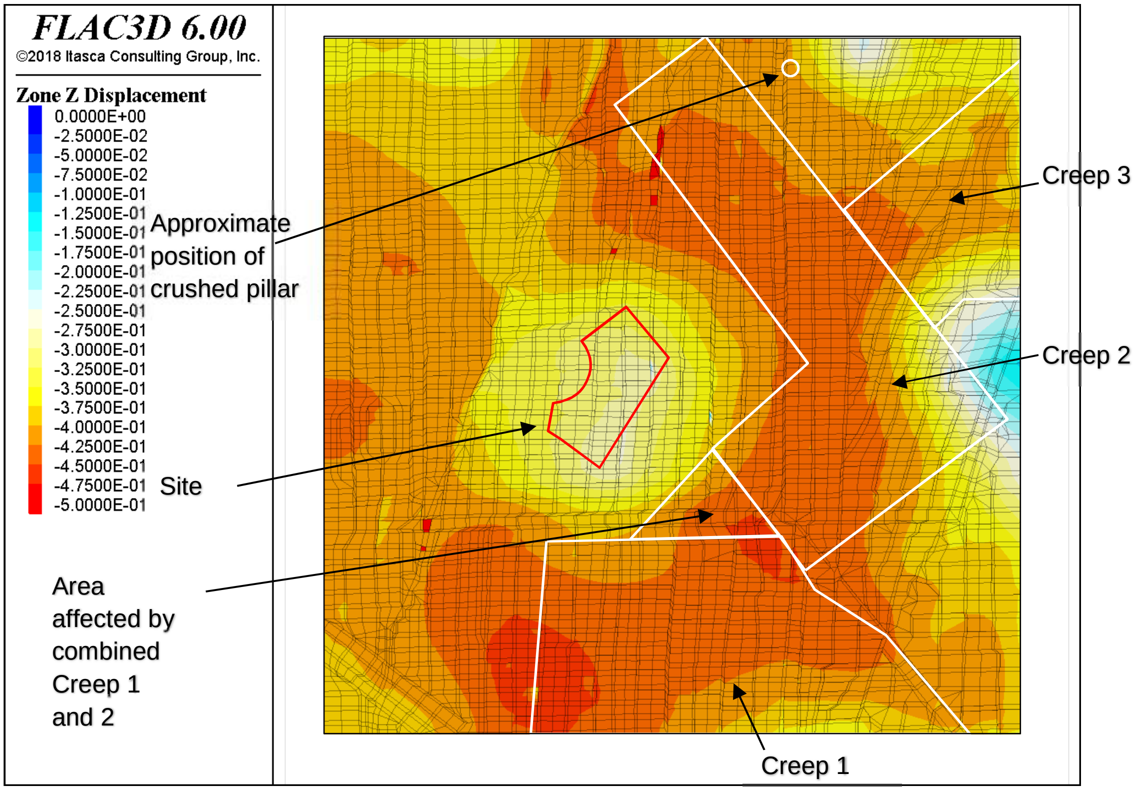

Figure 62: Conceptual vertical displacement with pillar coal at 28% strength with proposed grout

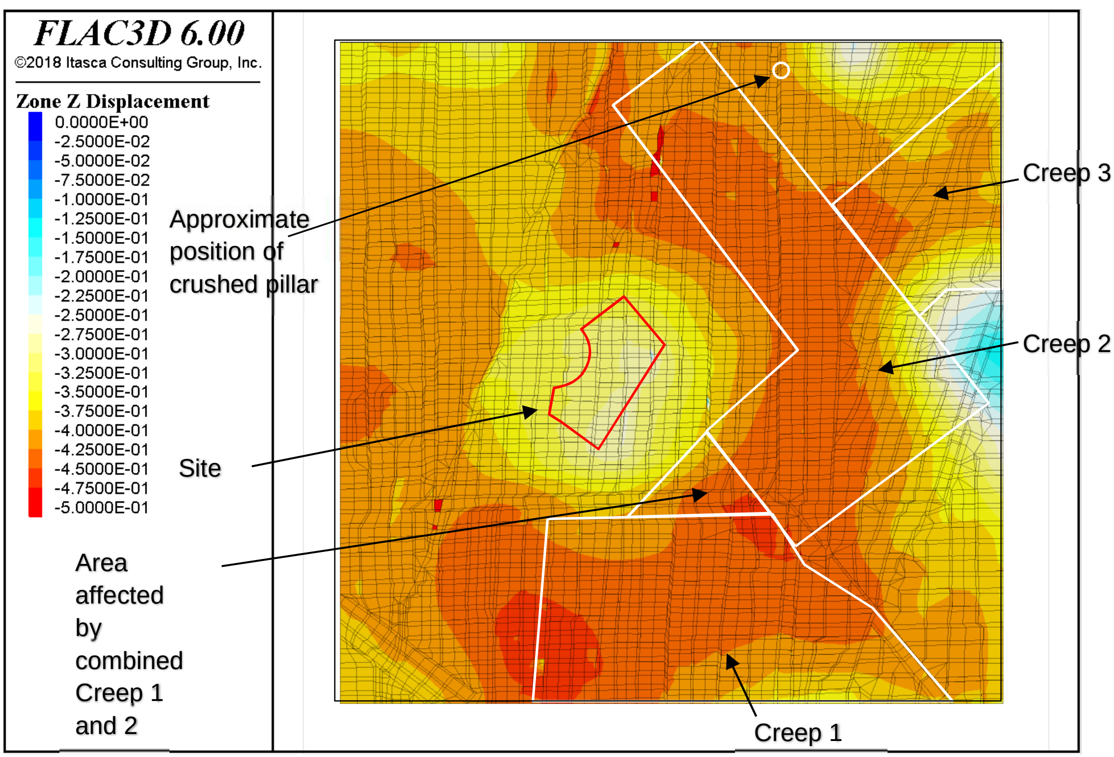

Figure 63: Conceptual vertical displacement with pillar coal at 25% strength with proposed grout

Using the above sequence as well as the movie sequence taken at regular intervals, the pillars locally under site after grouting and adopting the average pillar height of 5.1m, will support abutment loading to a reduction to approximately 70% of peak strength. At this strength reduction, the pillars supported by the grout will be subjected to a vertical stress in the order of 15MPa (refer to Figure 64 and Figure 65). It is noted this is conservative as the area has currently not crushed event though the Creep 2 and 3 areas have occurred.

Beyond this reduction, the pillars under the site may be anticipated to start to crush as well. However, instead of the wave of the crush front passing through the site, the effect will be a more controlled collapse.

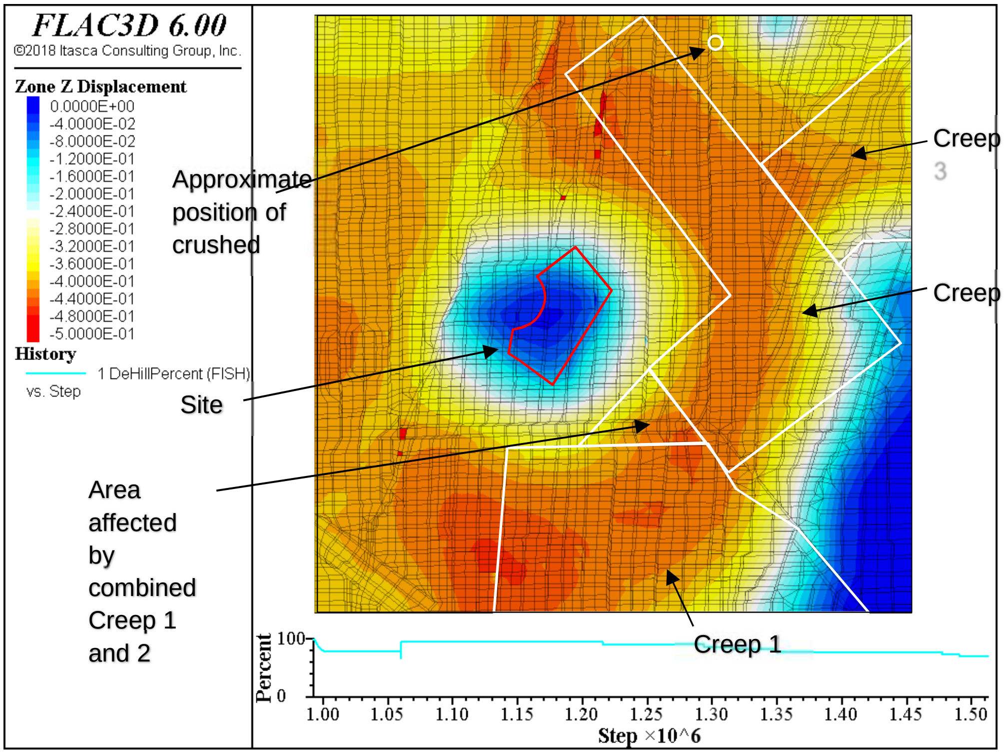

Figure 64: Conceptual vertical displacement with pillar coal at 70% strength with proposed grout (i.e. just before crushing of grouted pillars)

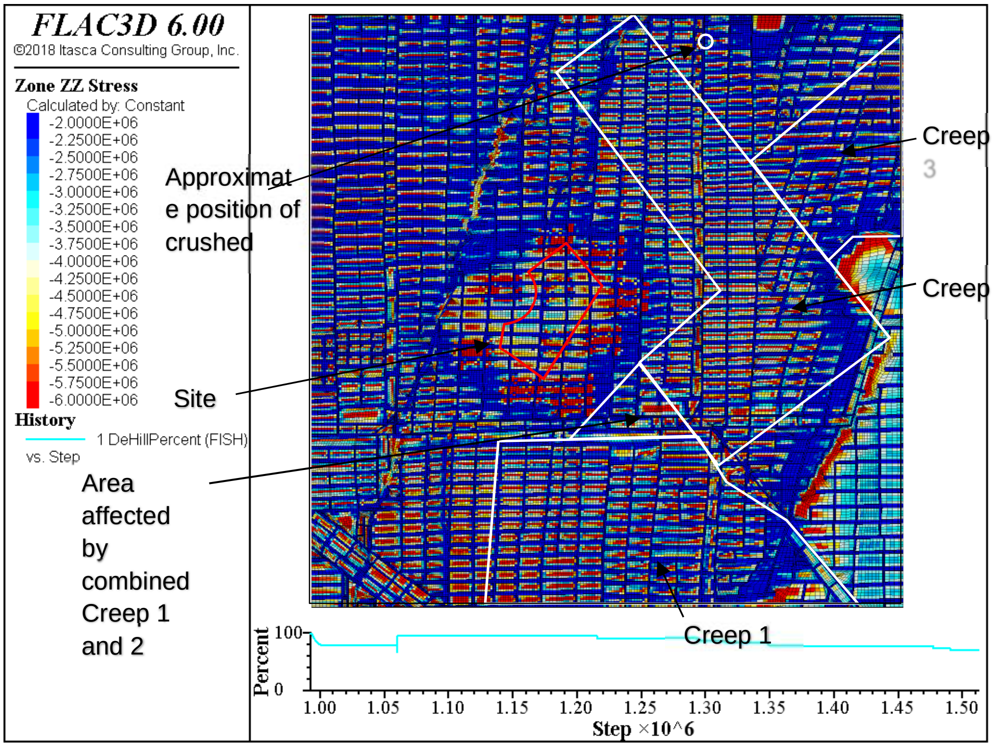

Figure 65: Conceptual vertical stress with pillar coal at 70% strength with proposed grout (i.e. just before crushing of grouted pillars)

5.6. Potential subsidence parameters

Based on the above, subsidence is still considered possible for the site even after grouting. The worst-case condition for the site is considered to be at the 70% strength value shown in Figure 64 (Refer to Drawing 6.)

Using the model, it is assumed that The Site may be subjected to up to 160mm settlement (although 40mm of this may have already occurred due to the historical creeps (Refer to Drawing 7). At the site, the radius of tensile curvature is expected to get down to 11km with tensile strain of up to 0.9mm/m estimated using the formula Strain (mm/m) = 10/ (curvature in km) (Holla 1987).

Similarly, between the 120mm contour and the 160mm contour, the compressive radius of curvature may be as little as 15km which may be expected to exert compressive strains up to 0.7mm/m (over a length of 10m).

The maximum tilts are all estimated to be generally less than 4mm/m.

It is noted an allowance for an additional 20% on the above values should be allowed for within the ultimate design of the structures.

Should the pillars continue to fail beyond the worst case 70% strength reduction, the modelling indicates the maximum tensile strain may reduce from 0.9mm/m back to 0.5mm/m. However, an even settlement profile as shown in Drawing 8 is not expected with variations in mining height observed at mine level (Coffey Report 754-NTLGE220504-AH.Rev2 dated 17 December 2018).

6. Conclusions

A 3D numerical analysis has been completed to assess an appropriate grouting strategy for the proposed development to control the way the site may subside were the historical Creep events remobilise.

Using this model, the area should have collapsed during the historical creep events even with a pillar height of 5.1m, less than the 6.6m present within BH04.

Using this model, it was assessed that:

- The current factor of safety of the panel of workings is in the order of 1
- The maximum differential subsidence that may be experienced by the site may be 160mm. Further weakening of the grouted pillars will result in less curvature due to the limited void space at mine level.
- The tilts estimated for the development are 4mm/m.
- The maximum tensile strains were assessed to be less than 0.9mm/m while the compressive strains were assessed to be up to 0.6mm/m (from the 120mm to 160mm contour only).
- The curvature has been estimated to be a minimum of 11km concave down and 16km concave up (from the 120mm to 160mm contour only on Drawing 6).

Guidance on the uses and limitations of this report is presented in the attached sheet, *'Important Information about your Coffey Report'*, which should be read in conjunction with this report.

If you have any questions regarding this report or should you require further assistance on this project, please contact Jules Darras or the undersigned.

Signature:	
Full name:	Simon Baker
Title:	Senior Geotechnical Engineer
Date:	18 January 2018

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Important information about your **Coffey** Report

As a client of Coffey you should know that site subsurface conditions cause more construction problems than any other factor. These notes have been prepared by Coffey to help you interpret and understand the limitations of your report.

Your report is based on project specific criteria

Your report has been developed on the basis of your unique project specific requirements as understood by Coffey and applies only to the site investigated. Project criteria typically include the general nature of the project; its size and configuration; the location of any structures on the site; other site improvements; the presence of underground utilities; and the additional risk imposed by scope-of-service limitations imposed by the client. Your report should not be used if there are any changes to the project without first asking Coffey to assess how factors that changed subsequent to the date of the report affect the report's recommendations. Coffey cannot accept responsibility for problems that may occur due to changed factors if they are not consulted.

Subsurface conditions can change

Subsurface conditions are created by natural processes and the activity of man. For example, water levels can vary with time, fill may be placed on a site and pollutants may migrate with time. Because a report is based on conditions which existed at the time of subsurface exploration, decisions should not be based on a report whose adequacy may have been affected by time. Consult Coffey to be advised how time may have impacted on the project.

Interpretation of factual data

Site assessment identifies actual subsurface conditions only at those points where samples are taken and when they are taken. Data derived from literature and external data source review, sampling and subsequent laboratory testing are interpreted by geologists, engineers or scientists to provide an opinion about overall site conditions, their likely impact on the proposed development and recommended actions. Actual conditions may differ from those inferred to exist, because no professional, no matter how qualified, can reveal what is hidden by earth, rock and time. The actual interface between materials may be far more gradual or abrupt than assumed based on the facts obtained. Nothing can be done to change the actual site conditions which exist, but steps can be taken to reduce the impact of unexpected conditions. For this reason, owners should retain the services of Coffey through the development stage, to identify variances, conduct additional tests if required, and recommend solutions to problems encountered on site.

Your report will only give preliminary recommendations

Your report is based on the assumption that the site conditions as revealed through selective point sampling are indicative of actual conditions throughout an area. This assumption cannot be substantiated until project implementation has commenced and therefore your report recommendations can only be regarded as preliminary. Only Coffey, who prepared the report, is fully familiar with the background information needed to assess whether or not the report's recommendations are valid and whether or not changes should be considered as the project develops. If another party undertakes the implementation of the recommendations of this report there is a risk that the report will be misinterpreted and Coffey cannot be held responsible for such misinterpretation.

Your report is prepared for specific purposes and persons

To avoid misuse of the information contained in your report it is recommended that you confer with Coffey before passing your report on to another party who may not be familiar with the background and the purpose of the report. Your report should not be applied to any project other than that originally specified at the time the report was issued.

Interpretation by other design professionals

Costly problems can occur when other design professionals develop their plans based on misinterpretations of a report. To help avoid misinterpretations, retain Coffey to work with other project design professionals who are affected by the report. Have Coffey explain the report implications to design professionals affected by them and then review plans and specifications produced to see how they incorporate the report findings.

Data should not be separated from the report*

The report as a whole presents the findings of the site assessment and the report should not be copied in part or altered in any way. Logs, figures, drawings, etc. are customarily included in our reports and are developed by scientists, engineers or geologists based on their interpretation of field logs (assembled by field personnel) and laboratory evaluation of field samples. These logs etc. should not under any circumstances be redrawn for inclusion in other documents or separated from the report in any way.

Geoenvironmental concerns are not at issue

Your report is not likely to relate any findings, conclusions, or recommendations about the potential for hazardous materials existing at the site unless specifically required to do so by the client. Specialist equipment, techniques, and personnel are used to perform a geoenvironmental assessment. Contamination can create major health, safety and environmental risks. If you have no information about the potential for your site to be contaminated or create an environmental hazard, you are advised to contact Coffey for information relating to geoenvironmental issues.

Rely on Coffey for additional assistance

Coffey is familiar with a variety of techniques and approaches that can be used to help reduce risks for all parties to a project, from design to construction. It is common that not all approaches will be necessarily dealt with in your site assessment report due to concepts proposed at that time. As the project progresses through design towards construction, speak with Coffey to develop alternative approaches to problems that may be of genuine benefit both in time and cost.

Responsibility

Reporting relies on interpretation of factual information based on judgement and opinion and has a level of uncertainty attached to it, which is far less exact than the design disciplines. This has often resulted in claims being lodged against consultants, which are unfounded. To help prevent this problem, a number of clauses have been developed for use in contracts, reports and other documents. Responsibility clauses do not transfer appropriate liabilities from Coffey to other parties but are included to identify where Coffey's responsibilities begin and end. Their use is intended to help all parties involved to recognise their individual responsibilities. Read all documents from Coffey closely and do not hesitate to ask any questions you may have.

* For further information on this aspect reference should be made to "Guidelines for the Provision of Geotechnical information in Construction Contracts" published by the Institution of Engineers Australia, National headquarters, Canberra, 1987.

Drawings

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NOTICE OF PROPOSED INTEGRATED DEVELOPMENT

Environmental Planning and Assessment Act 1979

22 January 2019

The City of Newcastle
PO Box 489, Newcastle
NSW 2300 Australia
Phone: 4974 2000
Fax: 4974 2222
Email: mail@ncc.nsw.gov.au
www.newcastle.nsw.gov.au

Subsidence Advisory NSW
PO Box 488G
NEWCASTLE NSW 2302

Dear Sir/Madam

Application No:	DA2019/00061
Land:	Lot 1 DP 204077
Property Address:	11-17 Mosbri Crescent The Hill NSW 2300

The above Development Application lodged with Newcastle City Council by Crescent Newcastle Pty Limited, seeks Council's consent to carry out the following development on the subject property:

Residential accommodation comprising three residential flat buildings (161 dwellings) multi dwelling housing (11 dwellings), strata subdivision, demolition and associated site works.

Reason for referral: Integrated Development
The proposal is 'Integrated Development' requiring a separate approval under the *Coal Mine Subsidence Compensation Act 2017.*

Written notice of your decision concerning the general terms of approval in relation to the development application (including whether or not you will grant an approval) is required within 40 days of the date of this letter.

Section 91A(5) of the *Environmental Planning and Assessment Act 1979* provides that Council may determine this Development Application if you have not provided notice of whether or not you will grant the approval, or if the general terms of your approval have not been provided, within the 40 day period referred.

Please Note:
As Council is processing applications in an electronic manner please refer click on the link below for access to Council's E-Services Development Tracking Portal to view submitted documentation relating to the application.

Click here to access a copy of the Statement of Environmental Effects, Plans and all submitted documentation.

Contact details
Any comments should be returned via email mail@ncc.nsw.gov.au, referencing the Development Application number.

Please contact me on 4974 2731 as soon as possible if you do not expect that a reply will be made within this period.

Yours faithfully

William Toose
SENIOR DEVELOPMENT OFFICER

Hannah Stephenson

From: SA Risk
Sent: Friday, 8 February 2019 12:04 PM
To: F.Renton@enquest.com.au
Subject: FW: Responsibility For Grouting Costs
Attachments: Referral - Subsidence Advisory NSW - DA2019-00061 - 11-17 Mosbri Crescent The Hill.pdf; Prelim Investigation.pdf; Mine subsidence boudaries map - Newcastle Mines Grouting Fund.jpg

Hi Frank

Thank you for sending your enquiry through.

I can confirm that Subsidence Advisory NSW does not pay for grouting on private developments.

The Newcastle Mines Grouting Fund administered by the Hunter & Central Coast Development Corporation does provide funding for grouting, but this is limited to a small area within the Newcastle CBD (see attached map).

For more information on this Fund, please see https://www.hccdc.nsw.gov.au/newcastle-mines-grouting-fund-0

In the case of the development at Mosbri Crescent, The Hill, this site is outside of the eligible area for funding, and we expect all grouting costs would be covered entirely by the developer.

Kind Regards,

Rhea
Administration Officer

Subsidence Advisory NSW | An Agency of the Department of Finance, Services and Innovation
p 02 4908 4300
e SA-Risk@finance.nsw.gov.au | www.subsidenceadvisory.nsw.gov.au
Ground Floor, Government Offices, 117 Bull Street Newcastle West NSW 2302

From: Frank Renton [mailto:F.Renton@enquest.com.au]
Sent: Friday, 8 February 2019 11:30 AM
To: SA Mail <SA-Mail@finance.nsw.gov.au>
Subject: Responsibility For Grouting Costs

As the result of a very informative telephone conversation with Rhea this morning I would like to request a definitive answer to a question I have on a NCC development application DA2019/0061 at 11-17 Mosbri Cres, The Hill, NSW 2300.

QUESTION

Who is responsible for meeting costs of grouting, as recommended in the "preliminary investigation' (single page extraction is attached) ?

I would appreciate an email response at your earliest convenience, as the DA process has allowed an extremely short time frame for the public to submit objections to the DA.

Thanks and regards

--

Frank Renton

Telephone (+61) 0418 681 314

The above estimations do not include the mine subsidence numerical modelling that is currently underway.

9. Preliminary recommendations

9.1. Yard Seam

Evidence of Yard Seam workings were encountered during this investigation. Due to the unmapped nature of the workings within the Yard Seam it is recommended a drilling and grouting exercise be completed prior to construction although after demolition of the existing buildings.

Boreholes may be spaced based on a regular grid pattern at 10m intervals (north to south) attempting to encounter at least every second bord. East to west these may be increased to 20m. Boreholes that encounter a pillar should be redrilled at a distance of 3m.

At the completion of drilling, a high mobility grout should be pumped into all boreholes. This grout should have a flow cone (in accordance with ASTM C 939 or similar) value of 20 seconds to 30 seconds, resulting in a slurry with the consistency of a 'thin milkshake' or 'creamy soup'.

This is currently estimated to require in the order of 71 boreholes to the Yard Seam and a volume of grout in the order of 1,400m^3 to 2,000m^3 (20m^3 to 30m^3 per borehole). Due to the spacing of the boreholes the grouting may be considered a bulk grouting solution.

After grouting, the potential for subsidence from the Yard Seam can be considered to be ameliorated, and the subsidence parameters within the Yard Seam in Section 8.4.1 will be no longer relevant.

9.2. Borehole Seam

Numerical modelling and detailed settlement analysis for the Borehole Seam is currently being completed separately.

Preliminary it may be assumed that the site will require eight coal pillars around the outside of the site to support abutment loading from reaching the coal pillars under the site. Each coal pillar to be stabilised will likely require four grouting boreholes (two in each bord). At the two eastern corners a third consecutive bord should be grouted to protect from abutment loading.

Inside the site. a further two pillars will need additional support, each with two grouting boreholes, one on each side of the pillar to be supported.

This results in 40 grouting boreholes to the Borehole Seam. This borehole pattern is shown on Drawing 12.

From the boreholes in this investigation, the void heights are between 0.5m and 1.65m with between 3m and 5m of rubble infill. This means the grout take will be highly variable between boreholes between 100m^3 and 600m^3 for each location. Preliminarily suggest allowance for 400m^3 per borehole.

The boundary locations will be outside the site to push the collapse front away from the site and in turn reduce subsidence parameters for the site. As these borehole will be completed on angles, the works may be completed with the buildings in place should it be preferential to commence early works.

The estimation of concrete required is approximately 18000 m3
The cost of concreting is estimated at $300/m3
Therefor total cost of grouting $5.4 million

Hannah Stephenson

From: Melanie Fityus
Sent: Monday, 11 February 2019 2:09 PM
To: [redacted]
Cc: Kieran Black
Subject: Development at 11-17 Mosbri Crescent

[redacted],

Kieran and I would like to have a meeting with you to discuss your proposed sub-surface stabilisation works for the NBN studios redevelopment.

Later this afternoon is possible but I can't do tomorrow. Wed onwards will be fine. Give me a call.

Thanks

Melanie Fityus
Senior Risk Engineer
Subsidence Advisory NSW | Department of Finance, Services and Innovation
p 4908 4329 (New Number)
e Melanie.Fityus@finance.nsw.gov.au | **w** www.subsidenceadvisory.nsw.gov.au
Ground Floor, Government Offices, 117 Bull Street, Newcastle West. NSW 2302.

NSW GOVERNMENT

Hannah Stephenson

From: Melanie Fityus
Sent: Monday, 11 February 2019 5:08 PM
To: [redacted]
Cc: SA Risk; Kieran Black
Subject: Geotechnical Report - 11-17 Mosbri Crescent The Hill - TBA1904135 & TSUB19-00543

Hi [redacted],

Thanks for meeting with me and Kieran today.

In accordance with SA NSW merit assessment procedure, we require your report (754-NTLGE220504-AI dated 18 January 2019) to be peer reviewed by a suitably qualified expert.

We will place your application on hold pending this review and receipt of a peer report from your consultant.

Regards

Melanie Fityus
Senior Risk Engineer
Subsidence Advisory NSW | Department of Finance, Services and Innovation
p 4908 4329 (New Number)
e Melanie.Fityus@finance.nsw.gov.au | **w** www.subsidenceadvisory.nsw.gov.au
Ground Floor, Government Offices, 117 Bull Street, Newcastle West. NSW 2302.

coffey
A TETRA TECH COMPANY

Crescent Newcastle Pty Ltd
Proposed Multi - Building Residential Development

754-NTLGE220504-AI

Mine Subsidence Assessment Report

12 March 2019

Technology
is the product
of intelligence
not the
cause of it

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Proposed Multi - Building Residential Development - 11-17 Mosbri Crescent, Cooks Hill, NSW 2300

Prepared for
Crescent Newcastle Pty Ltd

Prepared by
Coffey Services Australia Pty Ltd
19 Warabrook Boulevard
Warabrook
NSW 2304 Australia
t: +61 2 4016 2300
ABN 55 139 460 521

12 March 2019

754-NTLGE220504-AI.Rev1

Quality information

Revision history

Revision	Description	Date	Originator	Reviewer	Approver
Version 0	Report Draft	18/01/2019	Simon Baker	Jules Darras	Simon Baker
Revision 1	Report Final	12/03/2019	Simon Baker	Jules Darras	Simon Baker

Distribution

Report Status	No. of copies	Format	Distributed to	Date
Draft	1	PDF	Richard Anderson, Mark Purdy	18/01/2019
Final	1	PDF	Richard Anderson, Mark Purdy	12/03/2019

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Tables

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Executive Summary

The Site located at 11-17 Mosbri Crescent Cooks Hill is known to be located over abandoned workings in both the Yard Seam and the Borehole Seam. The Borehole Seam is at a depth of 92m to 100m with variations due to surface topography.

Historical Creep events (i.e. crushing of the pillars) were modelled using FLAC3D to develop an understanding what may subsidence may occur should the pillars under the site weaken sufficiently. Using this model, the area should have collapsed even with a pillar height of 5.1m, less than the 6.6m present within BH04.

Coffey completed a numerical analysis to assess the effectiveness of a proposed grouting scheme for the Borehole Seam to control the risk of subsidence. The proposed grouting scheme included the grouting of two locations per bord, either side of eight coal pillars. At the two critical corners, an additional bord (i.e. three bords) was deemed necessary while within the centre of the site the grouting was reduced to only one location per bord (Refer to Drawing 4). It is noted the grouting scheme has been designed primarily to control the pattern of subsidence rather than to fully grout the site and prevent all subsidence.

Using this model, it was assessed that:

- The factor of safety of the panel of workings in their current condition is in the order of 1
- After grouting, the maximum differential subsidence that may be experienced by the site is estimated to be 160mm. Further weakening of the grouted pillars will result in less curvature due to the limited void space at mine level.
- The tilts estimated for the development are 4mm/m.
- The maximum tensile strains were assessed to be less than 0.9mm/m while the compressive strains were assessed to be up to 0.6mm/m (from the 120mm to 160mm contour only).
- The curvature has been estimated to be a minimum of 11km concave down and 16km concave up (from the 120mm to 160mm contour only on Drawing 5).

1. Introduction

Crescent Newcastle Pty Ltd (Crescent) commissioned Coffey Services Australia Pty Ltd (Coffey) to carry out a mine subsidence investigation for the proposed multi building residential development located at 11-17 Mosbri Crescent, Cooks Hill, NSW referred to hence forth as The Site.

This report addresses the scope of work outlined in our proposal referenced as 754-NTLGE220504.P01.Rev02, Section 2.2.1 *Mine subsidence numerical analysis*, dated 27 August 2018. Preliminary contamination assessment, geotechnical and mine subsidence investigations will be reported separately.

The currently proposed development at The Site will include:

- Construction of residential accommodation comprising 172 dwellings, being:
  - Eleven (11) two storey townhouse style dwellings fronting Mosbri Crescent, located above a basement car park containing 34 visitor spaces and 11 resident spaces
  - Three (3) residential flat buildings (Building A, B, and C) containing 161 dwellings, ranging from one to three bedrooms; being:
    - Building A including a nine (9) storey east wing and six (6) storey west wing
    - Building B comprising seven (7) storeys and a roof top communal open space, with (9) town house style dwellings facing the internal courtyard
    - Building C comprising five (5) levels
- Interconnected car parking for Building A, B & C located on the ground floor and first level, contains 1 visitor spaces and 196 resident spaces
- Pedestrian path, providing connection from Mosbri Crescent to Kitchener Parade
- Associated landscaping, communal open space, services and site infrastructure.

The Site is sloping south westerly towards Mosbri Crescent Reserve and existing ground RLs within the footprint of the Building A, B and C varies between RL 36m AHD and RL 38.00m AHD. The combined basement levels will require excavation of approximately 8.5m to 9.5m below existing ground level (RL 28.10m AHD and RL 29.60m AHD) at the rear (eastern) side of the property although the proposed excavation is generally less than 4m.

Two storey townhouses are proposed along Mosbri Crescent with single basement level. Maximum excavation required for the proposed townhouses will be approximately 4.5m below ground level (basement RL 25.40m AHD to RL 27.40m AHD).

Vehicular access to the proposed development is via ramp from Mosbri Crescent connecting with proposed basements driveways, located next to apartment building located at 9 Mosbri Crescent, north western side of site.

Prior to this report Coffey was given following documents:

- Site Survey Plan prepared by Monteath & Powys Pty Ltd, titled as "Detail Survey Over Lot 1 DP204077, NBN Studios, Mosbri Crescent, The Hill", referenced as 15/047 and dated 10/4/15, inclusive
- Preliminary Architectural Drawings prepared by Marchese Partners International Pty Ltd, titled as "11-17 Mosbri Crescent, The Hill NSW 2300", referenced as job 171114 and comprises of drawing from DA2.01 to DA2.11, dated as 10/10/2018, water marked as work in progress

The Site is known to be located over abandoned workings in both the Yard Seam and the Borehole Seam.

This report aims to:

- Assess the factor of safety of the mine workings beneath The Site

- Assess the potential maximum subsidence that may be experienced at The Site
- Assess subsidence parameters applicable to proposed developments in the area given the current grouting works completed in the area

This report presents in the results of a numerical modelling phase using FLAC3D.

The following report presents the steps followed in the numerical analysis of the mine workings, the data used in this assessment, and the resultant findings and recommendations for design. This report does not include assessment of potential movements from the construction of the building itself (i.e. consolidation of soil layers) and does not address footing design parameters.

2. Background

Coffey completed a mine subsidence investigation to assess the condition of the mine workings and overburden, Coffey Report 754-NTLGE220504-AH.Rev2 dated 17 December 2018. This report should be read in conjunction with the above report although a brief summary is provided below. Mine workings exist under The Site within the Borehole Seam at a depth of 92m to 100m below ground level by the AACo from their New Winnings Pit (also known as Sea Pit). These workings are shown Record Tracing RT566, Sheet 4 (completed in 1906, reproduced on Drawing 3) and Record Tracing RT566, Sheet 8 (showing extent at abandonment in 1916, reproduced on Drawing 2.) Mine workings also exist within the Yard Seam, however as they are unmapped an accurate numerical model of these workings is not possible without extensive drilling. Hence this report focuses on the lower Borehole Seam.

From the borehole log on RT566, Sheet 8, the working zone from the Borehole Seam ranged from 267' 0" to 284' 0" (81.4m to 86.6m) or 5.2m. The general workings comprised bords 6 yards wide (5.4m) and 33 yards long (30.2m) and pillars were 12 yards wide (11m) (Power 1912). This means the mine workings under The Site have a width to mined height ratio of approximately 2. These dimensions were not increased even under The Hill where the overburden load is substantially higher. This resulted in the failure of the coal pillars causing Creep 1 on 15 May 1906, Creep 2 on 17 October 1907 and Creep 3 on 17 January 1908. These events are recorded on RT566, Sheet 4 (refer to Drawing 4).

While areas outside the Creep events have been shown to have crushed elsewhere (Coffey report 754-NTLGE211941-AD May 2018), rock core samples and downhole logging of the coal pillars under The Site did not show evidence of crushing.

Since the time of mining, the roof of the workings has started to collapse over the bords where wider mined widths are present. This has resulted in a significant amount of rubble/ loose material on the floor of the workings (up to 5m in BH04).

3. Methodology for numerical modelling

3.1. Approach

This assessment included the following steps:

- Development of a large scale numerical model with the geological features of the area, including ground elevation and mine workings based on RT566 Sheet 8
- Trigger pillar collapses and assess paths of pillar creeps, recalibrate as necessary
- Add grout to selected pillar in the model and assessment of the consequent ground deformations at different strength reduction of the coal material
- Assessment of consequent ground deformations caused by pillar collapse.

To assess the FOS of the workings and resultant surface deflection, the three-dimensional numerical analyses proprietary software FLAC3D was used to simulate a pillar collapse of the workings. This simulation included attempts to model the pattern of previous crush events known to have already occurred within and around The Site.

The model was returned to previous state, grout was added to selected locations on both sides of pillars with the crush events trigged again, with a final phase of slowly degrading coal within the remaining standing pillars.

3.2. Geometry and mesh

A pillar run that impacts The Site may be initiated from weaker pillars outside of the immediate area. As such, a large area of mine workings was modelled to assess potential surface response behaviours at The Site and to reduce the impact of edge effects in the model affecting the ground response assessed at The Site.

For The Site, the model extended an area of 800m by 800m. This elemental ‘mesh’ adopted extends sufficiently broadly to recognise and reduce the impact of enable boundary fixities at The Site. This included:

- Surrounding The Hill which generally meant extending the whole of Creep 2 as well as large portions of Creeps 1 and 3.
- Having all model limits more than 200m from the site (i.e. boundaries at least twice the depth to workings around The Site).

The outlines of pillars within the workings were first digitised using polylines in AutoCAD based on the layout of pillars from RT566 Sheet 8 which is generally similar to the version on RT Sheet 4, except with the additional mining completed after 1906. The workings were rotated so that a principal stress corresponded with the x axis (generally along the pillars). The digitised geometry of the pillars was imported into FLAC3D, with the remaining irregular shapes converted to primitives before subdivision into pillars with four elements across and eight to twelve elements along the length to create generally squarish shaped elements.

To allow for easier identification in later stages, primitives of similar units were grouped together.

- Group 1 - Full height bords
- Group 2 - AACo standard coal pillars
- Group 3 - Fault coal
- Group 4 - Fault bord

Figure 1 shows this layout.

A slight fold in the linen map is observable on the RT566 Sheet 8 images, which decreased the apparent width of the pillars by an estimated 2m. As such, the pillar layout was completed with two parts, the zone above and below the fold on the linen map.

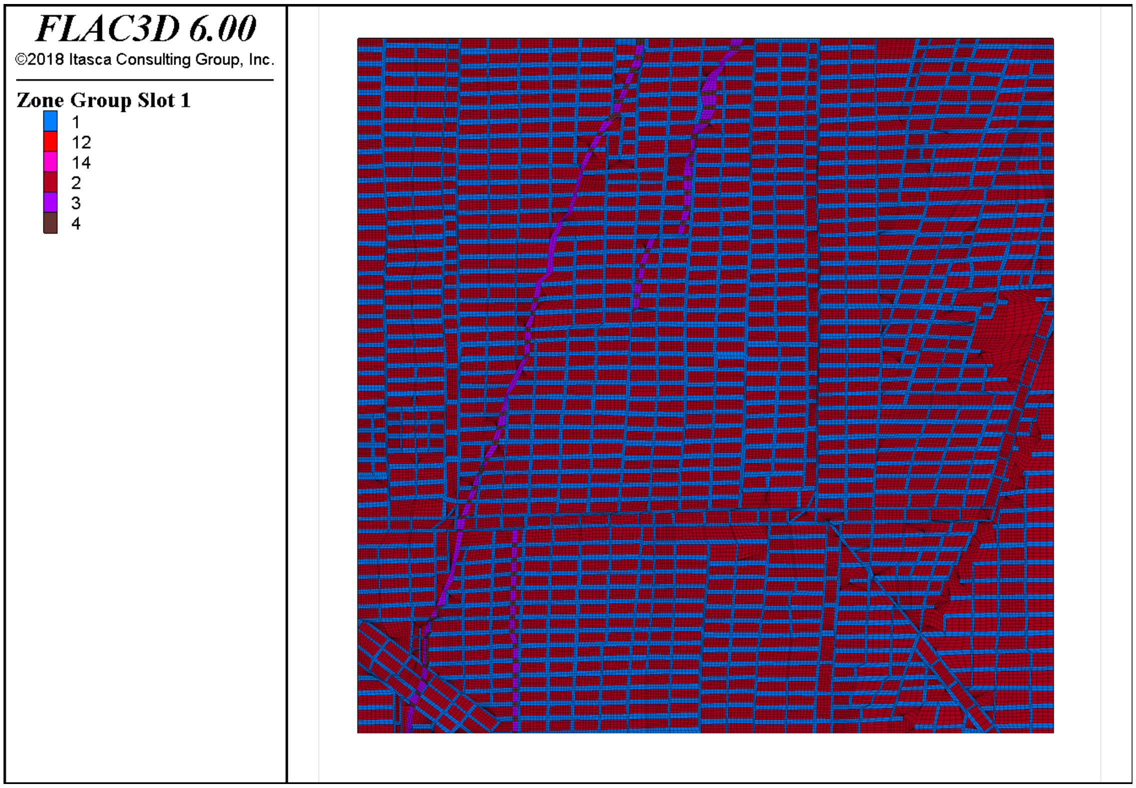

Figure 1: Mesh at Borehole Seam level

To build the vertical depth to the model, the Borehole Seam was assumed to be horizontal with the surface modified to resemble the additional overburden; the depth of the model was developed using surface contours and the seam dip of 1 in 90 for the Borehole Seam identified on Record Tracing Sheet 8.

The grid was then extruded in three stages, with the mesh refined at each stage to reduce the total number of elements to z equals 20m (i.e. where the surface topography changes means the unit no longer covered the whole model). To simulate topographic variation at the surface, above 20m, parts of the main grid were deleted with each layer extruded in 1 layer of 5m thick elements based on the third level of mesh elements. Slight adjustments were made to reduce numerical instability around cliff edges where cliffs are present. Figure 2 shows and example of this for 40m to 45m.

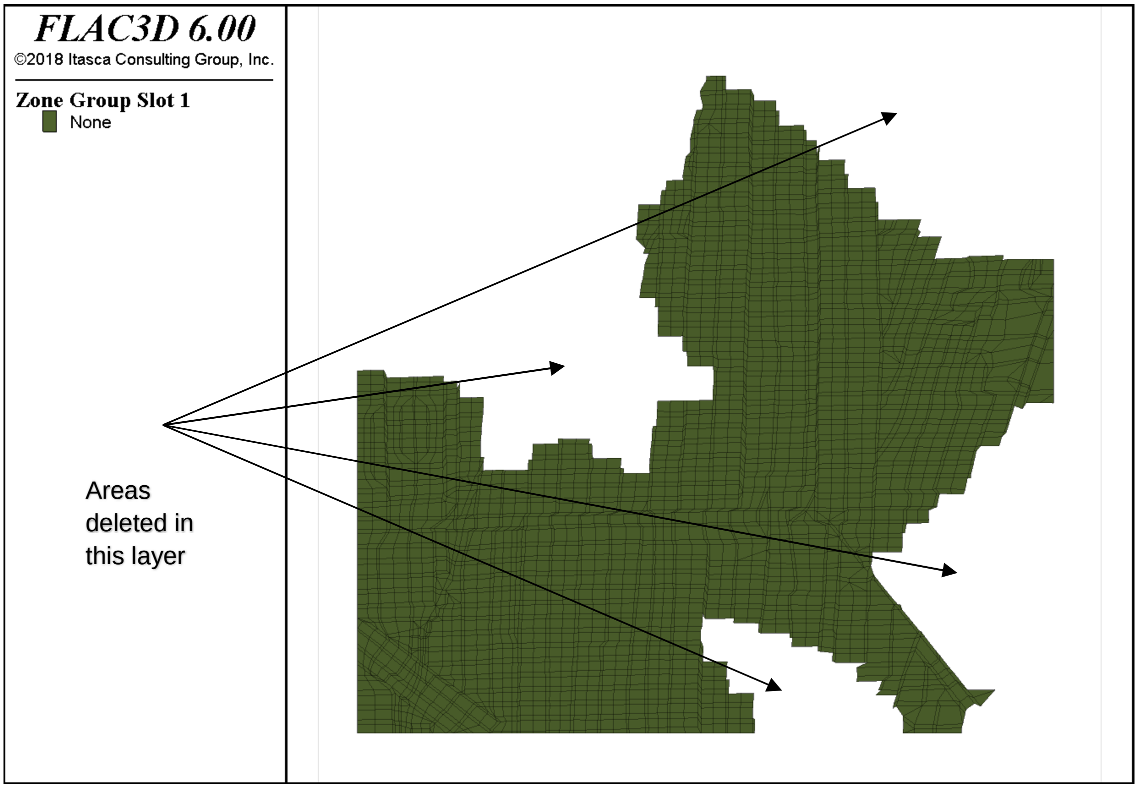

Figure 2: Example of mesh with cut outs for 40m to 45m

The resultant numerical model has approximately 1,100,000 quadrilateral elements. Around the pillars, these are generally 2m to 3m in width, increasing in size away from the pillar. The zones above and below the workings were regrouped as follows:

- Group 11 - Above workings
- Group 12 - Below workings
- Group 13 - Above workings fault zone
- Group 14 - Below workings fault zone

Figure 3 shows the final model.

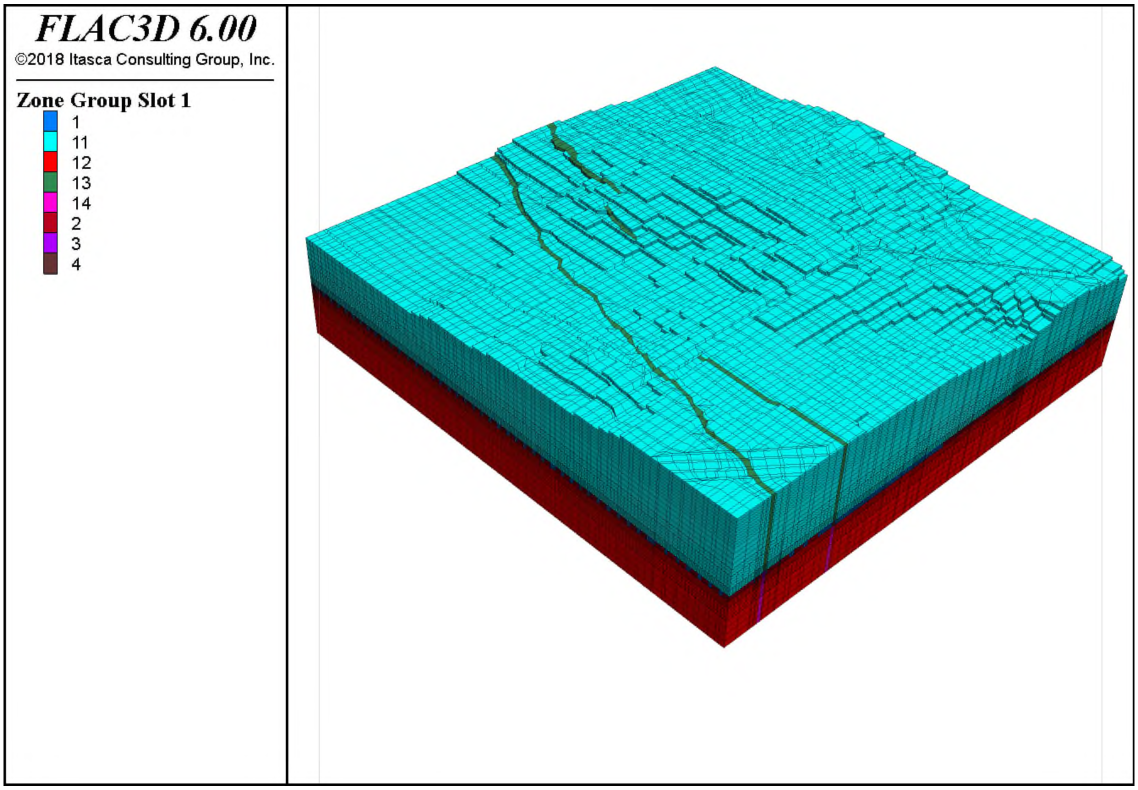

Figure 3: Complete model

3.3. Geotechnical model

The FLAC3D strain hardening/softening model with a Mohr-Coulomb failure criterion was adopted for the analyses. This model allows different cohesion values to be used depending on the strain. For the overburden rock, the FLAC3D strain hardening/softening ubiquitous joint model with a Mohr-Coulomb failure criterion was adopted to allow for planes of weakness into the rock mass to simulate bedding and allow some separation along these joints. Initial values of material parameters are based on approximations of borehole data using RocLab software and compared to published data. Table 1 has the adopted parameters for the general rock mass.

Table 1: Geotechnical model of layers used for 3 dimensional FLAC3D analyses

Material	Low to medium strength interbedded siltstone sandstone coal and tuff	High to very high strength interbedded siltstone and sandstone	Waratah Sandstone
Elevation (z) (m)	65 to -12	-12 to -55	-63 to -140
Density (γ kN/m3)	24	25.5	25.5
Youngs Modulus (E GPa)	0.15	1.7	4
Poisson's Ratio (ν)	0.25	0.25	0.25
Effective Cohesion (c'_{peak} kPa)	100	700	1200
Friction Angle (ϕ °)	30	45	45
Dilation Angle (ψ °)	5	10	10
Tension (kPa)	0.5	25	150
Bedding plane tension (kPa)	0	0	N/A
Bedding plane friction (°)	35	35	N/A
Bedding plane cohesion (kPa)	20	20	N/A

The effective cohesion was modelled to soften to 10% of the peak value at approximately 4% strain.

The ground is conservatively assumed to be drained with total stress (i.e. water level below mine level) despite the fact that the workings are flooded. This assumption causes the load applied to the mine pillars to be greater than possible because the effect of buoyancy on the effective weight of the ground has not been taken into account. This more closely resembles the loading at the end of mining.

Boundaries of the stratigraphic units were modelled using the drilling data at four general locations:

- VH01 (754-NTLGE206228-AG, 19 February 2018) (at the next-door site near the centre of the model)
- BH01 and BH02 (GEOTWARA22556AB-ACRev1, 13 March 2016 north western side of model)
- BH1C, BH1D, BH2A and BH2B (N8788-01-AH, 5 July 2004 south eastern corner of model)
- BH1 to BH3 (N7013-01-AE. dated 8 September 1998 north eastern corner of model)

The Borehole Seam in the area has a dip locally of up to 1 in 90. To simplify the construction of the model, the seam was assumed to be level, with the additional thickness of units included in the surface levels of each of the unit boundaries.

Only one significant fault was shown on the mine plans. The fault material was assumed to have the same strength of the respective surrounding rock of the same unit, however it was assumed to have reached its residual strength state (i.e. effective cohesion approximately 10% of peak strength (i.e. $c'_{fault} = c'_{residual} = 0.1 \times c'_{peak}$).

Material parameters for the coal pillars were calibrated to published empirical data and derivation of these parameters is presented in Section 3.4.

For the model, the horizontal stress in the major principal direction (i.e 'x' or north east to south west or along the pillars) has been assumed to be equivalent to a coefficient of earth pressure at rest (k_0) (i.e. (i.e.$\frac{\sigma_{h\,soil}}{k_0} = 1$)) for the soil zone and increasing at rock level at a similar rate similar to ¾ of vertical stress (i.e. $\Delta\sigma_{hx\,rock} = \frac{3}{4}\Delta\sigma_v$). Similarly, in the minor direction (i.e. 'y' or north west to south east or across the pillars) the horizontal stress was also taken as k_0. While within the rock zone the rate of increase in stress was taken as ½ of the vertical rate of change (i.e. $\Delta\sigma_{hy\,rock} = \frac{1}{2}\Delta\sigma_v$).

This means within the soil zone, the horizontal pressure is approximately 9kPa times the depth while in the rock zone the horizontal pressure is approximately 9kPa times depth of soil plus 18.75kPa times depth within rock in the x direction (principal) and approximately 9kPa times depth of soil plus 12.5kPa times depth within rock in the y direction (minor).

Although no pillars were modelled within the Yard Seam, an interface was allowed for. Table 2 provides properties of this failure plane.

Table 2: Failure properties of Yard Seam interface

Unit	Peak Effective Cohesion (c' MPa)	Peak Friction Angle Adopted (ϕ°)	Residual Effective Cohesion (c' MPa)	Residual Friction Angle Adopted (ϕ°)	Tension (kPa)	Stiffness Normal (E GPa)	Stiffness Shear (E GPa)
Yard Seam	0.2	16	0.05	15	1	60	30

3.4. Calibration of coal pillar strength

A critical factor in understanding the stability of the workings is the strength of the coal pillars. The strength of a coal pillar relies on three aspects:

- The intact coal strength
- The effect of discontinuities controlling the rock mass behaviour
- The coal pillar geometry, affecting the degree of confinement within the coal pillar core
- Confinement at the top and bottom of coal pillars

The intact coal strength of a seam will be dependent on the 'quality' of the coal. 'Dull' or silty coal will typically have a greater strength than the higher quality 'bright' or clean coal. The latter has predefined face cleats (essentially cleavage) aligned perpendicular to the primary regional stress direction. Within a seam, the overall seam strength will tend to vary depending on the variation of the distribution of the different quality layers within the coal.

The strength of the coal pillars was calibrated using a pillar height of 6.5m (the approximate height of the Borehole Seam less 0.2m for inferior coal left at floor of mine). The upper shale zone within the coal pillars was assumed to be 1.5 x the strength of the coal.

$$Sp = 8.6 \text{ x } \frac{w^{0.51}}{h^{0.84}} \quad (1)$$

Where Sp = pillar strength, w = width and h = height in metres.

Sp = 8.6 x $10.5^{0.51}/6.5^{0.84}$ = 5.9MPa for the 10.5m wide pillar, (general seam in area)

The coal pillars have been modelled with:

- A peak strength as per Equation 1 above, before crushing of the pillar.
- A plastic phase that decreases in strength due to plastic deformation. Once the load on the pillar reaches its ultimate strength a strain softening phase is implemented at a volumetric plastic shear strain of 0.005 (0.5%) to 0.04 (4%).
- An after-crush phase where the rubble within the bord (combination of roof fall, expanded coal pillar and poor coal) provides confinement of the pillar. The amount of crush aimed for, for each of the individual pillars, at the site-specific pillar stress is estimated to be 0.5m.

The result of the pillar calibrations, with a course mesh similar to that used for the pillars within the model, are shown below in Figure 4 with the final parameters given in Tables 3 and 4.

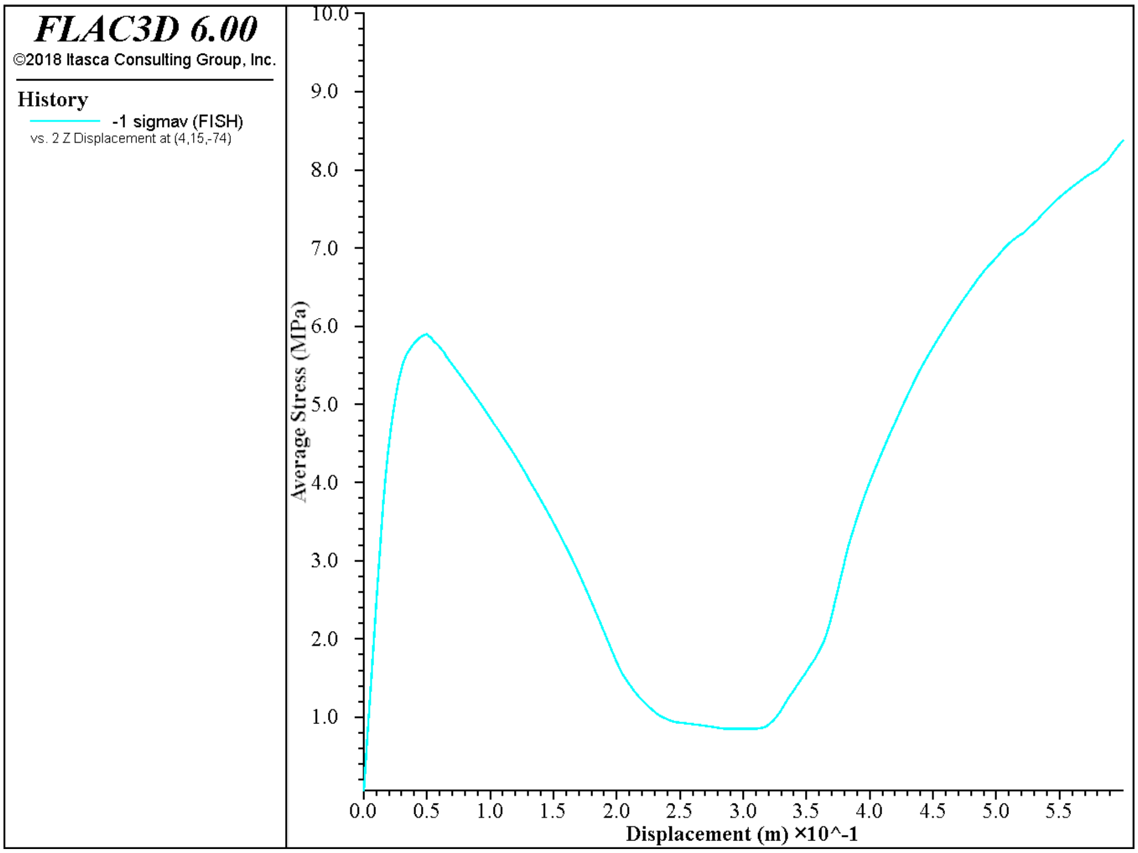

Figure 4: Original pillar calibration for the 10.5m coal pillars assuming a 6.5m height

Table 3: Summary of pillar calibration

Unit	Calibrated Effective Cohesion (c' MPa)	Friction Angle Adopted (ϕ°)	Tension (kPa)	Young's Modulus (E GPa)	Poisson's Ratio (ν)
10.5m pillar coal (6.5m high)	0.96	28	10	2	0.3
10.5m pillar siltstone high (6.5m high)	1.44	30	40	3	0.3

A series of two interfaces were adopted one at the top and one at the bottom of the coal pillars.

Table 4: Geotechnical model of interfaces within coal pillars used for the three-dimensional FLAC3D analysis

Unit	Peak Effective Cohesion (c' MPa)	Peak Friction Angle Adopted (ϕ°)	Residual Effective Cohesion (c' MPa)	Residual Friction Angle Adopted (ϕ°)	Tension (kPa)	Stiffness Normal (E GPa)	Stiffness Shear (E GPa)
Top Pillar	0.2	16	0.05	15	1	60	30
Bottom Pillar	0.2	16	0.05	15	1	40	20

4. Stages of calculation

The following stages were adopted in the calculations:

- Construct the x-y (flat) plane of the model, based on of mine workings.
- Extrude main section body of model reducing the elements in the x-y plane in three stages.
- Deleting elements from the x-y plane before ‘extruding’ to account for surface topography
- Calibrate ground parameters with collected and inferred field data relevant to the area, including historical records and previous empirical relationships of pillar width and height to pillar strength.
- Apply the geostatic initial stresses to the model. For conservatism with respect to pillar stresses, the ground water has been assumed to be below mine level.
- Progressively excavate the mining voids (bords and headings) to simulate the condition after mining was completed (although at the current bord height of 8m).
- Trigger pillar run without modifying the strength of coal pillars and watch path of conceptual ‘creep’. The overburden stresses are distributed according to relative stiffness of the coal in each area and amount of collapse of pillars in the area. The degree of deformation (to a condition of collapse) is assessed, including how that deformation transpires to potential surface movement.
- Modify pillar parameters to get behaviour representative of the historic ‘creep’ events and repeat previous step.
- Add grout to select mine voids retrigger pillar run
- Progressively reduce strength and tension parameters of remaining pillars to assess conceptual reductions in strength required for pillar failure and resulting ground subsidence in different areas.
- This report was then developed.

5. Results and discussion

5.1. Excavation of bords

After application of in situ field stresses, the bords were excavated in stages in the model, as is required to prevent numerical instability during the analyses.

An output that summarises the final vertical stress after excavation (at completion of initial mining) is given below in Figure 5. This provides an image of the layout of workings, showing overburden stress being distributed between pillars’ cores and the extent of mining.

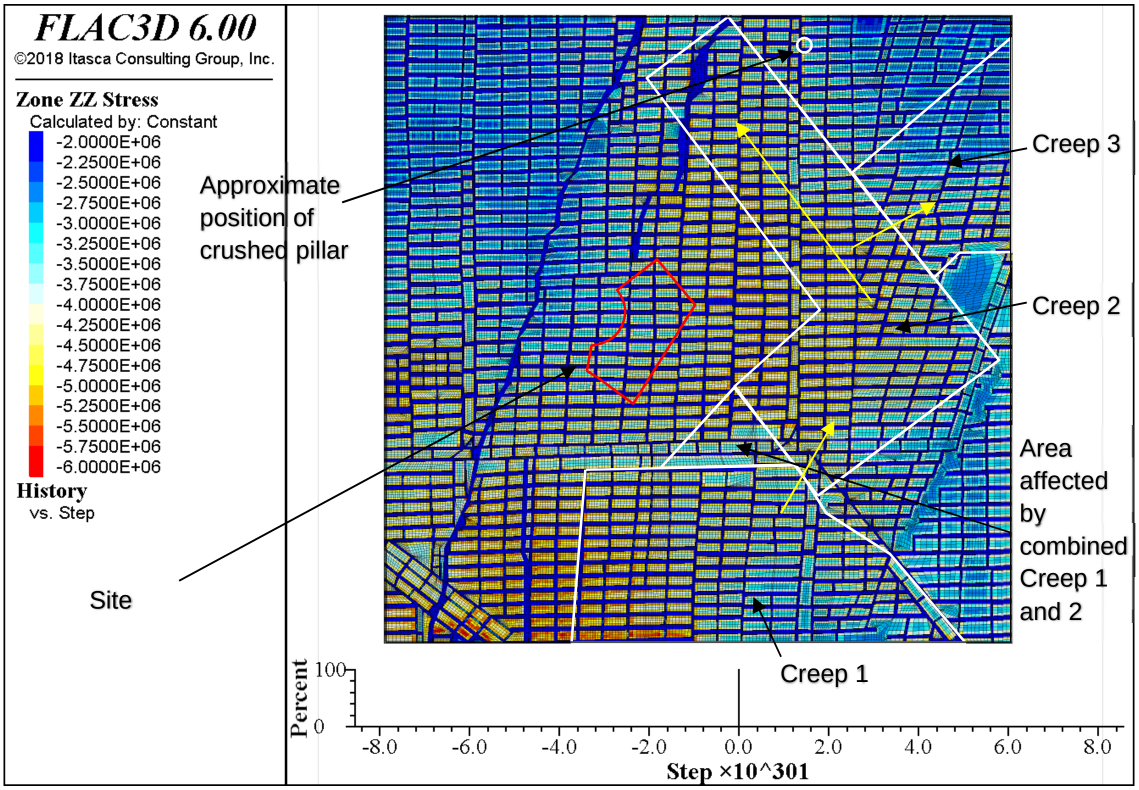

Figure 5: Vertical stress at Borehole Seam level before collapse with historical 'Creeps' shown

Figure 5 shows the variation in stress at the end of mining before the historical creep events (Creeps 1 to 3). It is noted the pillars around Creep 2 appear to behave elastically (i.e. load higher around the outside of the pillar 5MPa to the core of 4MPa) while in the western portion of the Creep 1 area, the highly stressed pillars are starting to behave plastically with over 5MPa though out. It is noted that the vertical depth to the mine workings and or thickness of workings near Creep 1 may have some inconsistencies to the actual conditions as the higher loaded area is west of the Creep 1 and a natural valley is present over the eastern portion of Creep 1 reducing the overburden. This is not deemed to substantially affect the results of the modelled ground behaviour at the location of The Site.

The assumed path of the 'Creeps' is shown by the yellow arrows. Of note is the low stress in the area of Creep 3. In this area the additional historical creep may be the result of the thicker Borehole Seam. Conversely, pillars around The Site although subjected to high overburden stresses have not apparently failed as a part of the historical creep events may be due to lower mined heights and or Borehole Seam thickness.

5.2. Modelling historical creep events

5.2.1. Similar properties through all coal pillars

Initially the model was set up with similar properties for all coal pillars. To observe the path of the modelled creep event (pillar failure), a small zone of pillars was weakened at the edge of the model within the Creep 1 area. Screen images were taken regular intervals within solving phase following the path of the modelled creep event. These images are shown in Figures 6 to Figure 13 (refer to Figure 5 for labels of each area).

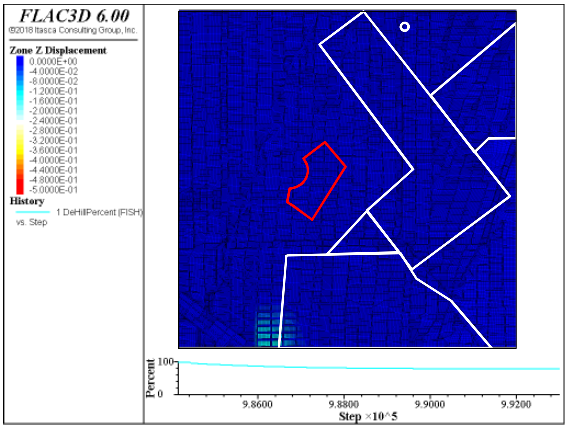

Figure 6: Screen shot one of modelled creep all same strength

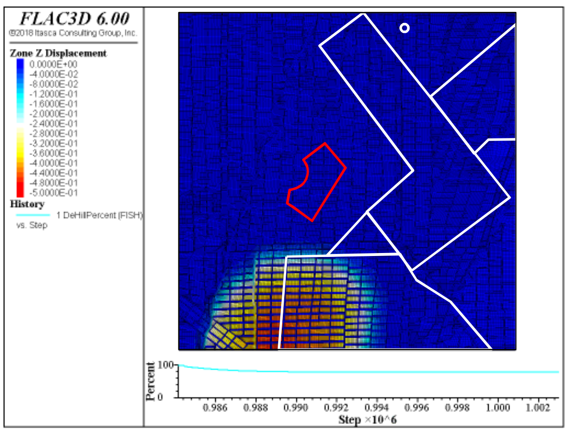

Figure 7: Screen shot two of modelled creep all same strength

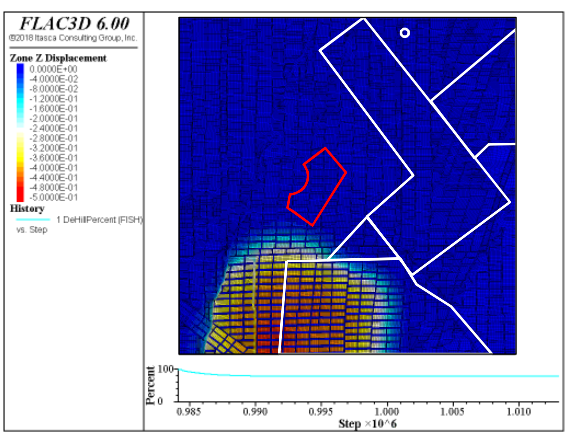

Figure 8: Screen shot three of modelled creep all same strength

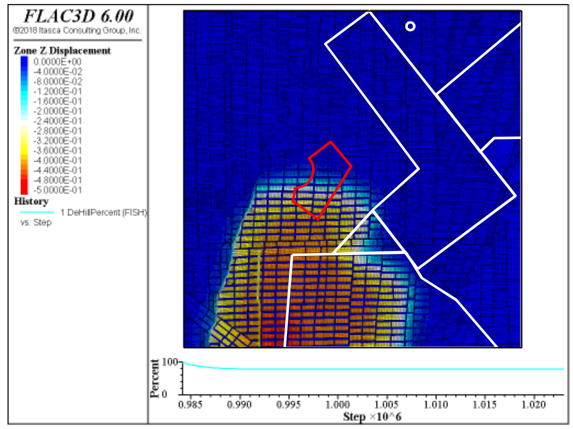

Figure 9: Screen shot four of modelled creep all same strength

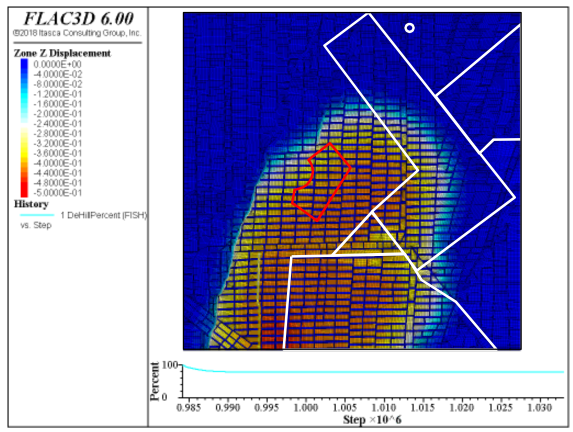

Figure 10: Screen shot five of modelled creep all same strength

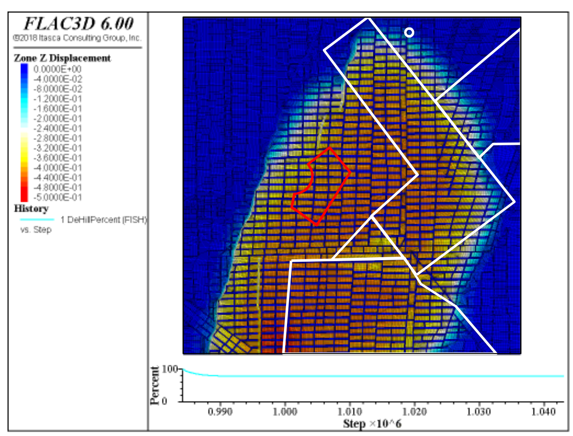

Figure 11: Screen shot six of modelled creep all same strength

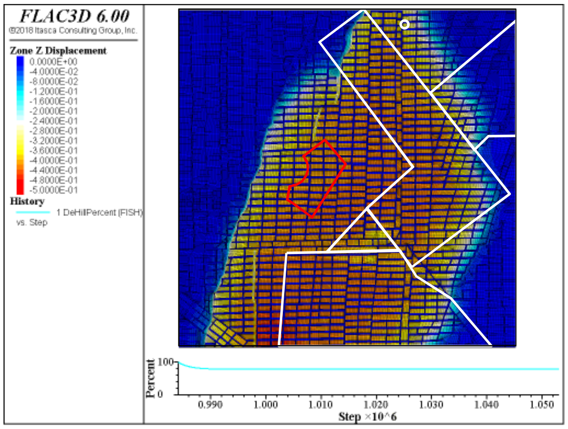

Figure 12: Screen shot seven of modelled creep all same strength

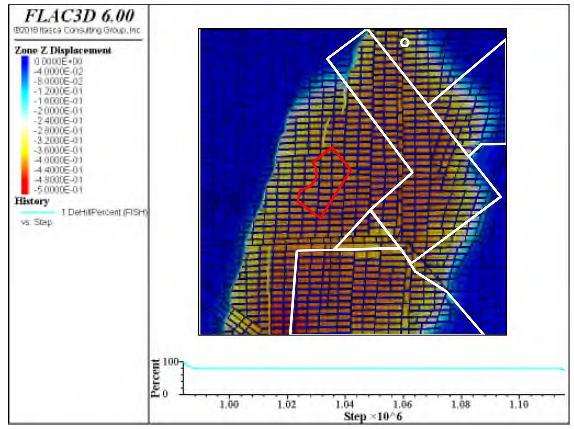

Figure 13: Screen shot eight of modelled creep all same strength

This resulted in a creep pattern that is inconsistent with the pattern of the actual historical creep events. As can be seen in the above, once the creep event is initiated, the creep event would be expected to progress through the whole area if the mining height was equal. However, it is known the heading south of The Site stopped the progression of historical Creep 1. A variation in mined heights or other variable must be considered to account for this discrepancy between the initially modelled creep and the known progression of the actual historical creep events.

5.2.2. Recalibration of coal strength at site

Even though the thickness of the coal seam at The Site was only 6m, the coal pillars appear to have not been crushed by past creep events (Coffey Report 754-NTLGE220504-AH.Rev2 dated 17 December 2018). As such, the strength of the coal around the site must be higher than the surrounding area. To more closely resemble the historical Creep events, the coal strength around The Site was increased in stages in order to simulate the historical creep events in the remodel. This was simulated by increasing c’ to 1.03MPa (similar to 6.0m high coal pillars), then to 1.1MPa, and finally 1.2MPa (similar to 5.1m high coal pillars.) Coal strength recalibration is shown in Figures 14 and 15. Figure 16 shows the area to recalibrated coal strengths are modelled.

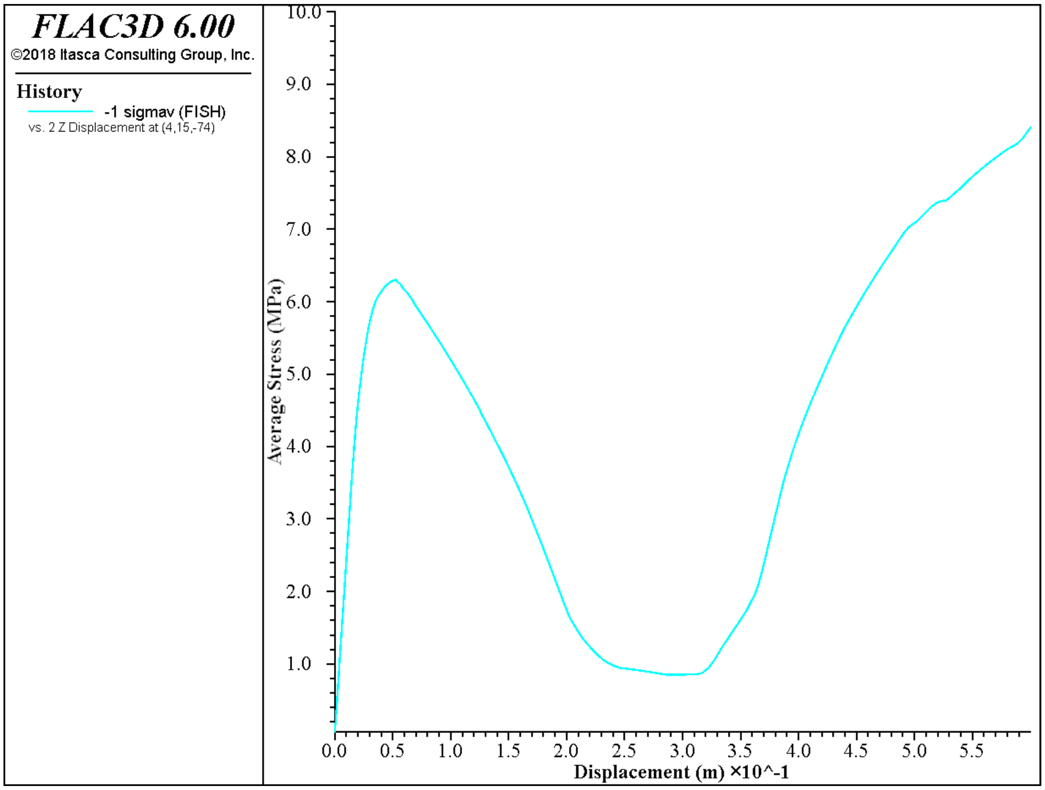

Figure 14: Recalibration curve with c' assumed to be 1.03MPa

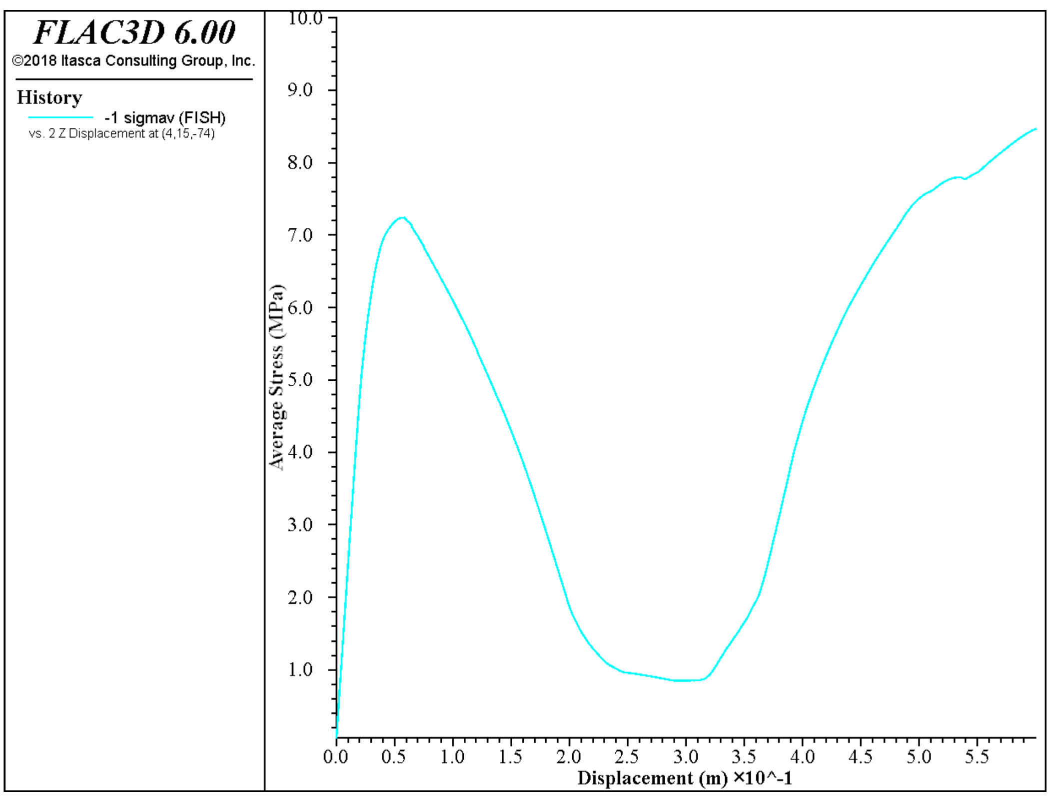

Figure 15: Recalibration curve with c' assumed to be 1.2MPa

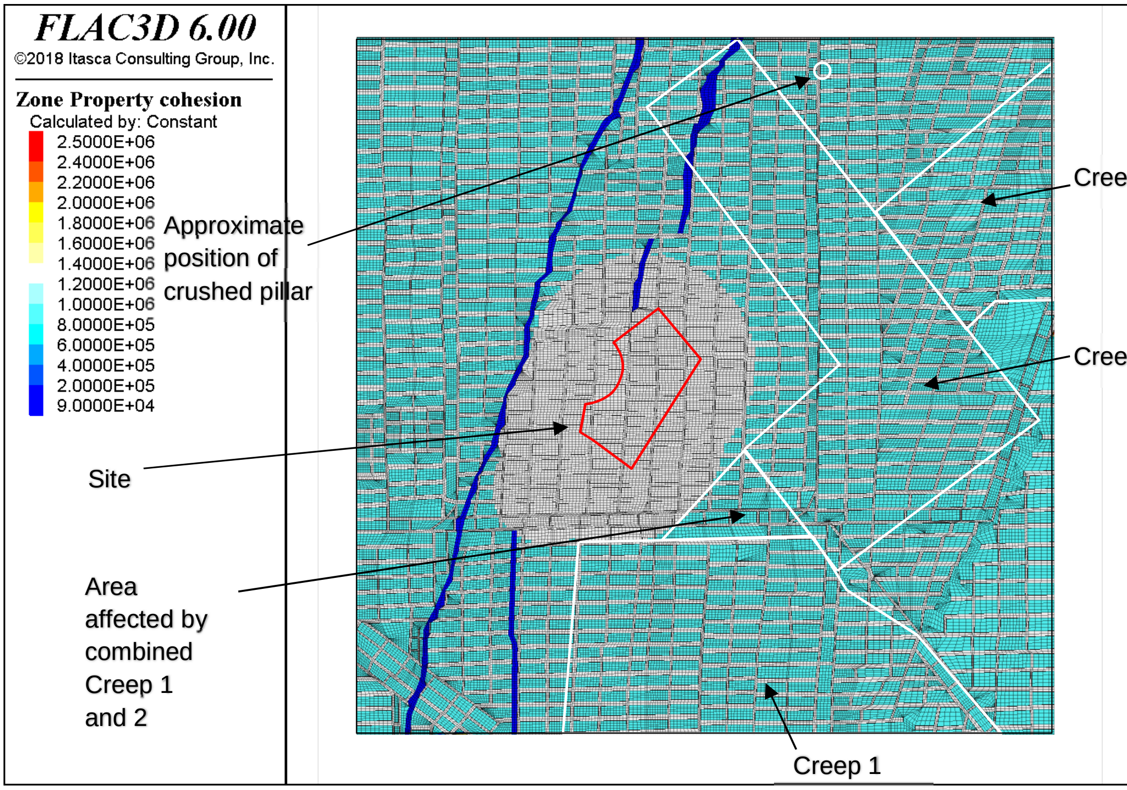

Figure 16: Area with higher cohesion in each reiteration

Figures 17 to 25 shows the sequence of image stills showing the path of the modelled creep assuming coal strength c'=1.03MPa (note the c' of the upper 2m roof collapse shale and silty coal is assumed to be 1.5 times higher).

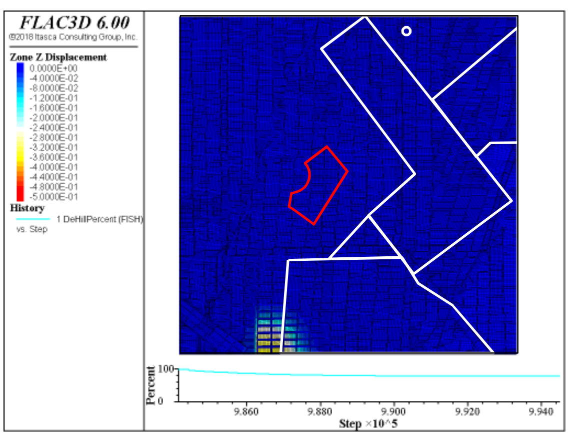

Figure 17: Screen shot one of modelled creep c' = 1.03MPa

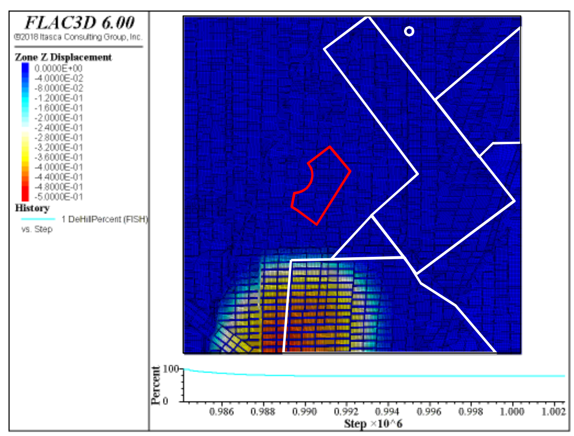

Figure 18: Screen shot two of modelled creep c' = 1.03MPa

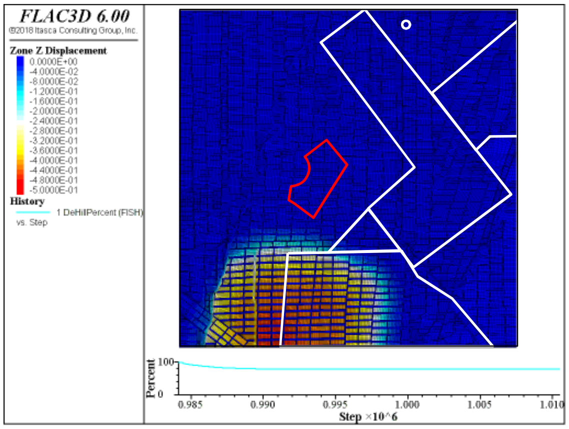

Figure 19: Screen shot three of modelled creep c' = 1.03MPa

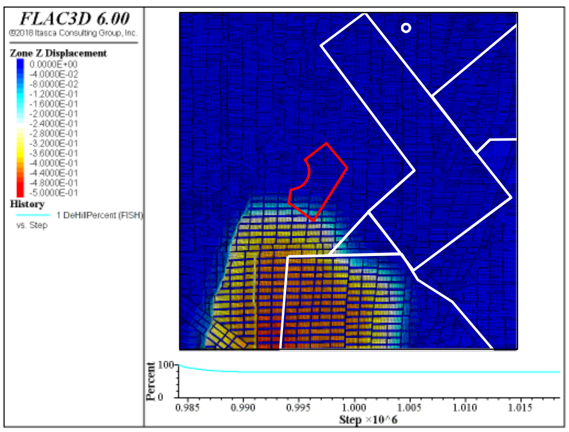

Figure 20: Screen shot four of modelled creep c' = 1.03MPa

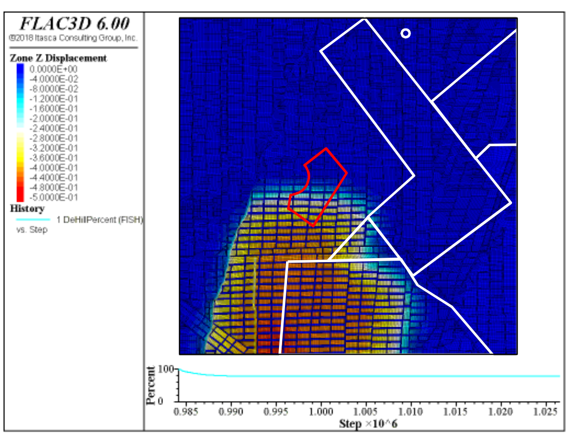

Figure 21: Screen shot five of modelled creep c' = 1.03MPa

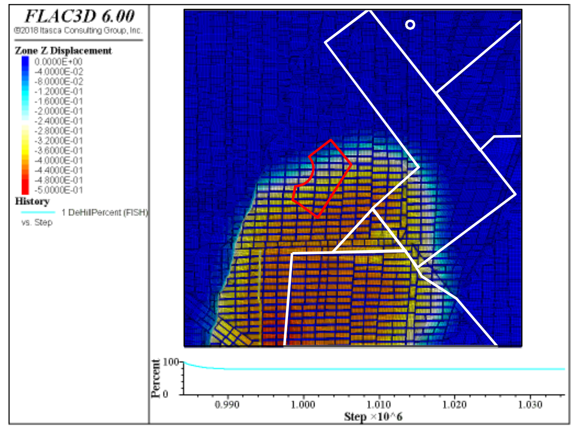

Figure 22: Screen shot six of modelled creep c' = 1.03MPa

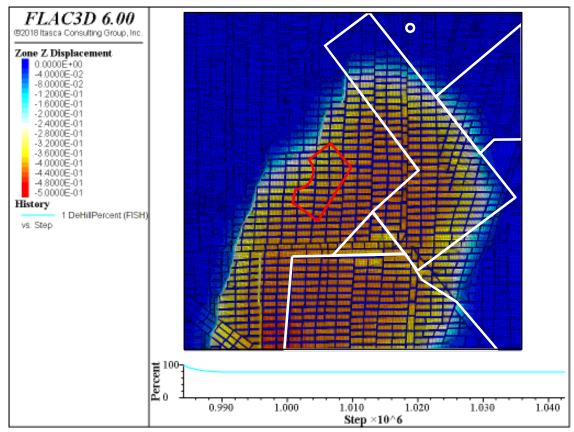

Figure 23: Screen shot seven of modelled creep c' = 1.03MPa

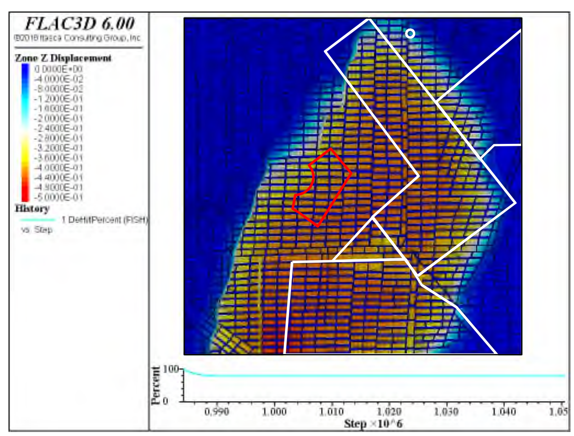

Figure 24: Screen shot eight of modelled creep c' = 1.03MPa

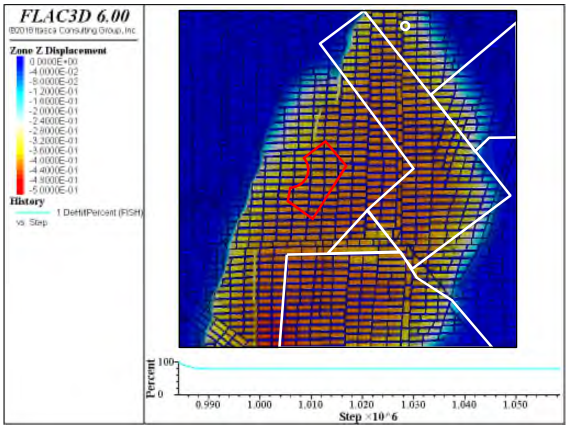

Figure 25: Screen shot nine of modelled creep c' = 1.03MPa

As the modelled creep path still appears inconsistent with that followed by the historical creep events, the coal strength c' around The Site was increased again, this time to 1.1MPa.

Figures 26 to 35 shows the sequence of image stills showing the path of the modelled creep assuming coal strength c'=1.1MPa (note the c' of the upper 2m roof collapse shale and silty coal is assumed to be 1.5 times higher)

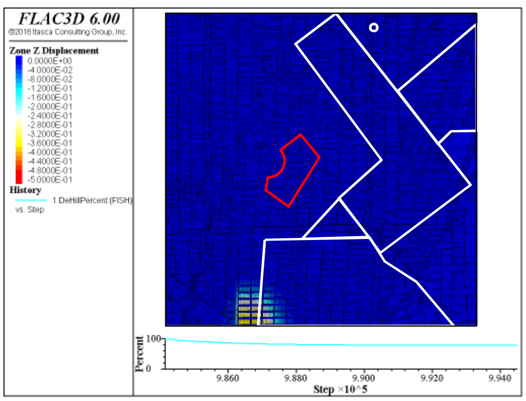

Figure 26: Screen shot one of modelled creep c' = 1.1MPa

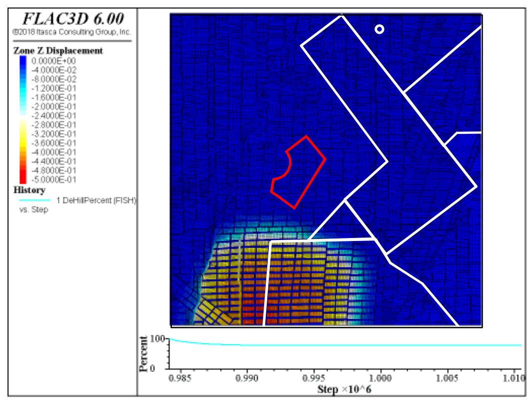

Figure 28: Screen shot three of modelled creep c' = 1.1MPa

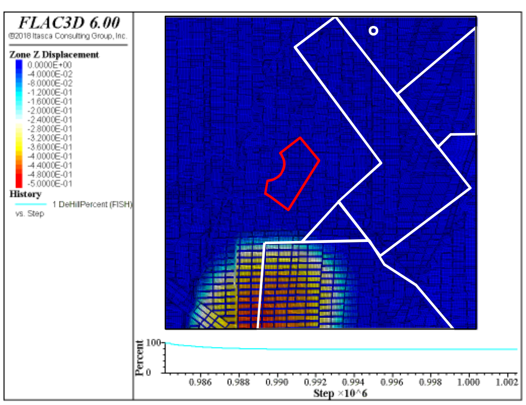

Figure 27: Screen shot two of modelled creep c' = 1.1MPa

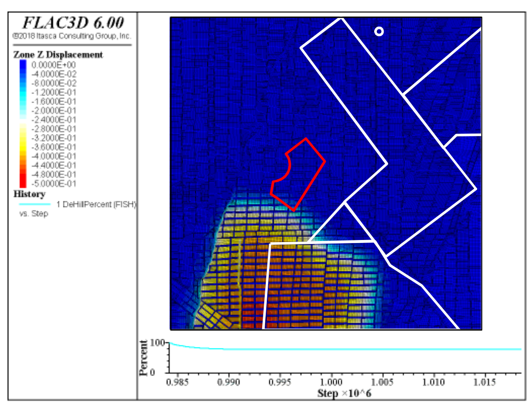

Figure 29: Screen shot four of modelled creep c' = 1.1MPa

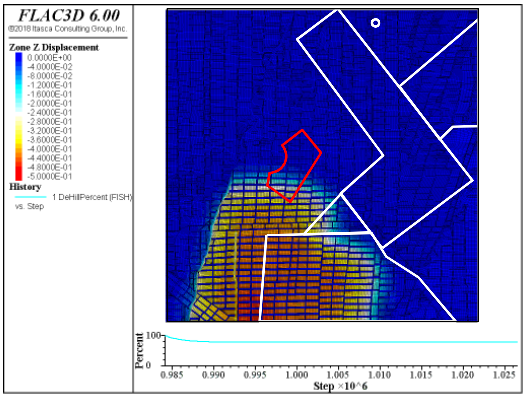

Figure 30: Screen shot five of modelled creep c' = 1.1MPa

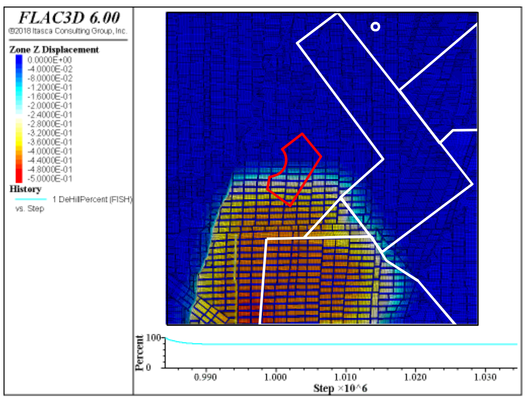

Figure 31: Screen shot six of modelled creep c' = 1.1MPa

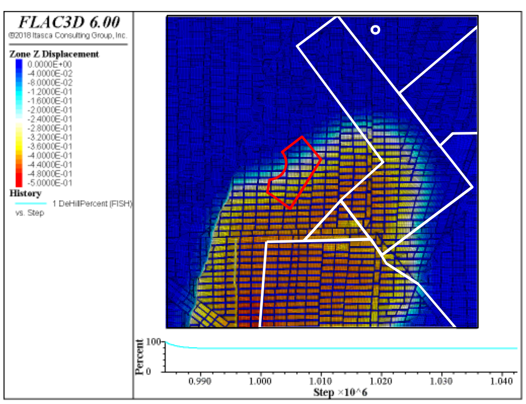

Figure 32: Screen shot seven of modelled creep c' = 1.1MPa

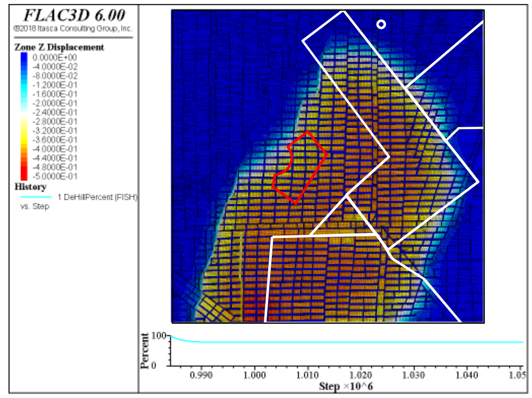

Figure 33: Screen shot eight of modelled creep c' = 1.1MPa

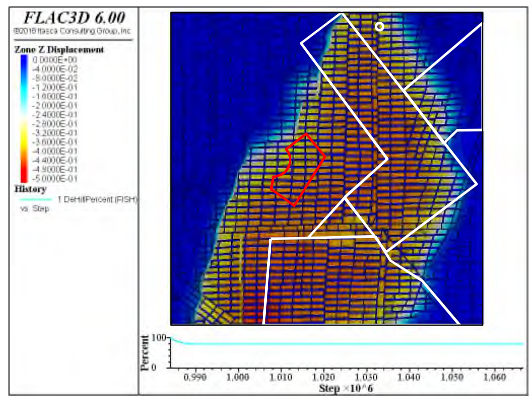

Figure 34: Screen shot nine of modelled creep c' = 1.1MPa

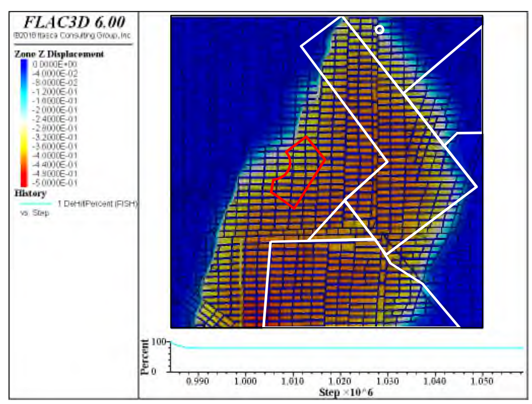

Figure 35: Screen shot ten of modelled creep c' = 1.1MPa

As the modelled creep path still appears inconsistent with that followed by the historical creep events, the coal strength c' around The Site was increased again, this time to 1.2MPa.

Figures 36 to 51 shows the sequence of image stills showing the path of the modelled creep assuming coal strength c'=1.2MPa (note the c' of the upper 2m roof collapse shale and silty coal is assumed to be 1.5 times higher)

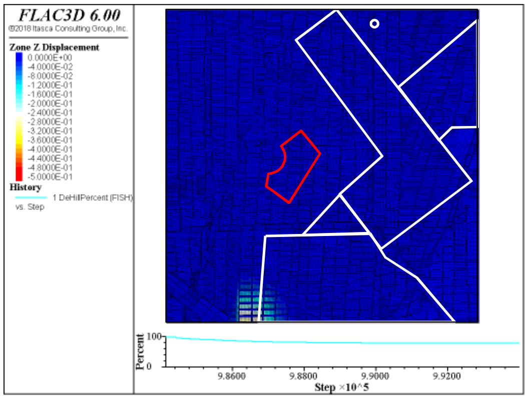

Figure 36: Screen shot ten of modelled creep c' = 1.2MPa

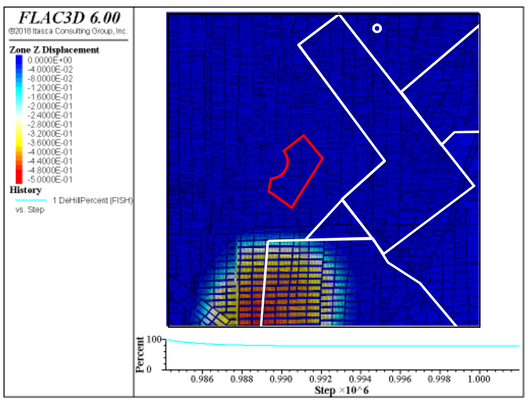

Figure 37: Screen shot two of modelled creep c' = 1.2MPa

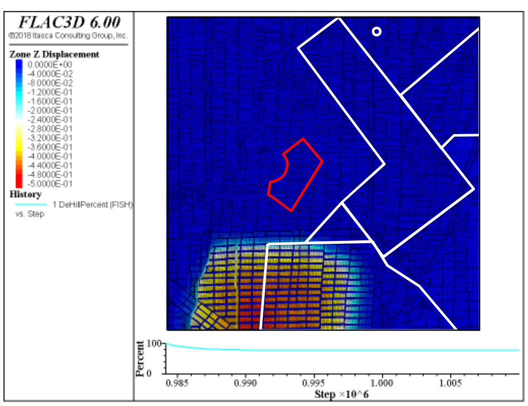

Figure 38: Screen shot three of modelled creep c' = 1.2MPa

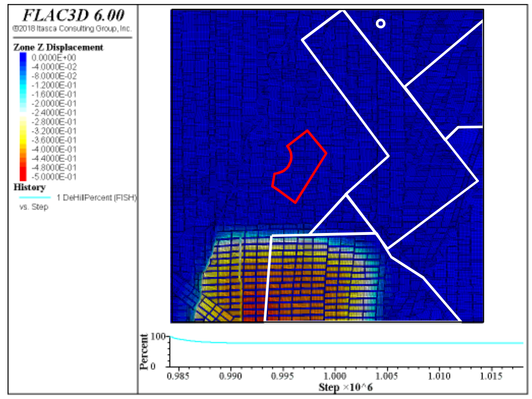

Figure 39: Screen shot four of modelled creep c' = 1.2MPa

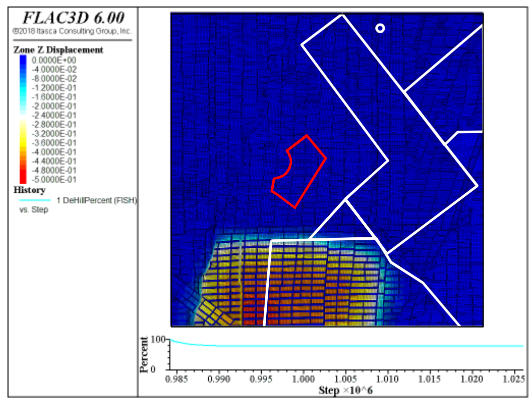

Figure 40: Screen shot five of modelled creep c' = 1.2MPa

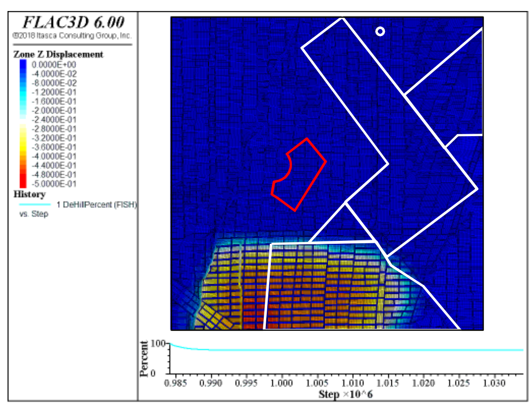

Figure 41: Screen shot six of modelled creep c' = 1.2MPa

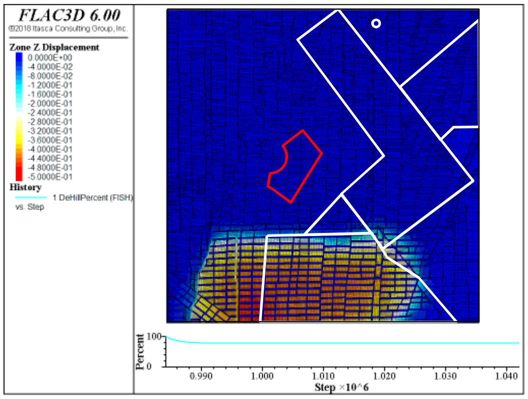

Figure 42: Screen shot seven of modelled creep c' = 1.2MPa

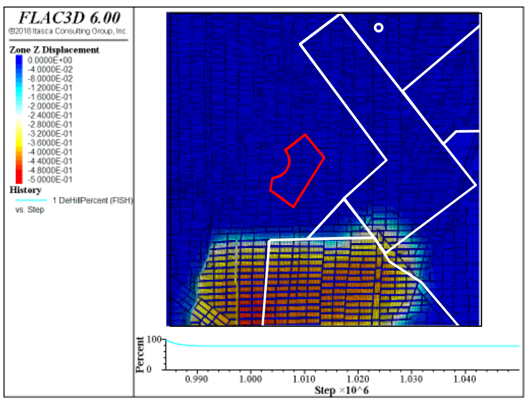

Figure 43: Screen shot eight of modelled creep c' = 1.2MPa

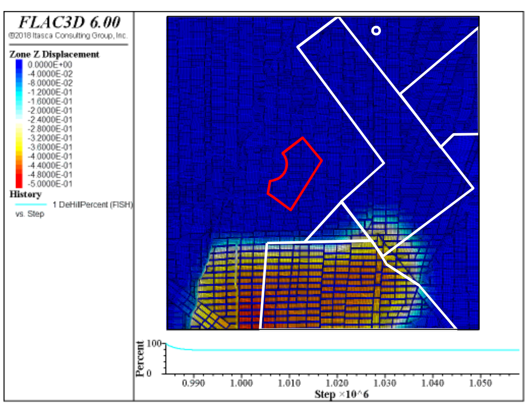

Figure 44: Screen shot nine of modelled creep c' = 1.2MPa

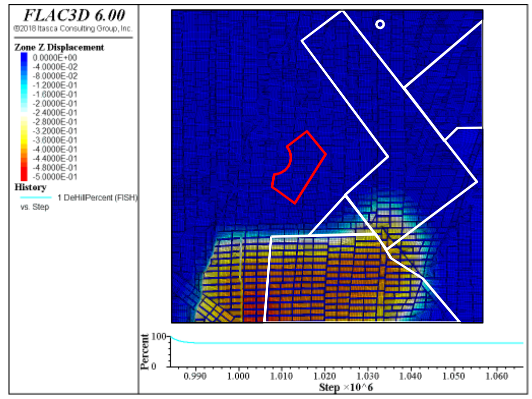

Figure 45: Screen shot ten of modelled creep c' = 1.2MPa

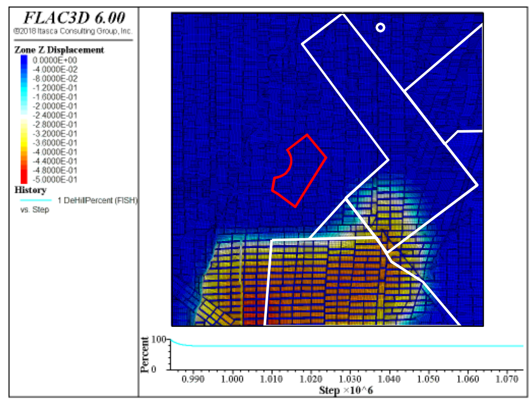

Figure 46: Screen shot eleven of modelled creep c' = 1.2MPa

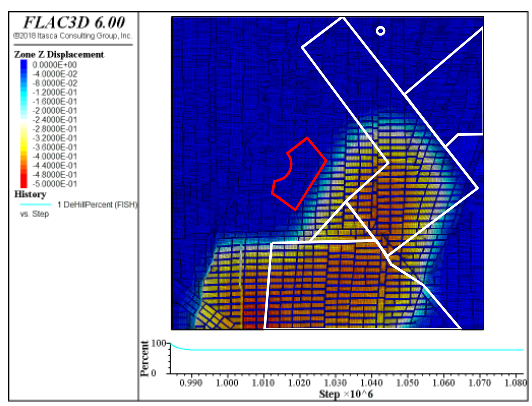

Figure 47: Screen shot twelve of modelled creep c' = 1.2MPa

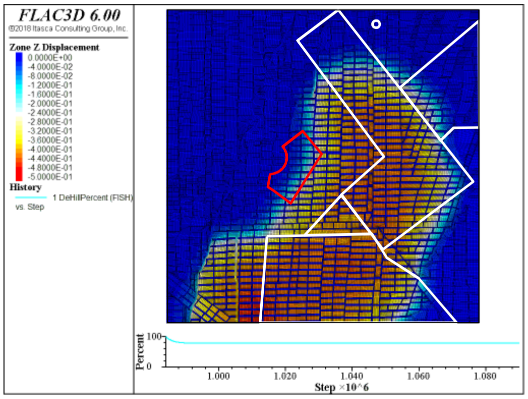

Figure 48: Screen shot thirteen of modelled creep c' = 1.2MPa

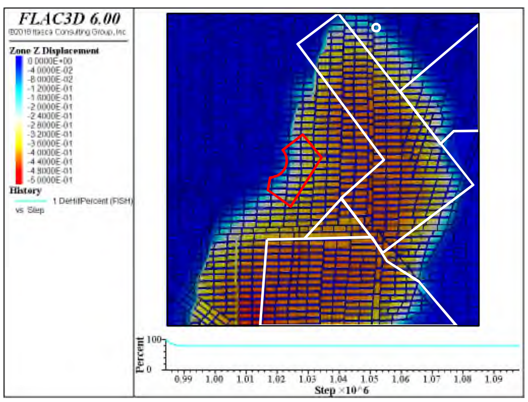

Figure 49: Screen shot fourteen of modelled creep c' = 1.2MPa

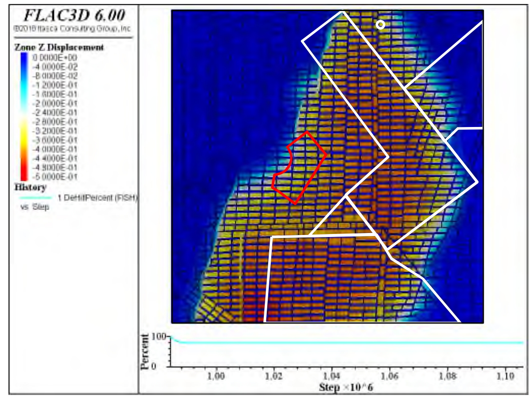

Figure 50: Screen shot fifteen of modelled creep c' = 1.2MPa

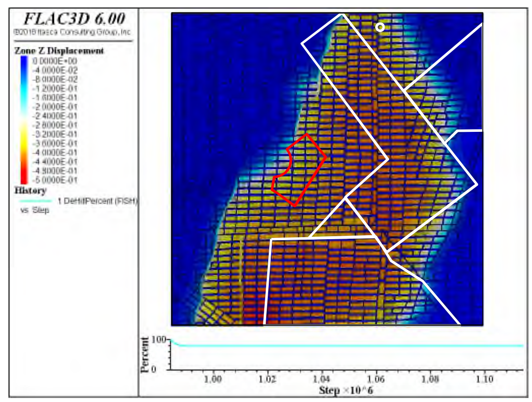

Figure 51: Screen shot sixteen of modelled creep c' = 1.2MPa

Although the model still has pillars under The Site failing at the new assumed coal strength, the path now appears to be more consistent with the historical creeps and as such further increase in coal strength for the coal pillars under The Site was not carried out. This allows for some conservatism.

5.3. Addition of grout to selected bords

To assess a suitable grouting strategy for the site, the model was reset back to the uncrushed state before adding grout to selected bords in two layouts. In the first layout, the grout was generally added in groups of four, two per bord either side of eight coal pillars supporting pillars half the depth to workings around the boundary of the site. At the two critical corners, an additional bord (i.e. three bords) was deemed necessary, while within the centre of the site the grouting was reduced to only one location per bord. In the second layout trialled, the grout was generally placed at the boundary only in groups of six.

The grouting strategies were developed to control the behaviour of the subsidence profile rather than to fill the whole area to eliminate all subsidence.

Due to the height of overburden and the low factor of safety of the area, the proposed grout strength is 5MPa for the Site. With reference ACARP 2001, the modulus of flyash grout may be expected to be 300 x the UCS strength. Allowing for some conservatism, a base modulus of 1,000MPa was adopted, reducing within the bord depending on the position within the rubble. The final adopted values for grout strength are shown in Table 5.

Table 5: Parameters for grout locations

Unit	Effective Cohesion (c' kPa)	Friction Angle Adopted (ϕ°)	Youngs Modulus (E MPa)	Poisson's Ratio (ν)
Proposed grout bottom 2m (i.e. significant rubble with poor permeation)	5	29	120	0.3
Proposed grout 2m to 6m (i.e. significant rubble with ok permeation)	250	29	500	0.3
Proposed grout upper 2m (i.e. Solid grout	500	29	1000	0.3

Figure 52 shows proposed grout locations for layout one with ground slopes visible in Figure 53. Similarly, Figure 54 shows proposed grout locations for layout two with ground slopes visible in Figure 55.

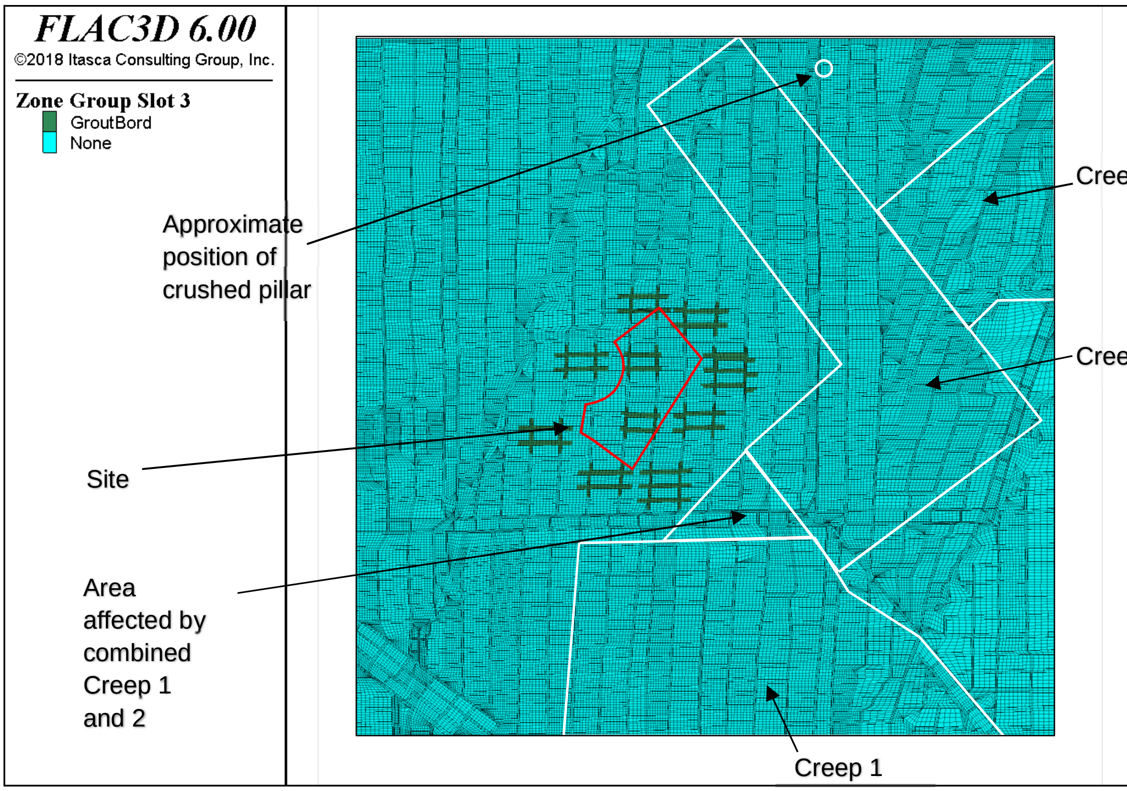

Figure 52: Proposed grout layout one

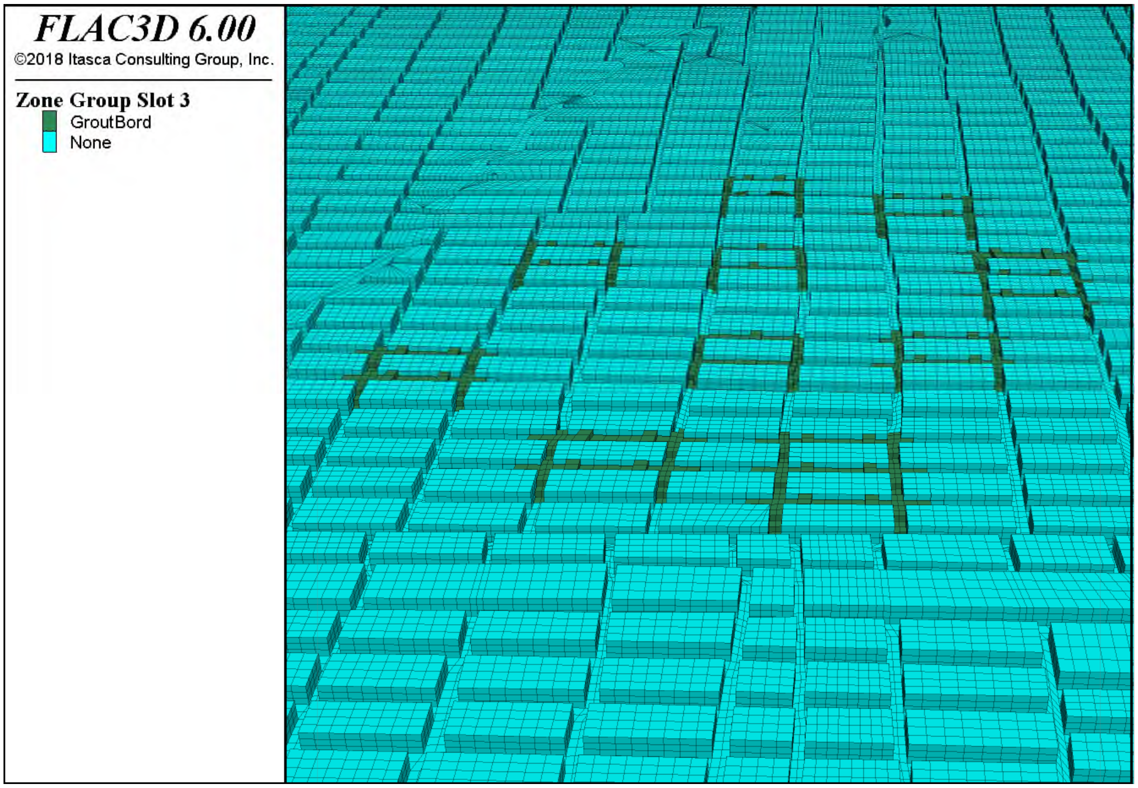

Figure 53: Closeup of grout locations with grout surface visible (i.e. cones of grout with a small 2m width zone connected to the roof with remaining grout 2m from roof) layout one

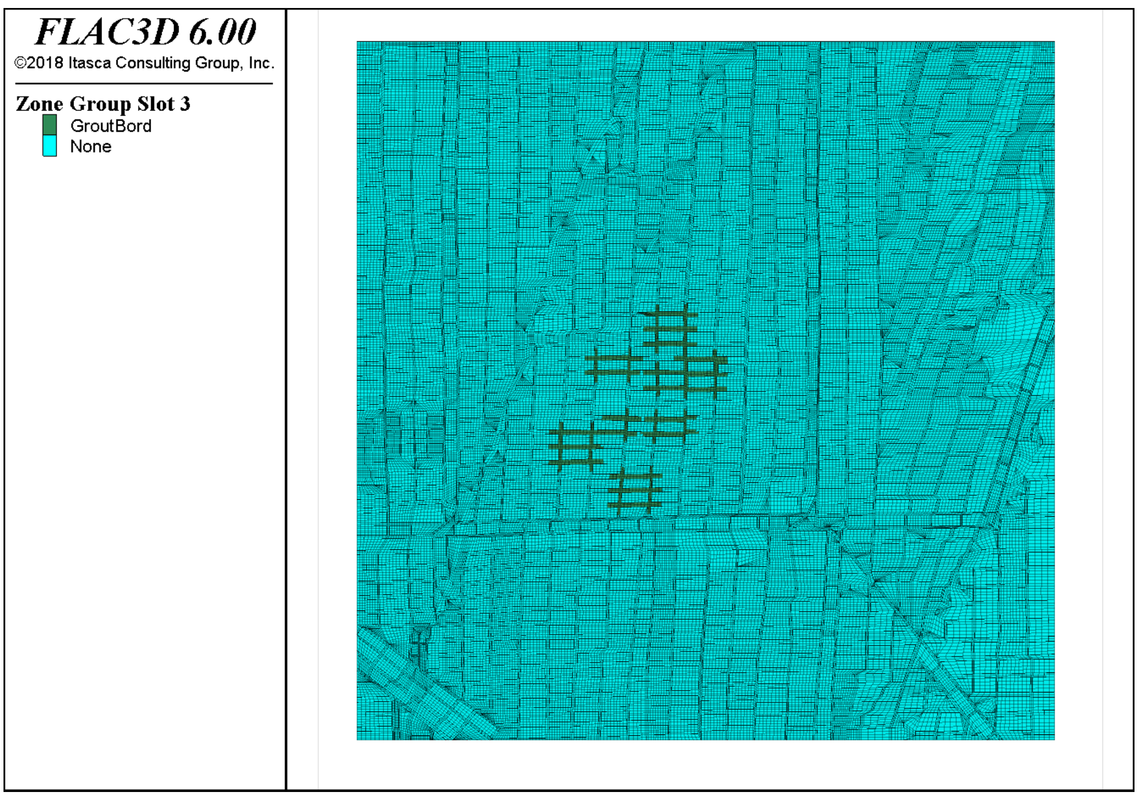

Figure 54: Proposed grout layout two

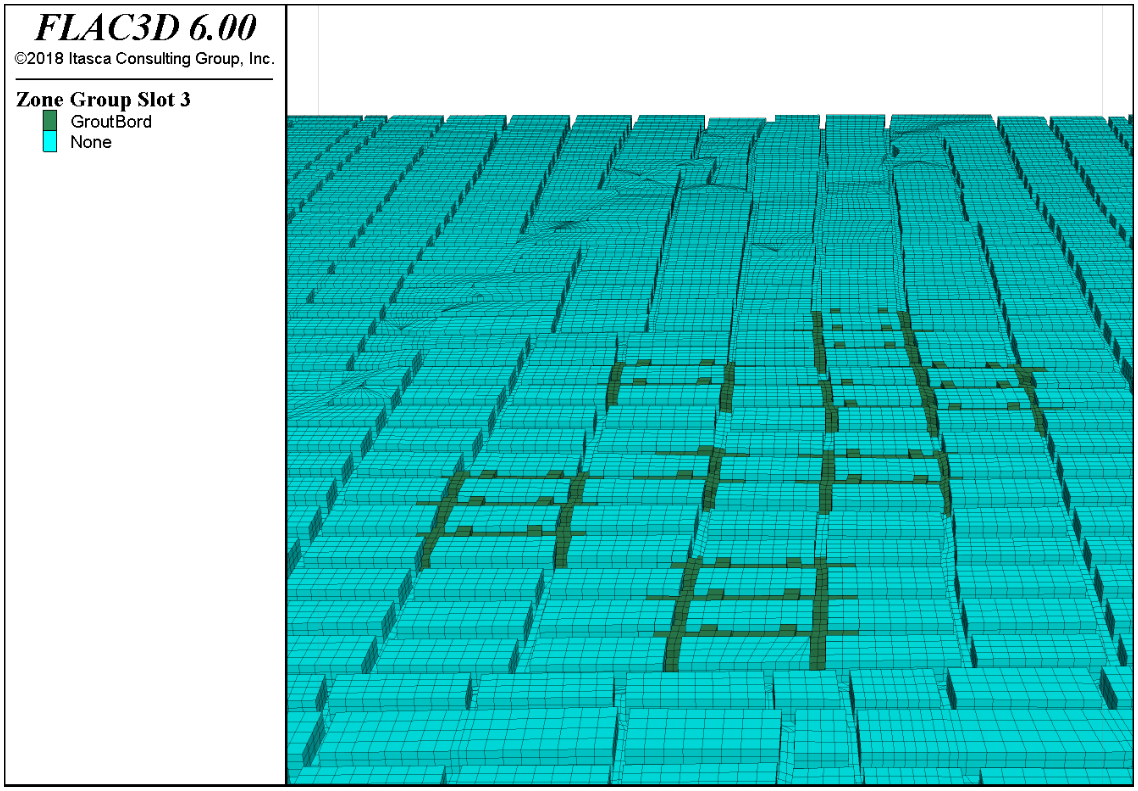

Figure 55: Closeup of grout locations with grout surface visible (i.e. cones of grout with a small 2m width zone connected to the roof with remaining grout 2m from roof) layout two

5.4. Gradual degradation of coal strength methodology

To allow for the possible/conceivable slow degradation of coal strength, the coal strength in the numerical model was reduced by approximately 5% for each stage solved by the modelling. The resultant condition for generally every five increments is then saved for later examination as well as at increment two. This results in the following reduction of coal strength:

- $0.95^{2} = 0.90$
- $0.95^{5} = 0.77$
- $0.95^{10} = 0.60$
- $0.95^{15} = 0.46$
- $0.95^{20} = 0.36$
- $0.95^{25} = 0.28$
- $0.95^{27} = 0.25$

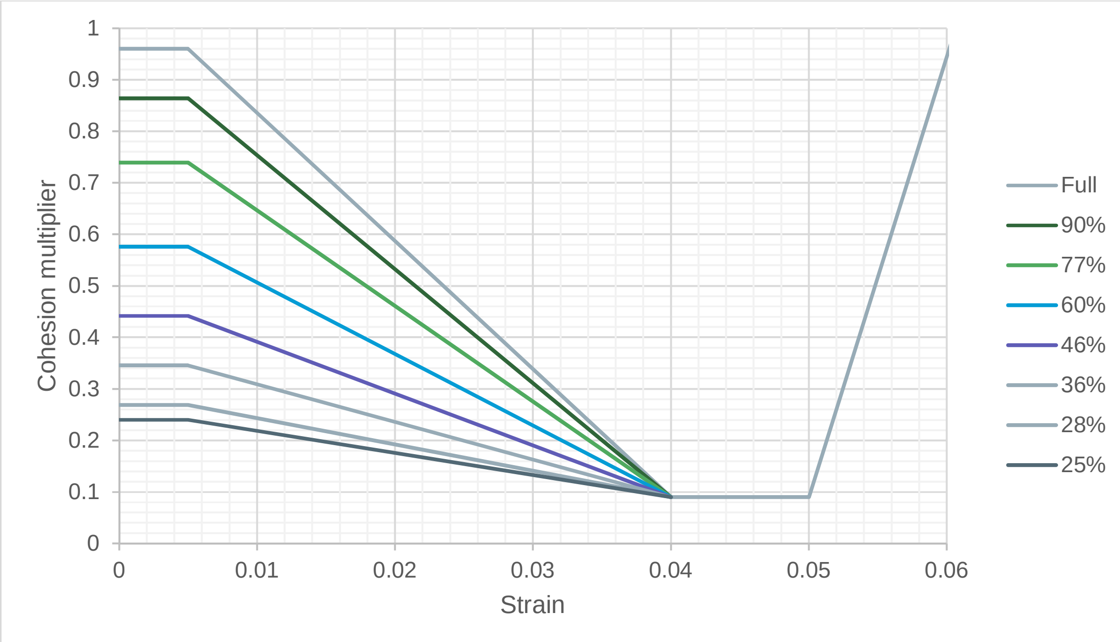

Figure 56: Degradation of peak coal strength

5.5. Output of results

Although the modelling of the pillar crushing causes several forms of displacements, we have chosen to output the conceptual vertical displacement (settlement) at surface level and its distribution at the surface to demonstrate the effect of potential future pillar crushing/convergence at surface level.

5.5.1. Retrigger of modelled creep with grout in place layout one

After the addition of the layout one grout, the pillar run was retriggered similar to as described above at the edge of historical Creep 1 in the most highly stressed pillars in the model. This settlement is shown in Figure 57. It is noted that with the addition of remedial grouting, the modelled creep and settlement did not extend to The Site as previously illustrated in figures 44 to 51.

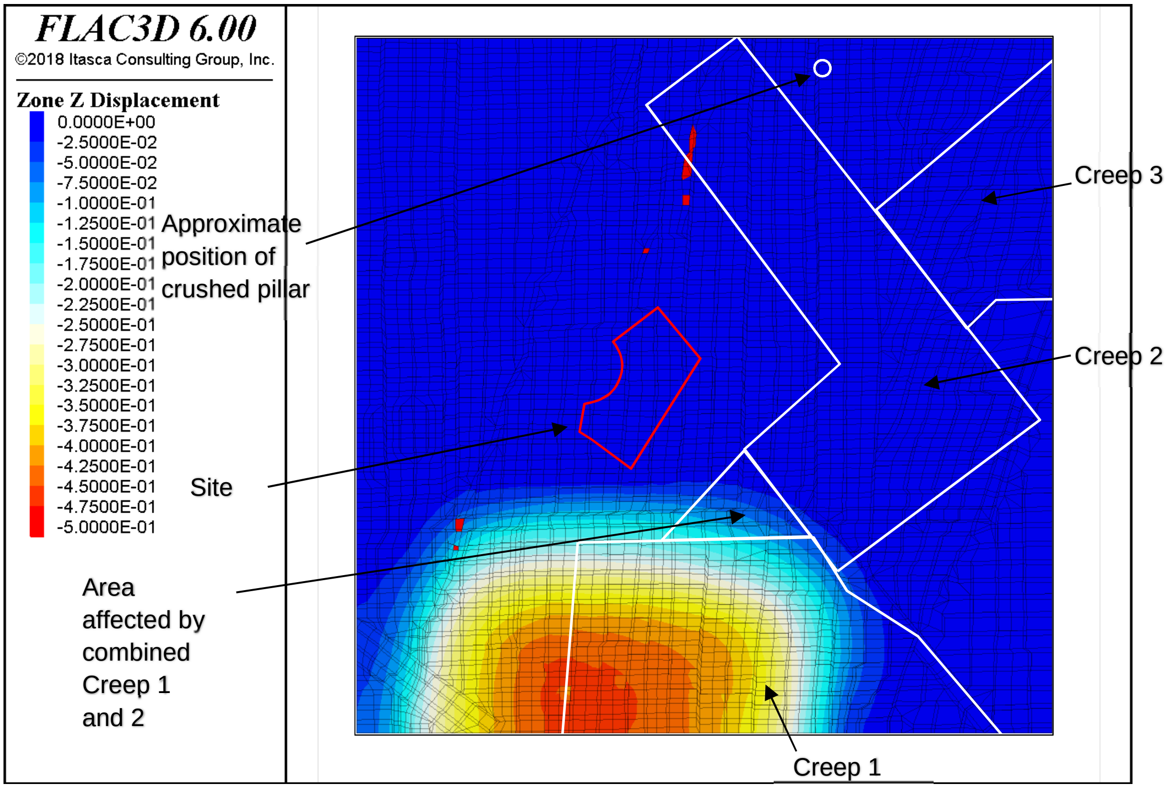

Figure 57: Modelled creep event conceptual surface displacement layout one.

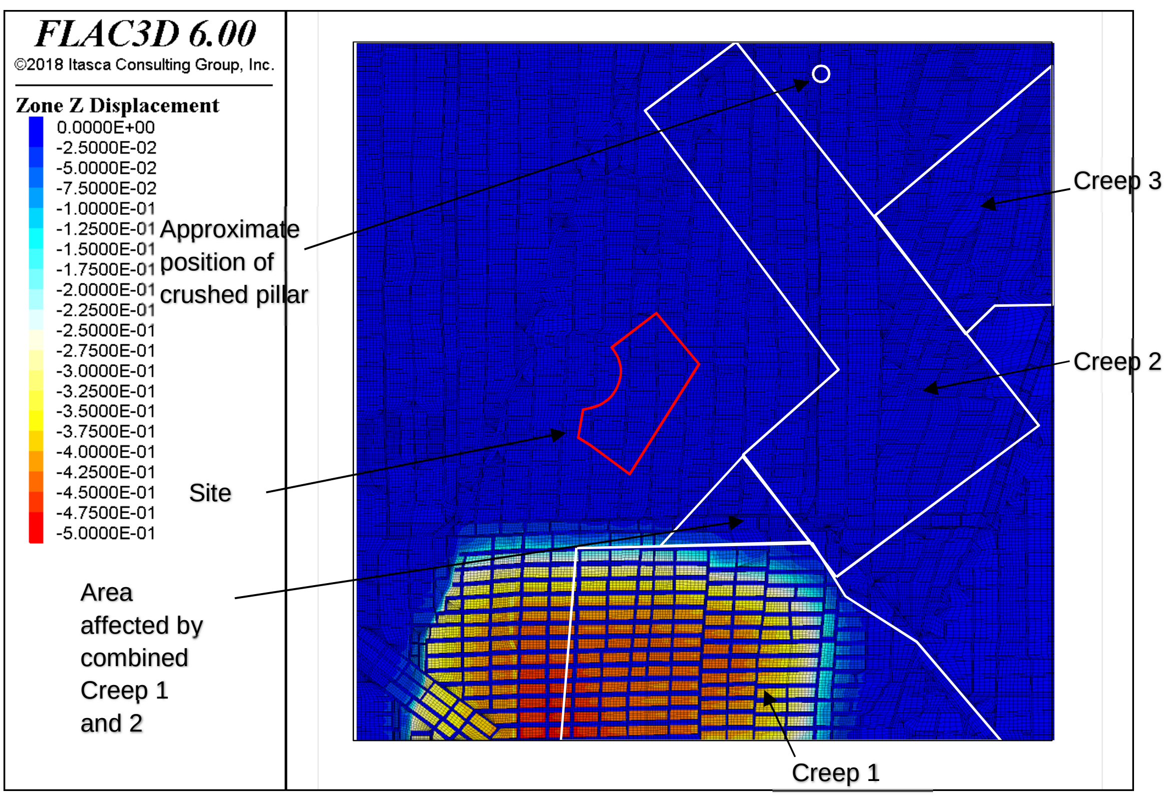

Figure 58: Borehole Seam crush after modelled creep layout one.

5.5.2. Degradation phase layout one

Figures 59 to 65 show the change in the crush front at strengths of 90%, 77%, 60%, 46%, 36%, 28% and 25%.

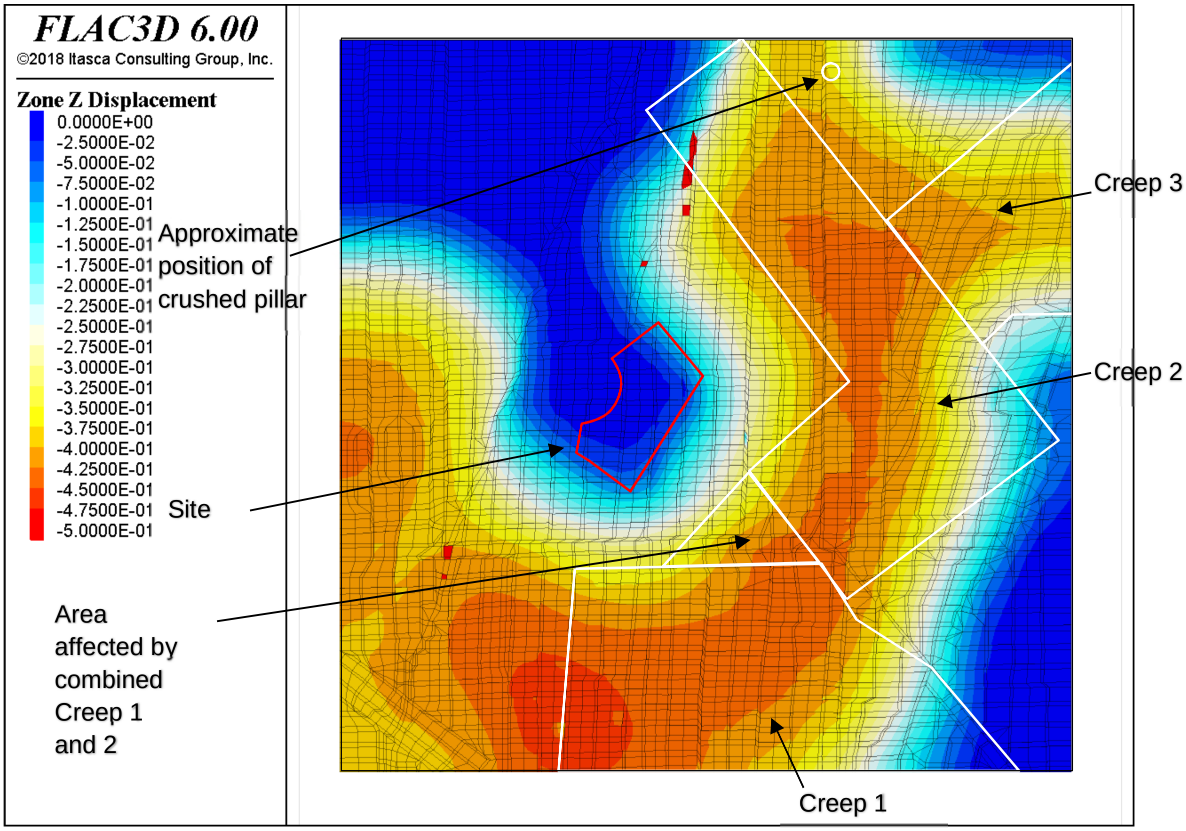

Figure 59: Conceptual vertical displacement with pillar coal at 90% strength with proposed grout layout one.

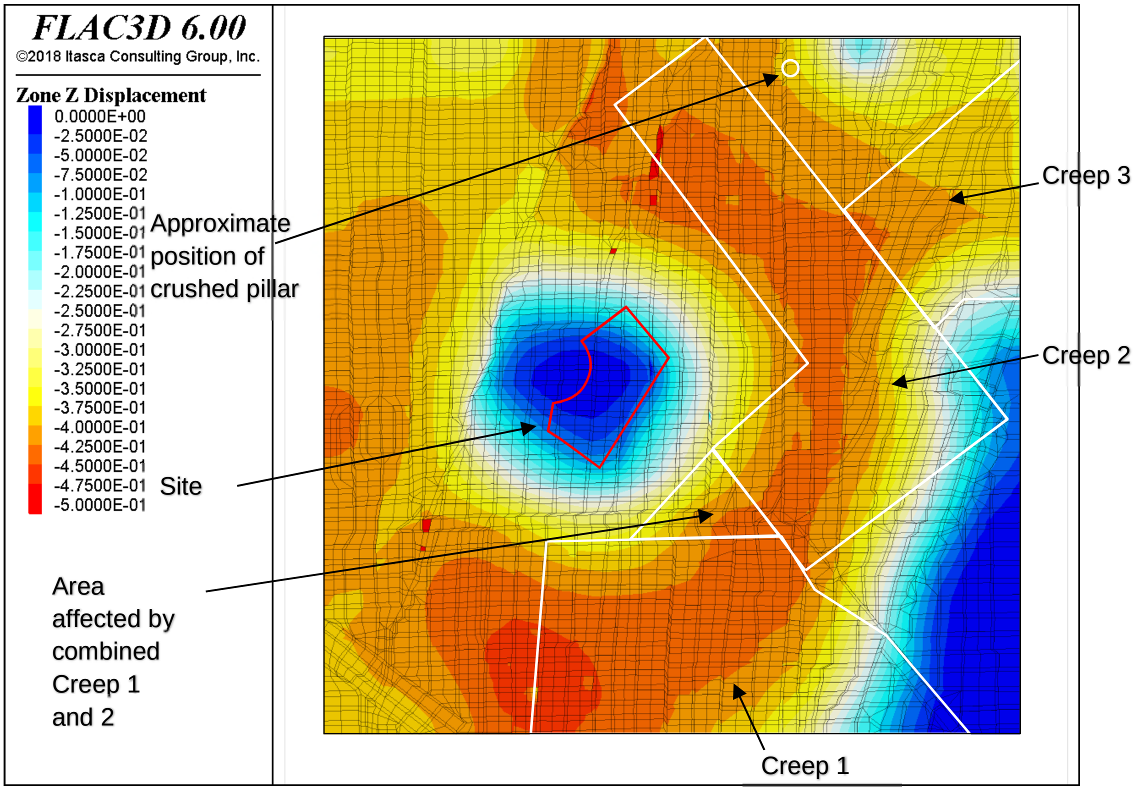

Figure 60: Conceptual vertical displacement with pillar coal at 77% strength with proposed grout layout one.

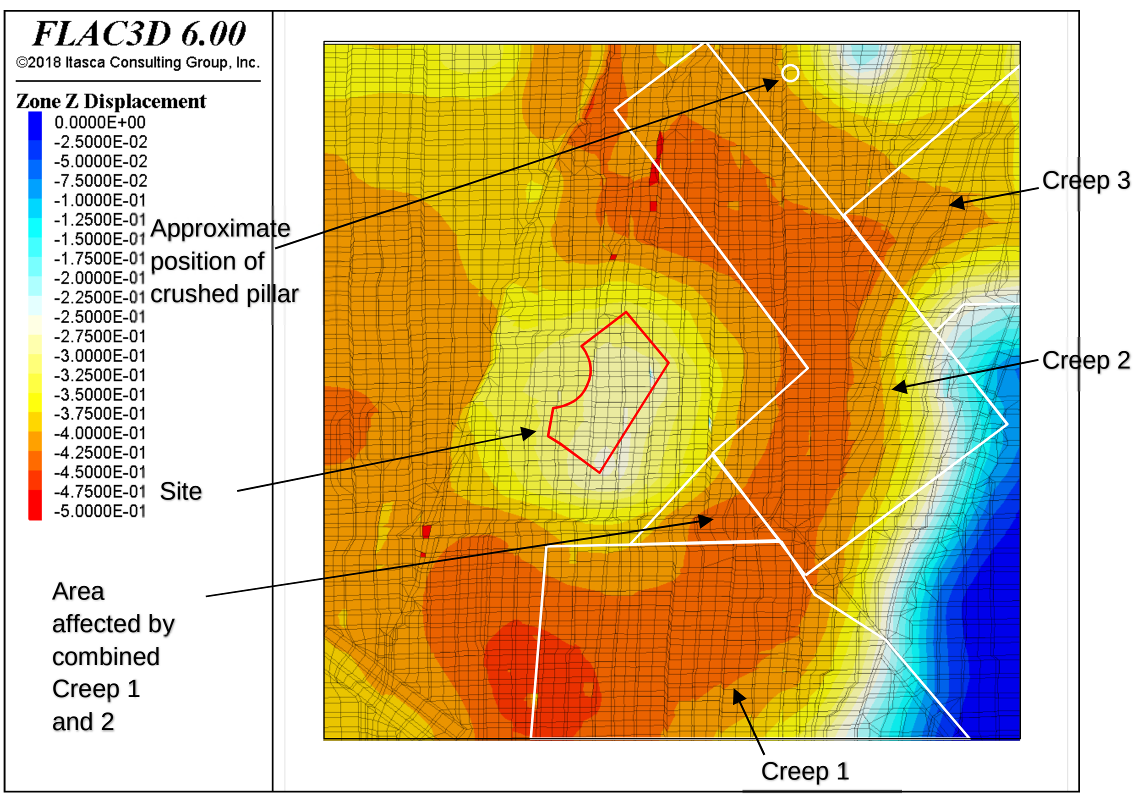

Figure 61: Conceptual vertical displacement with pillar coal at 60% strength with proposed grout layout one.

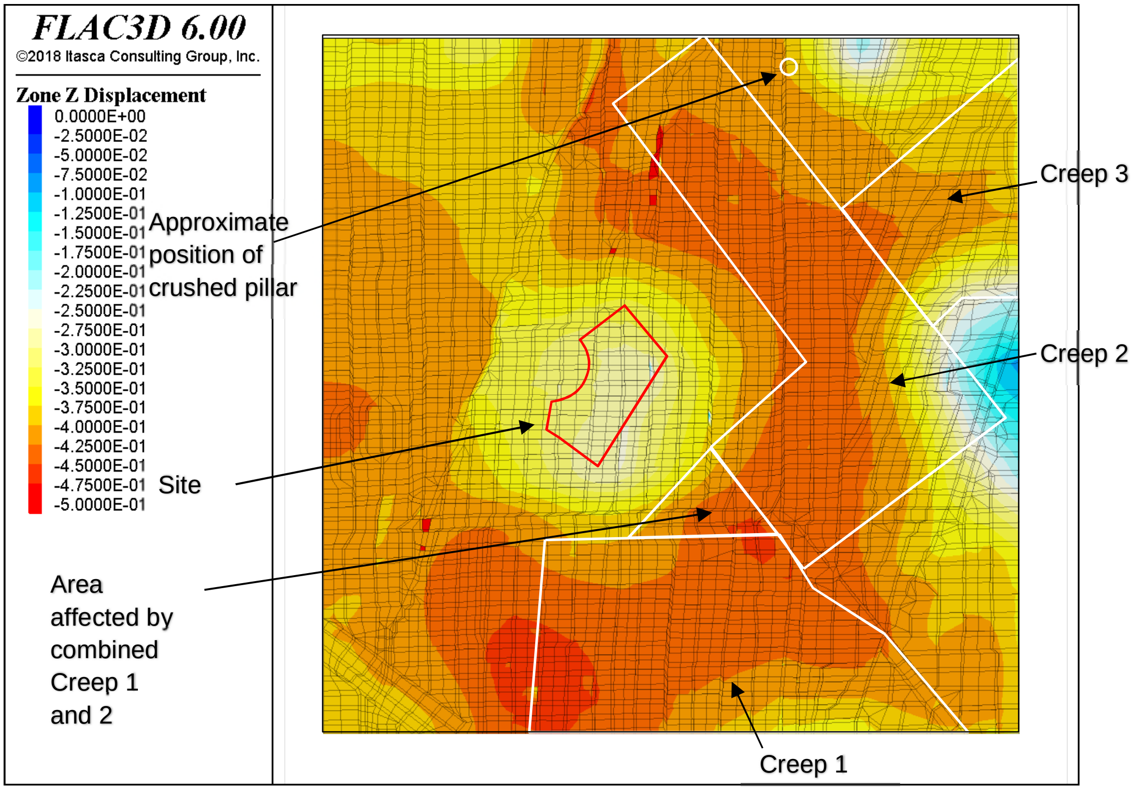

Figure 62: Conceptual vertical displacement with pillar coal at 46% strength with proposed grout layout one.

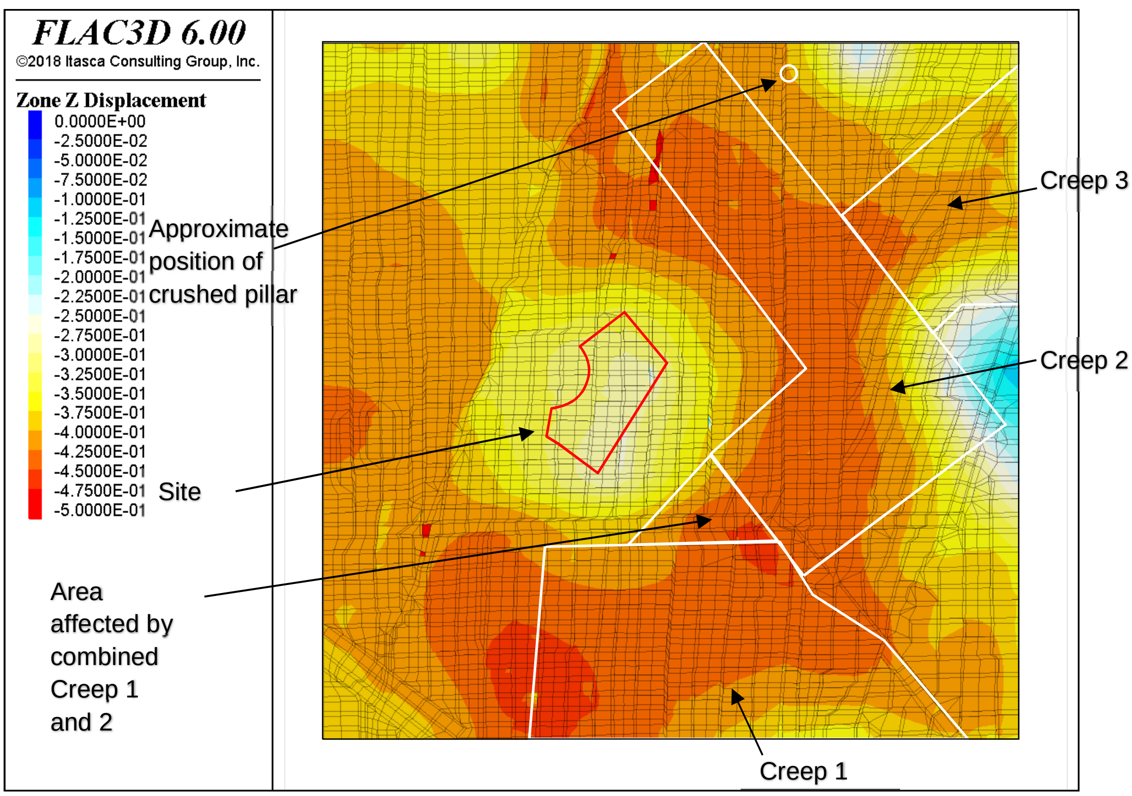

Figure 63: Conceptual vertical displacement with pillar coal at 36% strength with proposed grout layout one.

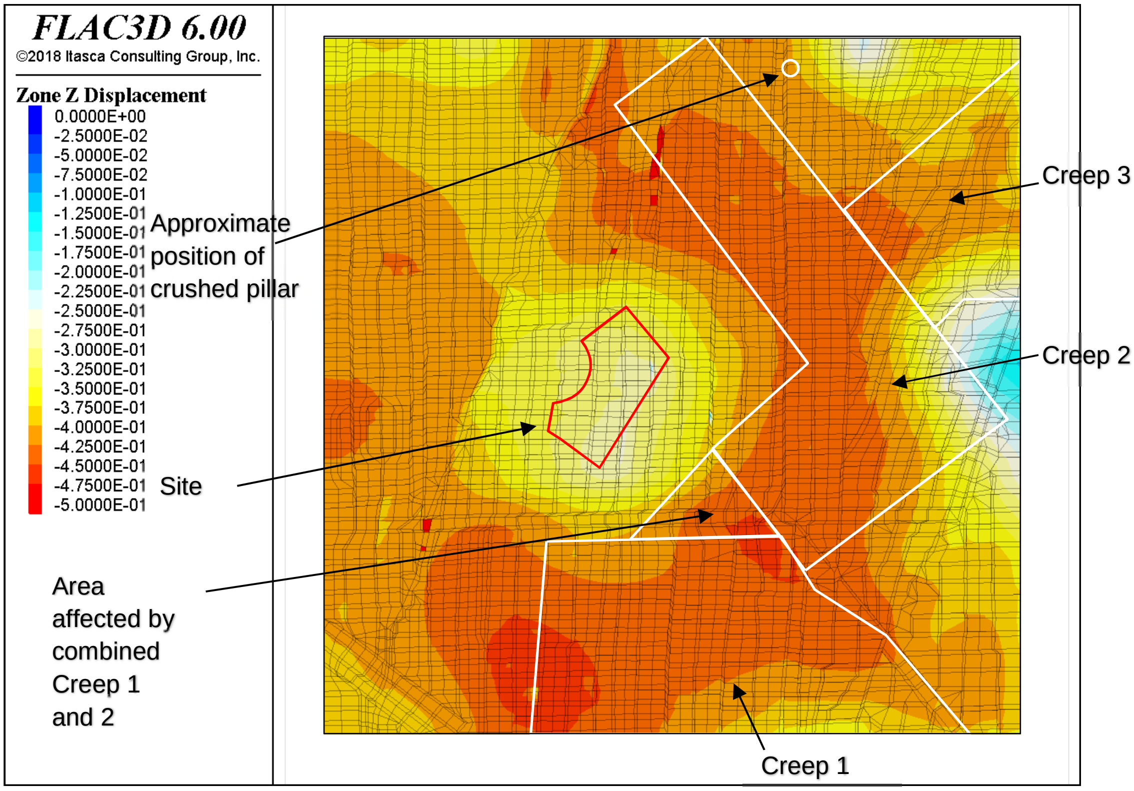

Figure 64: Conceptual vertical displacement with pillar coal at 28% strength with proposed grout layout one.

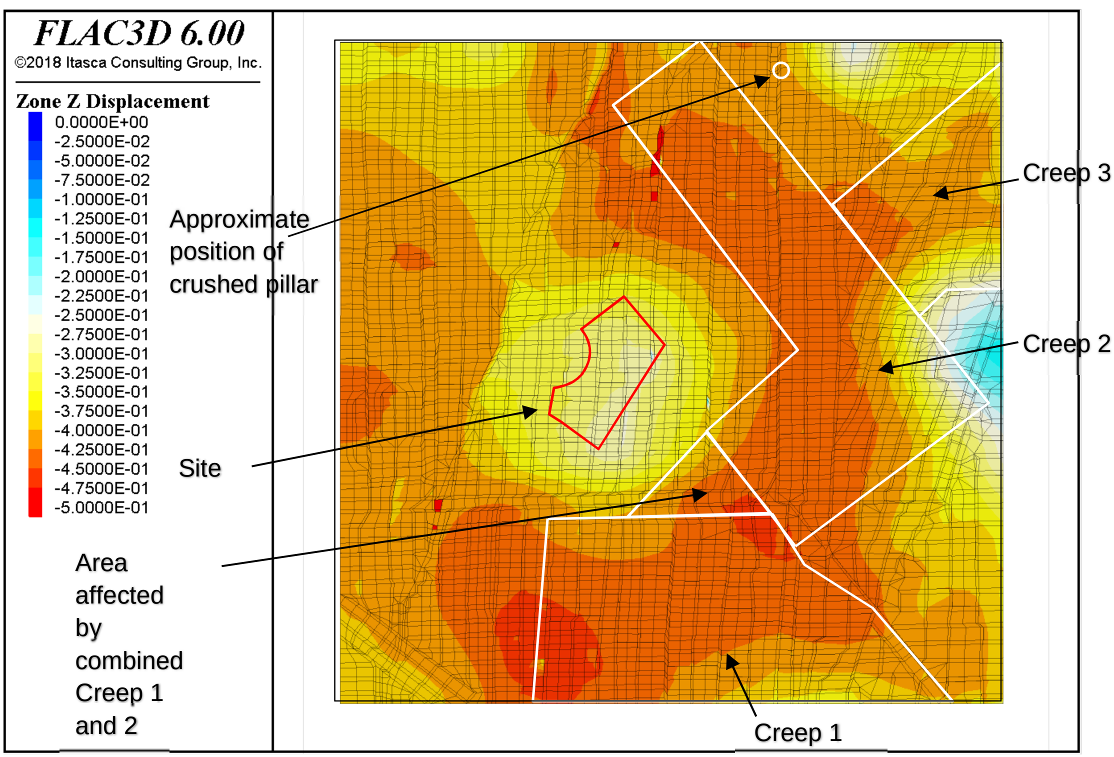

Figure 65: Conceptual vertical displacement with pillar coal at 25% strength with proposed grout layout one.

Using the above sequence as well as the movie sequence taken at regular intervals, the pillars locally under site after grouting and adopting the average pillar height of 5.1m, will support abutment loading to a reduction to approximately 70% of peak strength. At this strength reduction, the pillars supported by the grout will be subjected to a vertical stress in the order of 15MPa (refer to Figure 64 and Figure 65). It is noted this is conservative as the figures include subsidence from Creep 2 and 3 areas which have already occurred.

Beyond this reduction, the pillars under the site may be anticipated to start to crush as well. However, instead of the wave of the crush front passing through the site, the effect will be a more controlled collapse.

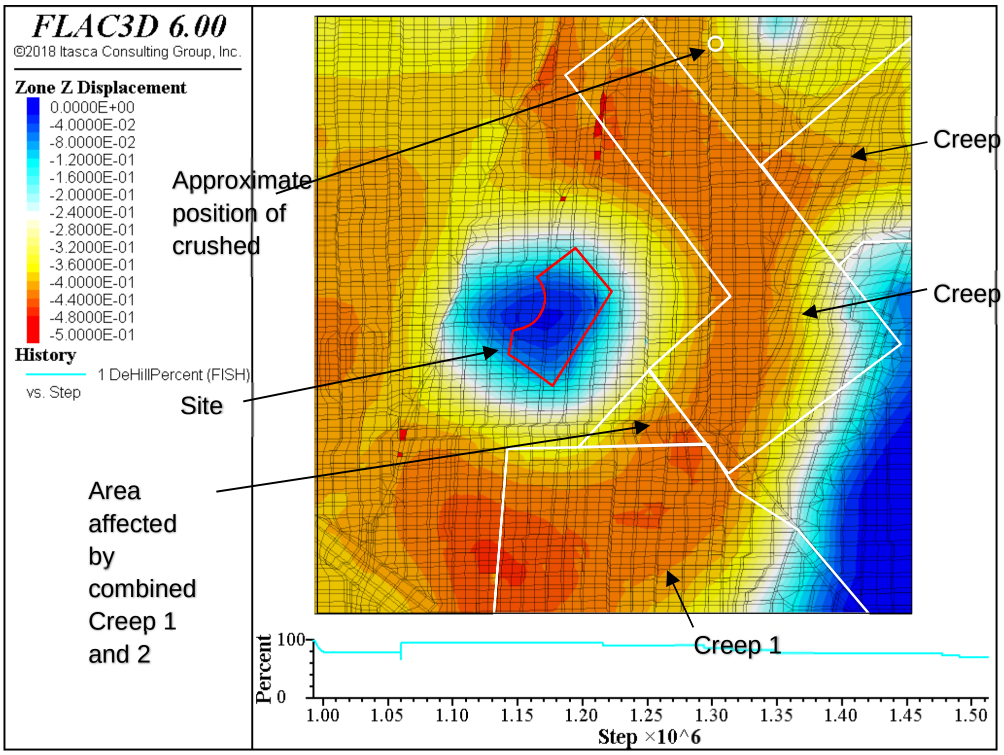

Figure 66: Conceptual vertical displacement with pillar coal at 70% strength with proposed grout (i.e. just before crushing of grouted pillars) layout one.

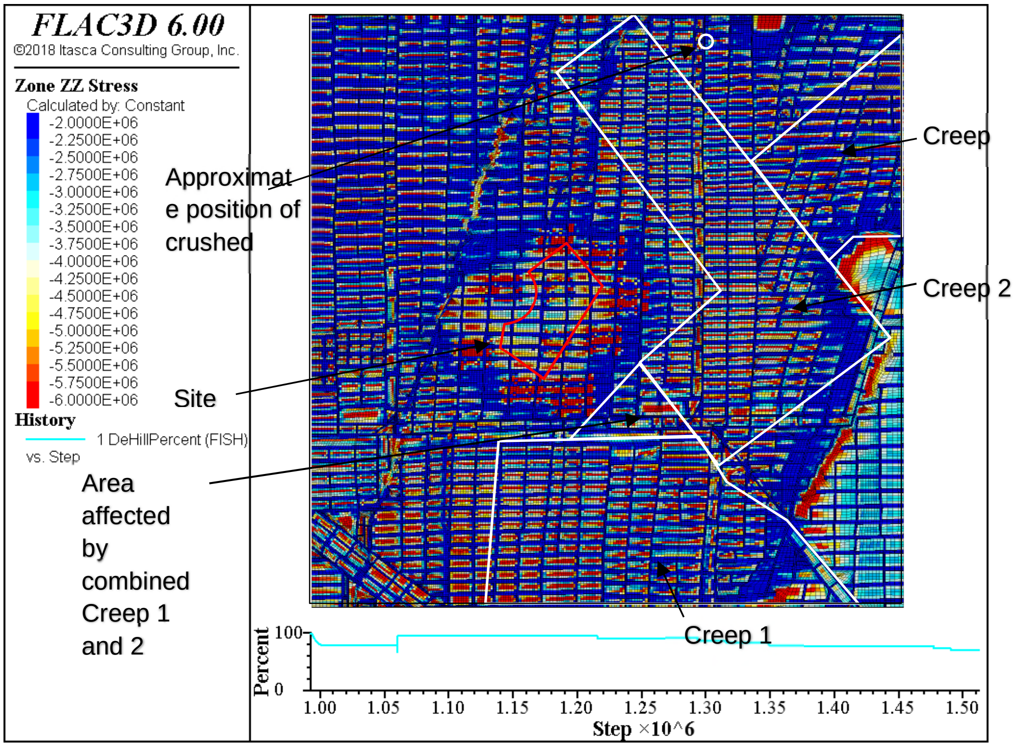

Figure 67: Conceptual vertical stress with pillar coal at 70% strength with proposed grout (i.e. just before crushing of grouted pillars) layout one.

5.5.3. Retrigger of modelled creep with grout in place layout two

Similar to layout one, after the addition of the layout two grout, the pillar run was retriggered similar to as described above at the edge of historical Creep 1 in the most highly stressed pillars in the model. This settlement is shown in Figure 68. It is noted that this produced similar results to layout one.

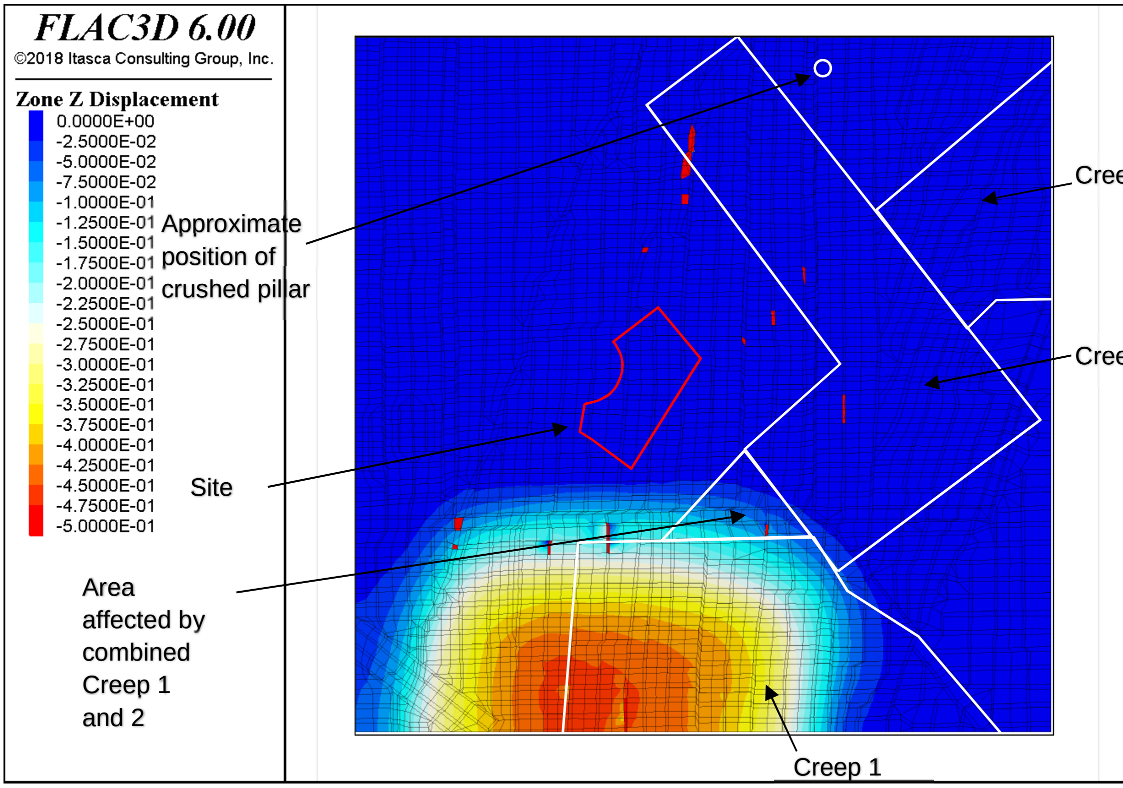

Figure 68: Modelled creep event conceptual surface displacement layout two.

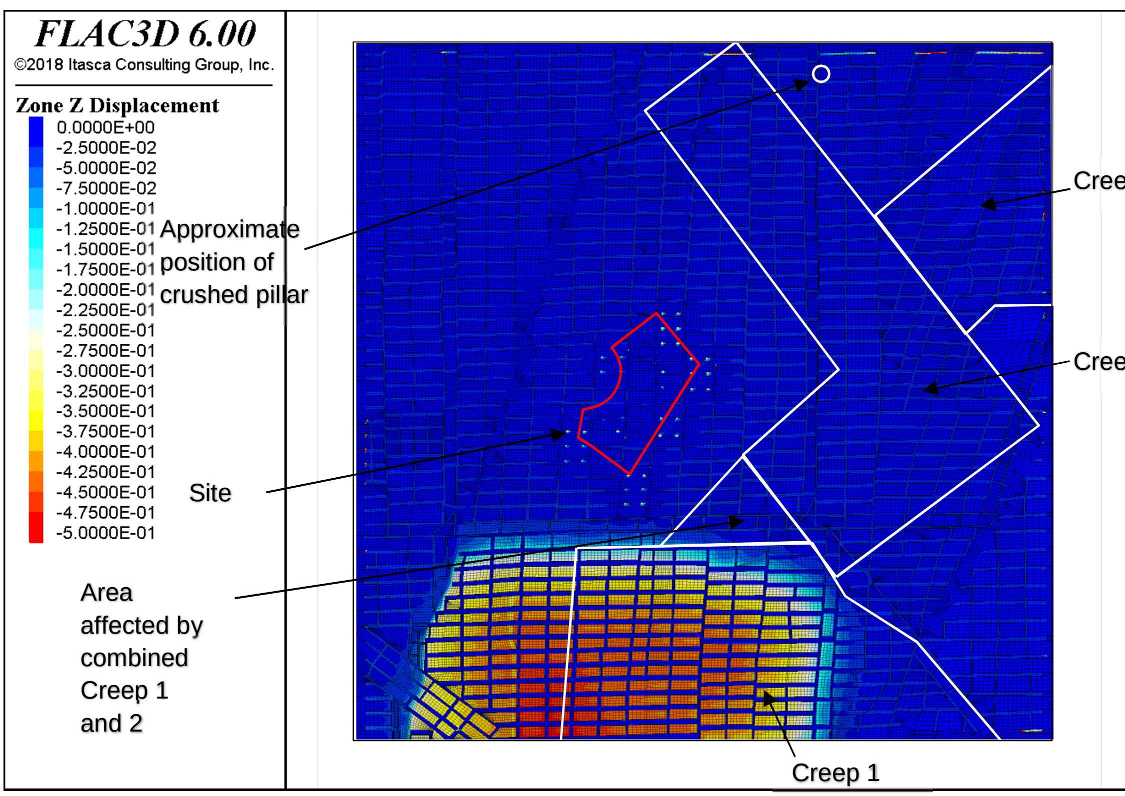

Figure 69: Borehole Seam crush after modelled creep layout two.

5.5.4. Degradation phase layout two.

Figures 70 to 76 show the change in the crush front at strengths of 90%, 77%, 60%, 46%, 36%, 28% and 25%. Note for layout two displacement was reset after Creep 1.

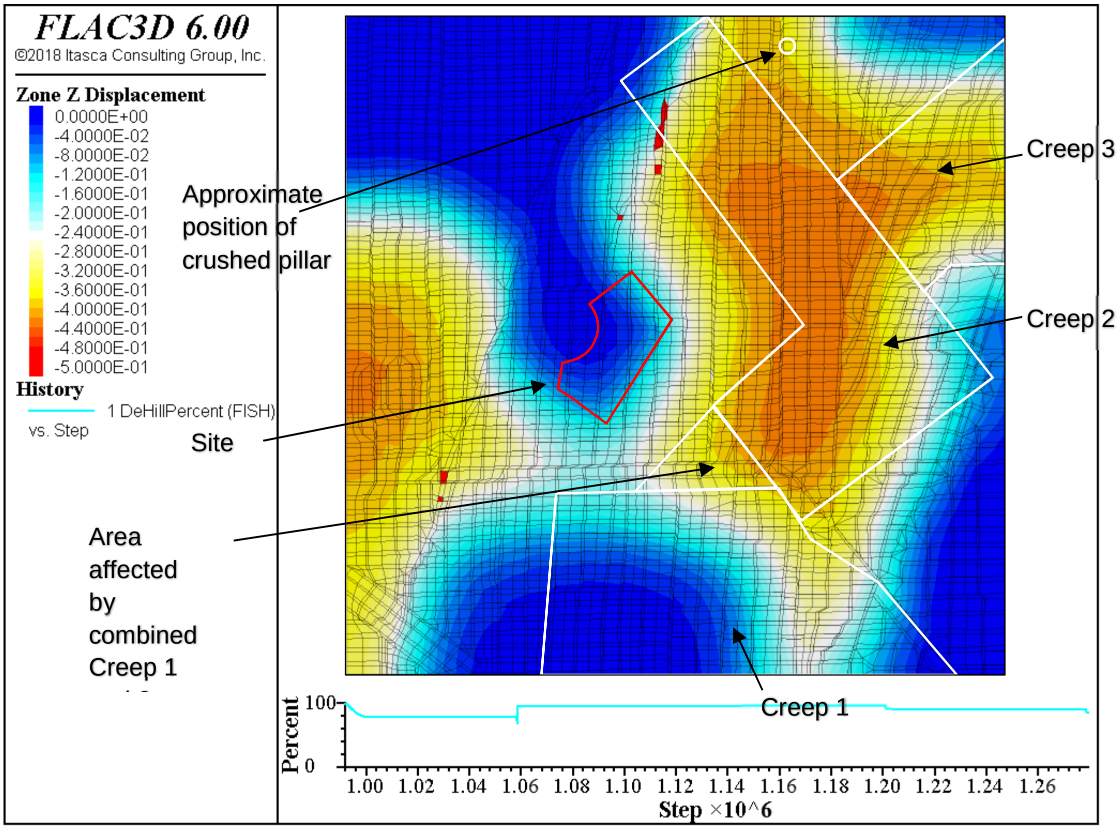

Figure 70: Conceptual vertical displacement with pillar coal at 90% strength with proposed grout layout two.

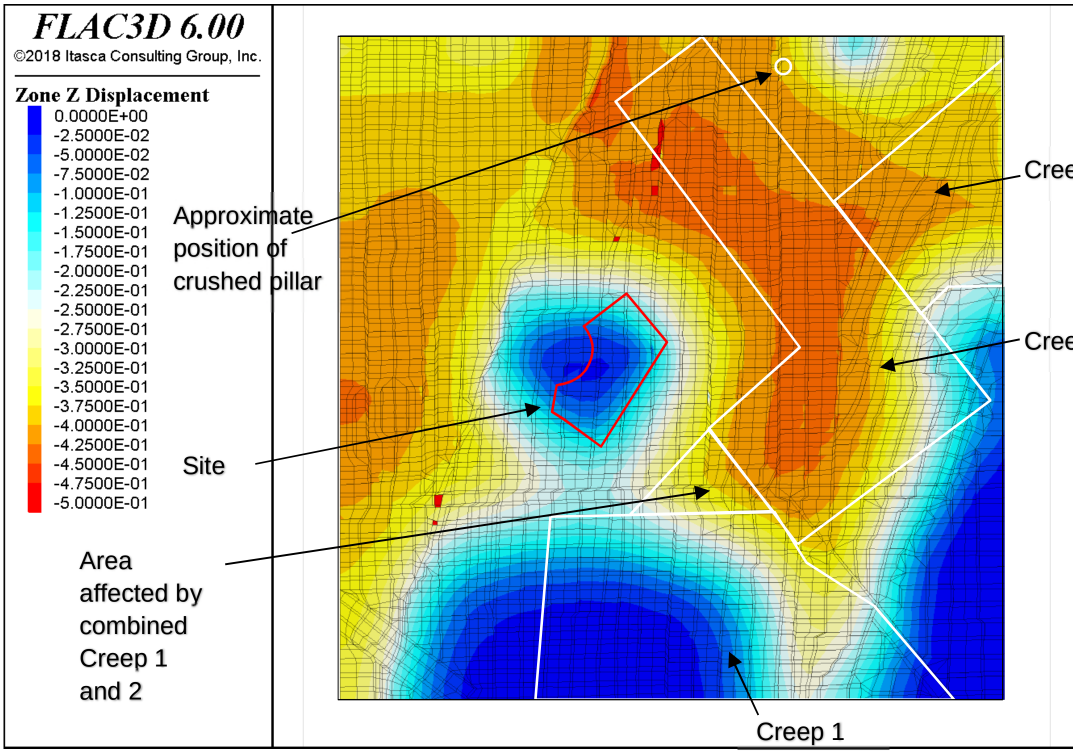

Figure 71: Conceptual vertical displacement with pillar coal at 77% strength with proposed grout layout two.

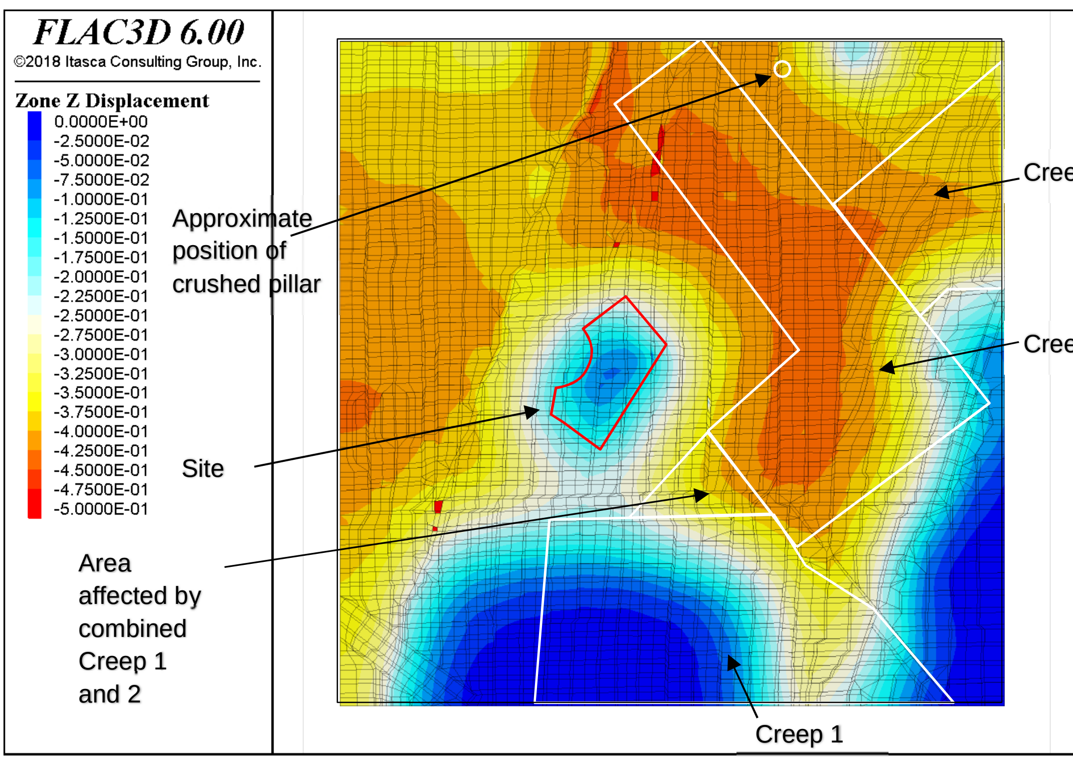

Figure 72: Conceptual vertical displacement with pillar coal at 60% strength with proposed grout layout two.

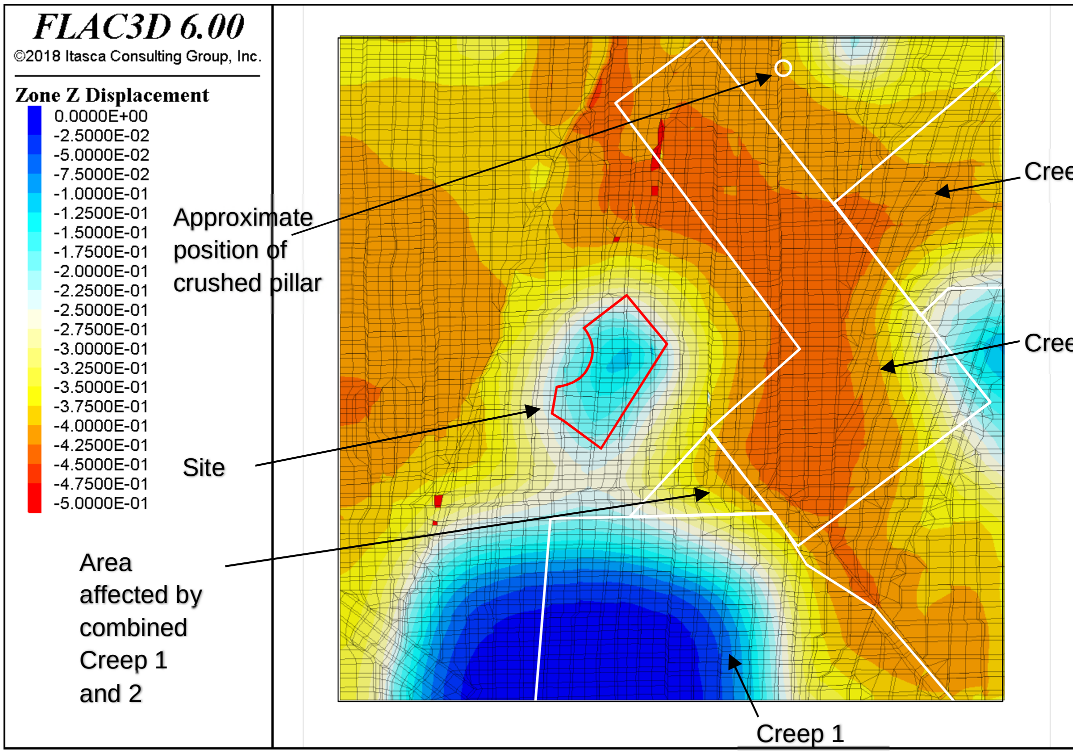

Figure 73: Conceptual vertical displacement with pillar coal at 46% strength with proposed grout layout two.

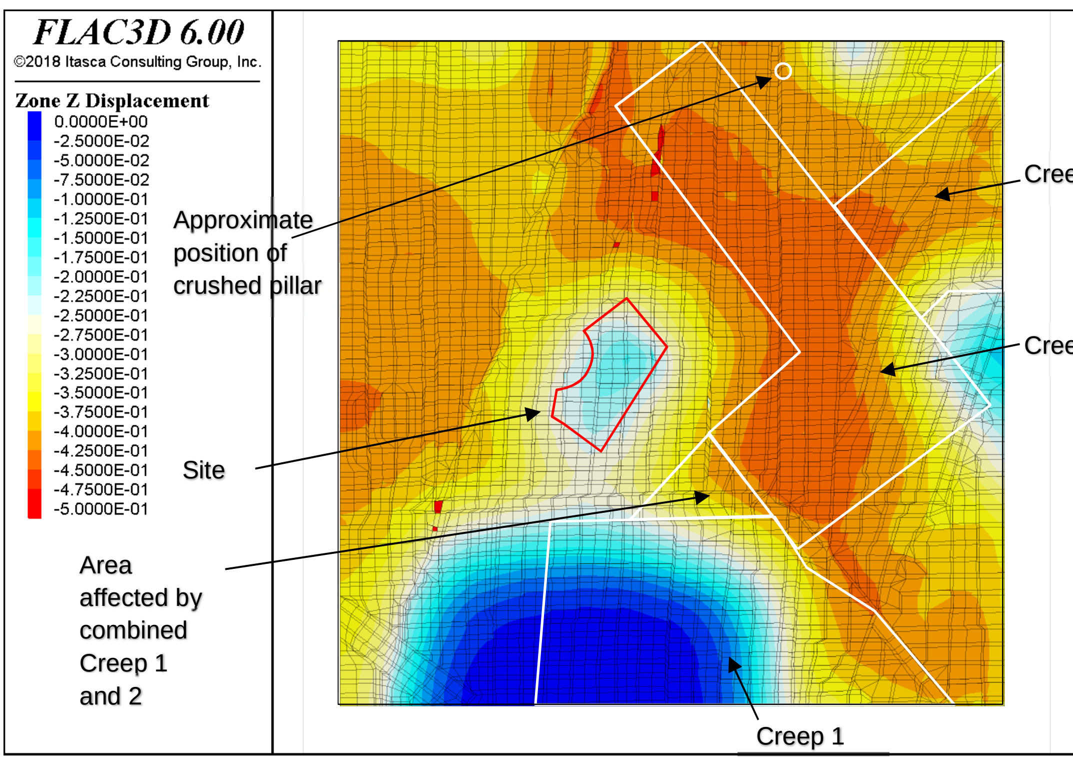

Figure 74: Conceptual vertical displacement with pillar coal at 36% strength with proposed grout layout two.

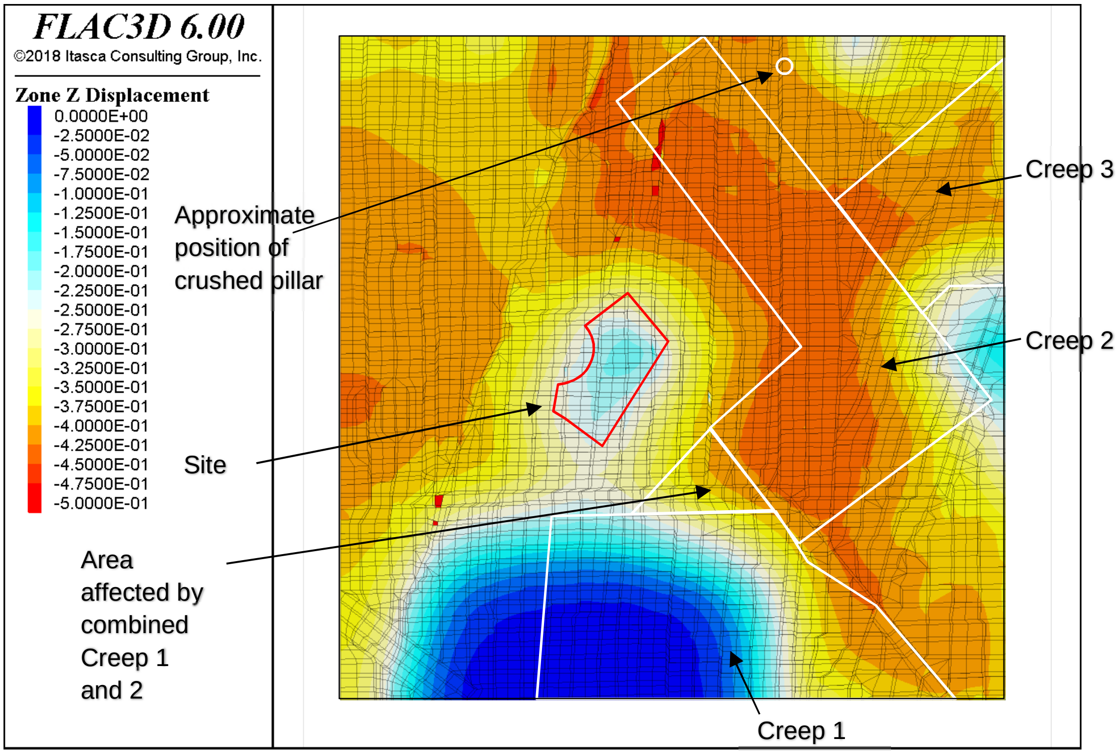

Figure 75: Conceptual vertical displacement with pillar coal at 28% strength with proposed grout layout two.

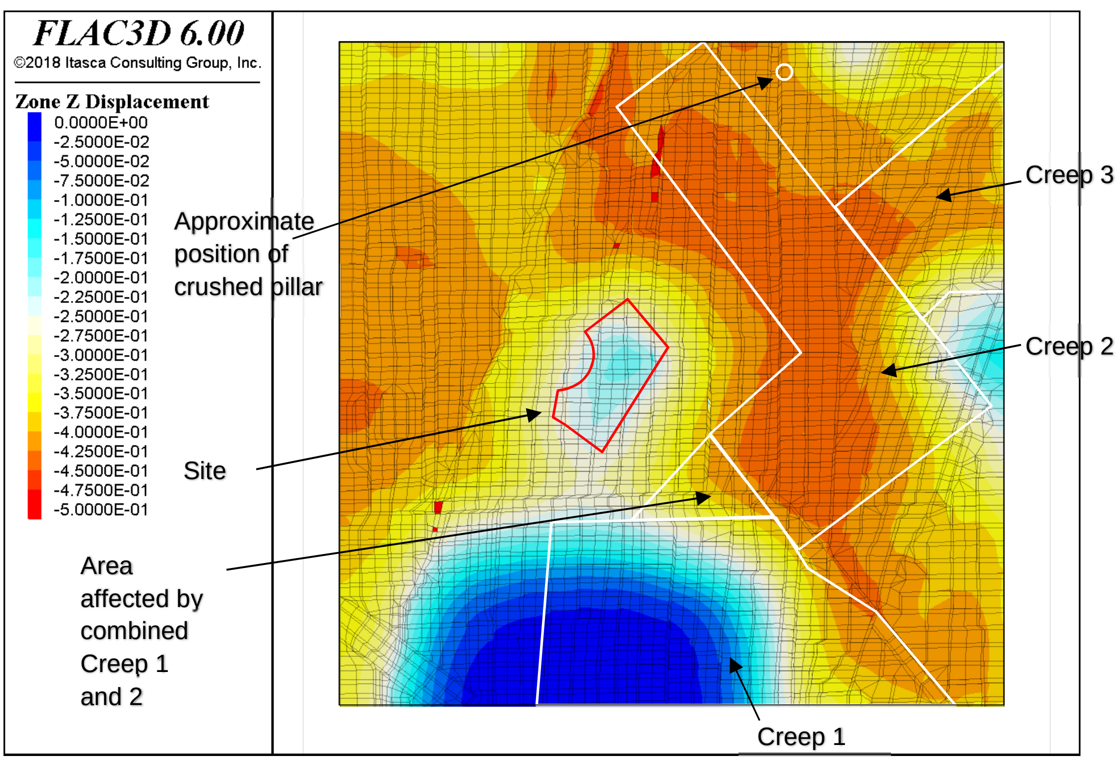

Figure 76: Conceptual vertical displacement with pillar coal at 25% strength with proposed grout layout two.

Using the above sequence as well as the movie sequence taken at regular intervals, the pillars locally under site after grouting and adopting the average pillar height of 5.1m, will support abutment loading to a reduction to approximately 70% of peak strength. At this strength reduction, the pillars supported by the grout will be subjected to an average vertical stress in the order of 9MPa to 11MPa (refer to Figure 77 to Figure 79). It is noted this is conservative as the figures include subsidence from Creep 2 and 3 areas which have already occurred.

Beyond this reduction, the pillars under the site may be anticipated to start to crush as well. However, instead of the wave of the crush front passing through the site, the effect will be a more controlled collapse.

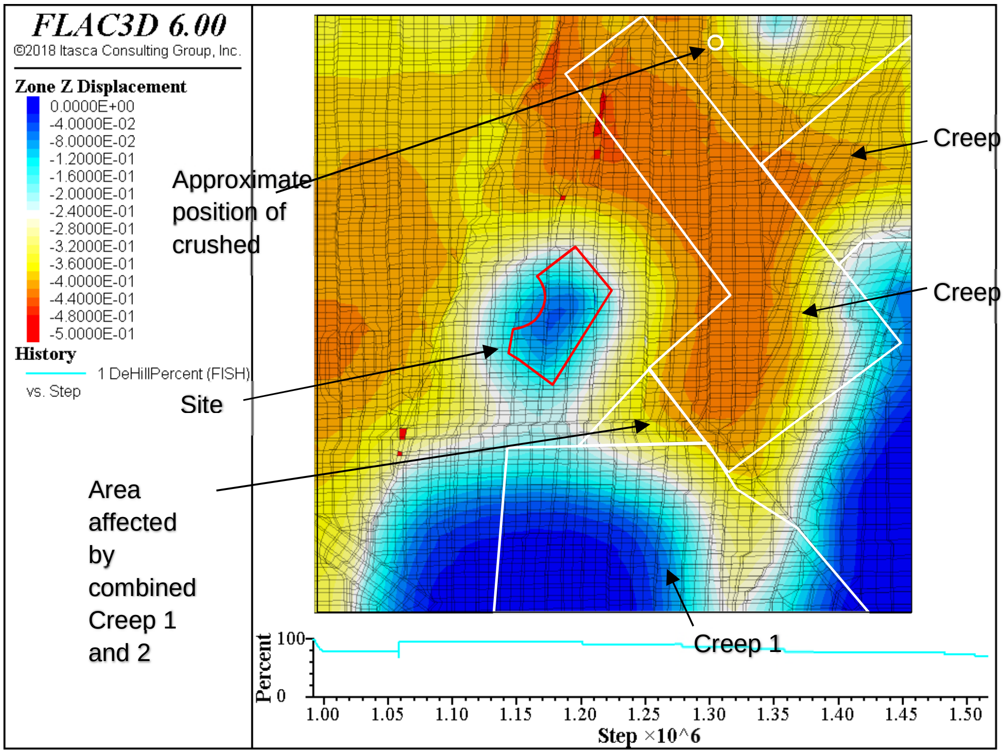

Figure 77: Conceptual vertical displacement with pillar coal at 70% strength with proposed grout (i.e. just before crushing of grouted pillars) layout two.

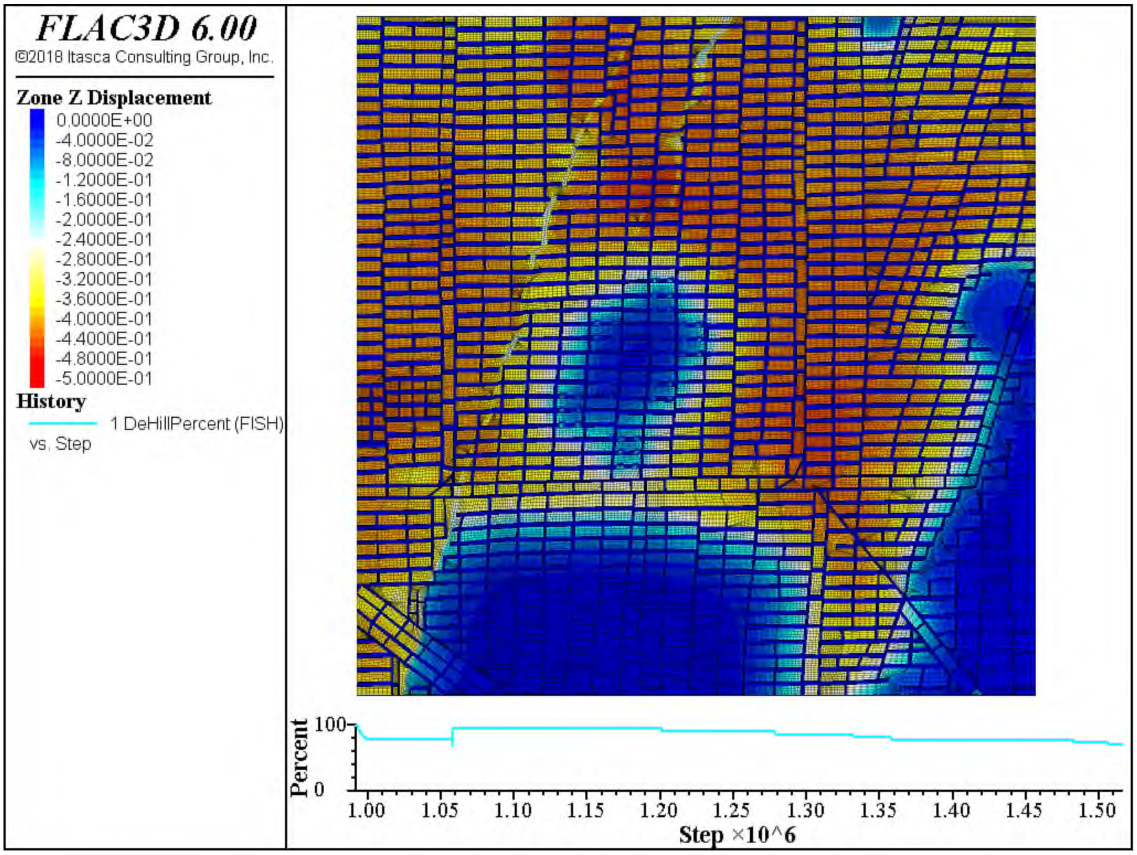

Figure 78: Conceptual vertical crush with pillar coal at 70% strength with proposed grout (i.e. just before crushing of grouted pillars) layout two.

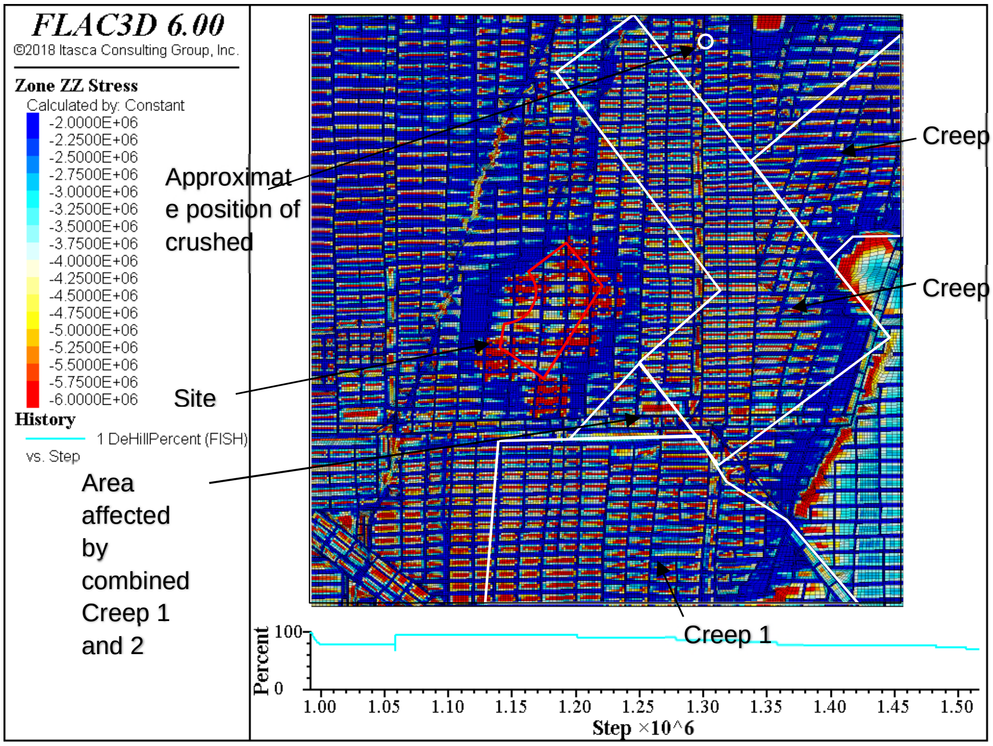

Figure 79: Conceptual vertical stress with pillar coal at 70% strength with proposed grout (i.e. just before crushing of grouted pillars)

5.6. Potential subsidence parameters

5.6.1. Layout one

Based on the above, subsidence is still considered possible for the site even after grouting. The worst-case condition (i.e. largest strains and tilts) for the site is considered to be at the 70% strength value shown in Figure 64 (Refer to Drawing 6.)

Using the model, it is assumed that The Site may be subjected to up to 160mm settlement (although 40mm of this may have already occurred due to the historical creeps (Refer to Drawing 7). At the site, the radius of tensile curvature is expected to get down to 11km with tensile strain of up to 0.9mm/m estimated using the formula Strain (mm/m) = 10/ (curvature in km) (Holla 1987).

Similarly, between the 120mm contour and the 160mm contour, the compressive radius of curvature may be as little as 15km which may be expected to exert compressive strains up to 0.7mm/m (over a length of 10m).

The maximum tilts are all estimated to be generally less than 4mm/m.

It is noted an allowance for an additional 20% on the above values should be allowed for within the ultimate design of the structures.

Should the pillars continue to fail beyond the worst case 70% strength reduction, the modelling indicates the maximum tensile strain may reduce from 0.9mm/m back to 0.5mm/m. However, an even settlement profile as shown in Drawing 8 is not expected with variations in mining height observed at mine level (Coffey Report 754-NTLGE220504-AH.Rev2 dated 17 December 2018).

5.6.2. Layout two

Similar to layout one, the subsidence parameters at 70% strength were reviewed for layout two (refer to Figure 77 (Drawing 9).

Using the model, it is assumed that The Site may be subjected to up to 220mm settlement (although 40mm of this may have already occurred due to the historical creeps (Refer to Drawing 7).

At the site, the radius of tensile curvature is expected to get down to 8km for the for layout two which is a tensile train of about 1.25mm/m using the formula Strain (mm/m) = 10/ (curvature in km) (Holla 1987).

Similarly, between the 160mm contour and the 220mm contour on Drawing 10, the compressive radius of curvature may be as little as 15km which may be expected to exert compressive strains up to 0.7mm/m after initially being subjected to tensile strains.

The maximum tilts are all estimated to be less than 4mm/m.

It is noted an allowance for an additional 20% on the above values should be allowed for within the ultimate design of the structures.

Should the pillars continue to fail beyond the worst case 70% strength reduction, the modelling indicates the maximum tensile strain may reduce from 1.25mm/m back to 0.8mm/m. However, an even settlement profile as shown in Drawing 11 is not expected with variations in mining height observed at mine level (Coffey Report 754-NTLGE220504-AH.Rev2 dated 17 December 2018).

6. Conclusions

A 3D numerical analysis has been completed to assess an appropriate grouting strategy for the proposed development to control the way the site may subside were the historical Creep events remobilise.

Using this model, the area should have collapsed during the historical creep events even with a pillar height of 5.1m, less than the 6.6m present within BH04.

Using this model, it was assessed that:

- The current factor of safety of the panel of workings is in the order of 1.
- For layout one
  - The maximum differential subsidence that may be experienced by the site may be 160mm. Further weakening of the grouted pillars will result in less curvature less differential between collapsed and uncollapsed workings.
  - The tilts estimated for the development are 4mm/m.
  - The maximum tensile strains were assessed to be less than 0.9mm/m while the compressive strains were assessed to be up to 0.7mm/m (from the 120mm to 160mm contour only).
  - The curvature has been estimated to be a minimum of 11km concave down and 16km concave up (from the 120mm to 160mm contour only on Drawing 6).
- For layout two
  - The maximum differential subsidence that may be experienced by the site may be 160mm with a maximum subsidence of 220mm. Further weakening of the grouted pillars will result in less curvature less differential between collapsed and uncollapsed workings.
  - The tilts estimated for the development are 4mm/m.

- The maximum tensile strains were assessed to be less than 1.25mm/m while the compressive strains were assessed to be up to 0.7mm/m (from the 120mm to 160mm contour only).
- The curvature has been estimated to be a minimum of 8km concave down and 16km concave up (from the 160mm to 220mm contour only on Drawing 10).

The above estimates may be improved upon after drilling of the boreholes used for grout placement.

Guidance on the uses and limitations of this report is presented in the attached sheet, *'Important Information about your Coffey Report'*, which should be read in conjunction with this report.

If you have any questions regarding this report or should you require further assistance on this project, please contact Jules Darras or the undersigned.

Signature:	
Full name:	Simon Baker
Title:	Senior Geotechnical Engineer
Date:	12 March 2019

Drawings

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DgS
Ditton Geotechnical Services

Crescent Newcastle Pty Ltd

c/- Stronach Property Pty Ltd

Independent Review of the Worst-Case Mine Subsidence and Grouting Plan Assessment for the Proposed Multi-Storey Building Re-Development at 11 - 17 Mosbri Close, The Hill

DGS Report No. COF-009/1

Date: 14 March 2019

ABN 43 113 858 910 ACN 124 206 962
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14 March 2019

Crescent Newcastle Pty Ltd

Attention: Mark Purdy
C/- Stronach Property Pty Ltd
PO Box 292, Wickham

Report No. COF-009/1 DRAFT

Dear Mark,

Subject: Independent Review of the Worst-Case Mine Subsidence and Grouting Plan Assessment for the Proposed Multi-Storey Building Re-Development at 11 - 17 Mosbri Close, The Hill

This report has been prepared in accordance with the brief provided on the above project.

Please contact the undersigned if you have any questions regarding this matter.

For and on behalf of
Ditton Geotechnical Services Pty Ltd

Steven Ditton
Principal Engineer

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1.0 Introduction

This report presents an independent review of the worst-case mine subsidence effect predictions and grouting works advice provided by Coffey Services Australia Pty Ltd (Coffey) for the proposed multi-storey building re-development of 11 - 17 Mosbri Close, The Hill.

The Coffey reports reviewed include:

- Report No 754-NTLGE220504-AH (Rev 3) (14 January 2019)
- Report No 754-NTLGE220504-AI (18 January 2019)
- Report No 754-NTLGE220504-AI (12 March 2019)

The proposed residential development will consist of eleven (11) 3-storey town houses (including common basement carparking) and three (3) buildings of five, seven and nine storeys (with no basements). It is understood that SA NSW have indicated the entire development will be assessed as a B3 Importance Level development in accordance with the Merit-based Guidelines (**SA NSW, 2018**).

The site is located above old AA Company bord and pillar workings in the Yard Seam at 42 m to 45 m depth and the Borehole Seam at a depth of approximately 92 m to 100 m. Subsidence from 0.25 m to 0.9 m occurred to the east and north of the site above similar mine workings about 112 years ago in the Newcastle CBD (a.k.a. Creeps 1, 2 and 3).

The 1908 Royal commission identified the subsidence was probably due to under-sized pillar instability in the Borehole Seam and possibly convict-era workings in the Dirty Seam (lower Dudley Seam). No pillar instability in the Yard Seam workings has been identified to-date.

The consequence of a pillar run occurring beneath the site is likely to be considered by the Subsidence Advisory NSW to be an unacceptable business and public safety risk. A grouting program in the workings will therefore need to be considered to reduce worst-case subsidence tilt, curvature and horizontal strain values to within tolerable limits as defined by structural engineers.

The outcomes from this study will be to confirm/clarify the Coffey assessments of (i) the likely extent of pillar instability that may occur beneath the site, (ii) worst-case subsidence effects for the non-grouted and grouted cases, and (iii) grouting works required (including characteristic strength and stiffness properties) to limit subsidence effects to tolerable levels in the event of (further) pillar failure beneath the site.

2.0 Previous Mine Workings Instability Background

Subsidence damage has occurred to buildings 1.0 to 1.5 km to the north east of the site in the Newcastle CBD (circa 1906 - 1908) due to several pillar (failure) run events known as 'Creeps 1, 2 and 3'. The pillars that crushed were located at depths ranging between 110 m and 80 m in the adjacent "New Winnings" or "Sea Pit"). The crushed pillars were significantly narrower than the Hamilton Pit workings below the site (11 m v. 15 m respectively).

A Royal Commission into the three Creeps was conducted in 1908 and concluded that the movements occurred due to undersized pillars in the Borehole Seam (Wilsons Heading) and Oliver's Fault.

The pillars were typically 11 m x 32 m in plan dimension with 5.5 m wide bords and 2.7 m wide cut-throughs (an extraction ratio of ~39%). The AA Company mined the Borehole Seam workings in three sections, giving a total mining height of 5.4 m. A 1.3 m thick unit of 'splint and band coal' (i.e. shaley coal) in the roof usually collapsed after removal of timber props to give an effective pillar height of 6.7 m.

The measured subsidence reported for Creeps 1 and 2 ranged between 0.225 m and 0.825 m with impacts including cracks up to 75 mm wide along the crest of the cliff above the Fortifications in King Edward Park and 20 mm wide through the floor of the Obelisk Reservoir (resulting in the complete loss of stored water). The creep area first extended to the barrier pillar that was left beneath the Cathedral and eventually worked its way around to the present-day mall in Hunter St.

No subsidence measurements were reported for Creep 3, except for a statement that no subsidence depressions were detected. The impact due to Creep 3 included differential settlement from 25 mm to 40 mm and crushing of concrete floors. The damage was also considered to have been exacerbated by sub-standard building practices at the time.

Subsidence appears to have developed relatively quickly (hours to days) based on reported damage to buildings on a given day for each 'creep' event (**To, 1988**). The three Creep events however, took over 1.5 years to develop, with each additional creep found to be an extension of the previous events. Additional failures in the Creep 2 area also occurred several years later in 1913 and 1925 (**Trove, 1925**)).

The presence of overlying mine workings (The Dirty Seam and Yard Seam) is thought to have contributed to the observed damage due to the Borehole Seam pillar failures. Flooded mine workings in the Creep 2 area was also noted in the Royal Commission Report, however, it is unlikely the water level would have been much higher than the roof line if other areas to the west were not flooded. The measured subsidence may therefore be assumed to be either dry case or first flooding[1] values.

[1] The first flooding case refers to the condition where the pillars are submerged but still subject to full overburden load. The FoS of the pillars may have therefore been at there lowest point if exposed shale units in the coal seam or above the splint coal had been softened by water.

3.0 Scope

The scope for this independent review has included:

(i) A review of pillar stability of AA Company mine workings in the Yard and Borehole Seams.

(ii) Assessment of the Geotechnical Uncertainty Factor (GUF) as defined in the SA NSW Merit Based Guideline (**SA NSW, 2018**) to assess the risk of trough subsidence to the proposed surface development.

(iii) A review of worst-case subsidence effects due to instability of pillars beneath the site;

(iv) A review of the grout remediation works proposed to satisfy SA NSW subsidence risk management criteria.

4.0 Available Data

The following information has been referred to for this site:

- Record tracings (RT566) of the AA Company workings (New Winnings or Sea Pit) in the Borehole Seam.

- A geotechnical investigation report of the Yard and Bore Hole Seam mine workings and overburden conditions beneath the site (**Coffey 2019a**) and Church St, 0.3km to the north of the site (**Coffey, 2018**).

- A numerical modelling report of mine workings stability and proposed grouting works to control residual subsidence effects to tolerable magnitudes on the site (**Coffey 2019b** and **Coffey 2019c**)

5.0 Methodology

The methodologies adopted to complete the independent review included the following:

(i) The geotechnical model for the site was based on drilling investigation data presented in **Coffey, 2019a** (BH1-4).

(ii) Estimates of FTA and abutment loading on pillars beneath the site in the event of a pillar run were made using an industry established empirical model (**ACARP, 1998**).

(iii) The Pillar FoS and probability of a pillar-run or panel collapse assessments were based on reference to published failed and un-failed pillar case histories for Australian Bord and Pillar Mines as presented in **UNSW, 1998**.

(iv) The assessment of the maximum predicted 'worst-case' subsidence deformations likely to occur above areas affected by a 'pillar run', was based on elastic shallow foundation models presented in **Das, 1998** and inelastic coal pillar / overburden strata responses were derived from Australian case studies presented in **DgS, 2018**.

(v) Estimates of maximum subsidence, tilt, curvature, and horizontal strain profiles / contours over the site for non-grouted and grouted cases were determined using and the 3-D Influence function **(SDPS®)** and contouring software (**Surfer12®**) as well as empirical models developed from Newcastle Coalfield pillar extraction and longwall mining data (**Holla, 1987**).

(vi) Proposed grouting arrangements were assessed using the Voussoir Beam model by **Deidrichs and Kaiser,1999** and sub-critical subsidence data over longwalls in **ACARP, 2003** (for ungrouted span estimates); **ACARP, 2001** (for grout properties) and **Donovan and Karfakis, 2004** and **DgS, 2018** (for grout confined pillar strengths).

6.0 Overburden and Mine Workings Conditions

The Yard and Borehole Seam mine workings are 43 m and 95 m below the site and are both bord and pillar workings with an average extraction ratio of 80% and 42% respectively. Typically, the surface of the site is located at RL 33 m AHD with the water table at RL 3 AHD. Both seams workings are flooded with ~13 m and ~ 65 m hydrostatic pressure head respectively due to the known hydraulic connection between the workings and the ocean.

Four cored borehole logs (BH1/2A in the north west corner and BH3/4 in the southeast corner of the site; see **Figure 2**) indicate that the overburden comprises 0.25 to 2.8 m of fill with residual sandy clay to a depth of approximately 4.7m, overlying 38 m of low to medium strength, interbedded coal, siltstone and sandstone above the 0.9 m to 1.2 m thick Yard Seam with voids ranging between 0.1 m and 0.91 m. The strata below the Yard Seam comprises 52 m of medium to high strength siltstone and sandstone (mean UCS of 50 MPa) overlying the Borehole Seam; see **Figure 3a**.

Drilling investigations at the site, which included coring, video inspections, sonar scanning and geophysical logging from surface to seam floor have found that the mine workings bord and pillar dimensions are in good agreement with the RTs. The middle and bottom coal sections appear to only have been mined at this location based on the void and rubble encountered in the bords (see below).

Based on the borehole logs alone, it has not been possible to observe or measure the original mining height directly due to the collapsed roof material. Reference to **To, 1988**, indicates that AA Company mined the lower 5.5 m of the 6.7 m thick Borehole Seam in three stages, starting with the 2.6 m thick middle section ('Big Tops' or Middle Coal), then the lower 1.7 m thick section ('Bottom Coal'), and finally an upper 1.2 m thick section ('Top Band Coal'). The top 1.2 m of the seam was shaley ('Splint and Band Coal') and was not mined.

Drilling data for BH 2A and 3 (through northern and southern site pillars respectively) indicates that the Borehole Seam is 5.9 m to 6.15 m thick at these locations respectively. The middle coal section thickness was also assessed to range from 1.95 m to 2.10 m with the bottom coal thickness ranging from 1.55 m to 1.65 m.

The drilling investigations also indicate that the mine roof has collapsed from 0.25 m to 0.45 m above the seam along the bords with rubble heights ranging from 4.05 m and 4.95 m. Voids of 0.55 m and 1.65 m exist above the rubble to give a total bord height range of 4.6 m (in the north) to 6.6 m (in the south); see **Figure 3b**.

Based on the above interpretation of the borehole data, the mining height beneath the site is assessed to have ranged between 1.95 m at BH 1/2A (Middle Coal mined only) at the northern boreholes and 3.75 m at BH 3/4 (Middle and Bottom Coal mined) at the southern boreholes. The estimates include 0.15 m and 0.4 m of respective stone band stowage; see **Figure 3b** also.

There is evidence of partial pillar crushing in the Borehole Seam in BH04 with several seam crush zones noted on the borehole log and sag subsidence of 200 mm in the overburden in BH03. The crushing only appears to have occurred at the southern boreholes, however.[2]

For the purpose of this review, the following average mine workings geometry in each seam workings have been assumed:

Yard Seam Workings:

- A cover depth range of 41.6 m and 43.8 m above the seam (mean of 42 m).
- An extraction ratio of 80%.
- An effective seam thickness (above the mine floor) of 1.11 m (north) to 1.10 m (south).
- Mining heights of 0.91 m (north) and 0.63 m (south) or 0.81 m and 0.43 m with 0.1 m and 0.2 m of mine reject stowage respectively.
- Collapsed roof material on the floor of 0.1 m (north) to 1.0 m (south).
- A void height above the rubble of 0.5 m (north) to 0.33 m (south). *Note: There is also 0.41 m to 0.1 m in the roof above sagging siltstone units that are 0.1 m to 0.6 m thick.*
- A total bord height of 1.95 m (north) and 1.53 m (south). *Note: height to first void above sagging siltstone units included as they may collapse.*
- Flooded workings with 13 m of hydrostatic pressure head below sea level.
- Average pillar width of 1.6 m.
- Average pillar length of 16 m.
- Average bord widths of 5.4 m.
- Average cut through widths of 3 m.

There is no plan available for the Yard Seam and Coffey have assumed similar north east bord and pillar alignment based on previous grouting works to the north.

[2] The Coffey reports assess that no crushing has occurred beneath the site, however the boreholes and numerical modelling analysis appear to suggest partial crushing has affected the south eastern corner of the site at least.

Borehole Seam Workings:

- A cover depth range of 93.6 m and 94.8 m above the seam (mean of 94 m).
- An extraction ratio of 42%.
- An effective seam thickness range (above the mine floor) of 4.35 m (north) to 6.15 m (south).
- Mining heights of 1.95 m (north) and 3.75 m (south) or 1.8 m and 3.45 m with 0.15 m and 0.4 m of mine reject stowage subtracted respectively.
- Collapsed roof material on the floor of 4.05 m (north) to 4.95 m (south).
- A void height above the rubble of 0.55 m (north) to 1.65 (south).
- A total bord height of 4.6 m (north) and 6.6 m (south).
- Flooded workings with 65 m of hydrostatic pressure head below sea level.
- Average pillar widths of 10.3 m (north) and 11.15 m (south).
- Average pillar lengths of 28.9 m (north) and 28.8 m (south).
- Average bord widths of 5.5 m (north) and 5.4 m (south).
- Average cut through widths of 4.3 m (north) and 3.8 m (south).

A summary of the current Borehole Seam mine workings conditions beneath the site is shown in **Figure 3b**.

A NW-striking fault and dyke structure is present in both of the workings.

The Coffey reports present a similar set of conditions but with the following slight differences noted:

- That there is no evidence of pillar crush or subsidence apparent in the borehole logs (DgS note evidence of at least 200 mm of subsidence in logs for BH03 and BH04 in the southern area of the site)
- An effective pillar height of 5.1 m to 6.6 m (DgS have adopted 4.85 m (north) and 6.65 m (south) for Credible Worst Case (CWC) pillar stability assessment purposes.

7.0 Structural Design and Risk Assessment Criteria

7.1 Importance Level of Proposed Developments

The assessment of appropriate subsidence risk control measures for new developments in the CBD will depend on the following 'Importance Level' category of the structures proposed:

Level B1 - Buildings up to 3 storeys (including roof-top access & no basement).
- <50 m maximum plan dimension.
- <$3M construction cost

Level B2 - Buildings up to 4 storeys (including roof-top access & basements).
- >50 m maximum plan dimension.
- $3M-$5M construction cost

Level B3 - Buildings > 4 storeys (including roof-top access & basements).
- >100 m maximum plan dimension.
- >$5M construction cost
- Function is essential to community health & education services or storage of hazardous materials.

The proposed development is understood to consist of Level B3 buildings with sub-division infrastructure.

7.2 Design Subsidence Event Cases for Bord and Pillar Panels

On-going review of uncertainties associated with pillar geometries and loading scenarios has led to the following pillar panel stability cases to be developed during a recent review of subsidence risk in the Newcastle CBD (refer to **DgS, 2018**):

Likely Case (LC) - pillar stability assessments assumed RT dimensions and seam thickness adopted as the likely pillar height in the event of mine workings roof collapse above the seam over time.

The Likely Case may be used to determine if the first workings are likely to be long-term stable under the design loading scenarios for Level B1 structures (i.e. FTA and abutment loading adjacent to second workings areas).

Credible Worst Case (CWC) - pillar side dimensions scaled from RT plans of the mine workings reduced by 0.5 m (a nominal amount due to the lack of observed spalling) below B2 and B3 buildings. The assumed adjustment in pillar dimensions allows for a conservative amount of rib spall, RT plan distortion, geological discontinuity effects.

The Credible Worst Case represents is appropriate for assessing the long-term stability of the pillars under the design loading scenarios (i.e. FTA and abutment loading adjacent to second workings areas) for B2 and B3 Buildings.

For B2 buildings, the mining height is assumed to equal the seam thickness. For B3 buildings, the effective pillar height may also need to be increased above the seam height to allow for roof fall above the seam. Recent studies in **DgS, 2018** recommends that an increase of 0.5 m should be applied to the seam thickness in the Newcastle CBD area when assessing long-term stability.

Absolute Worst Case (AWC) - pillars with w/h ratio < 8 are all assumed to crush in a panel regardless of FoS and represents the maximum possible subsidence event. If the pillars are small, it is possible that the CWC subsidence will be theoretically the same as the AWC subsidence as the FoS values are less than the minimum required for long-term stability.

7.3 Site Geotechnical Uncertainty Classification

The risk of trough and pot-hole subsidence on surface development is assessed by SANSW based on:

- The assessed level of geotechnical uncertainty (i.e. the GUF)
- The factor safety (FoS) and slenderness of the pillars (w/h)
- The type of structure (building importance level)

The GUF is a weighted index that ranges between 0 and 20 and considers the following sources of geotechnical uncertainty (R1 to R4) associated with the assessment of the long-term stability of the mine workings pillars:

R1 = Geological Environment (weighting of 2)

R2 = Level of Geotechnical Investigation (weighting of 2)

R3 = Type of coal mine plans (weighting of 3)

R4 = Method used to assess stability and impact (weighting of 3).

The sum of the products of each uncertainty source weighting and uncertainty score (1, 2 or 3) less 10 gives the overall GUF as follows:

GUF = R1 x U1 + R2 x U2 + R3 x U3 + R4 x U4 - 10.

The GUF is then categorised as either Low (GUF $\leq$ 5), medium (5<GUF$\leq$10) and high (GUF>10) and is used to define the minimum long-term stability factors (FoS & w/h), pillar geometry assumptions (pillar width reduction, mining height) and building design constraints for a site.

7.3.1 Trough Subsidence Risk

The assessed GUF due to trough subsidence caused by pillar instability in the Yard and Borehole Seam within the angle of draw from the site and the proposed B3 Level development at Mosbri Crescent is summarised in **Tables 1A** and **1B** for each seam.

Table 1A - Geotechnical Uncertainty Factor Assessment Summary for Trough Subsidence due to Yard Seam Instability at Mosbri Crescent

Uncertainty Source	**Description**	**Assessed Information**	**Uncertainty Score (U)**	**Weighted Score (R1 x U1)**
R1 (weighting of 2)	Geological Environment	No significant faulting or mine plan adjustments. Seam dip < 10°.	**1**	**2**
R2 (weighting of 2)	Level of Geotechnical Investigation	4 site-specific boreholes in north and southern areas of site including sonar to establish bord and pillar widths & 2 cored holes to establish seam thickness & mining height.	**1**	**2**
R3 (weighting of 3)	Type of coal mine plans	No mine plan (RT) but known to be hand worked, first workings with reasonably regular mining layout.	**3**	**9**
R4 (weighting of 3)	Method used to assess stability and impact	Due to lack of mine plan, pillar stability assessment was done using established empirical methods only to estimate FoS & subsidence effects. Previous pillar crush instability in BH Seam workings to the east and north with possible yield of pillars in the southern area of the site requires abutment loads to be applied to pillars.	**3**	**9**
			Geotechnical Uncertainty Factor (GUF)	12 (High)

The GUF of 12 for the Yard Seam mine workings indicates a ‘High’ uncertainty in regard to long-term stability assessment criteria. For B3 Level buildings, ‘High’ uncertainty is unacceptable for a non-grouted solution. Further investigative drilling is unlikely to result in a significantly reduced GUF to allow a non-grouting solution, however.

Table 1B - Geotechnical Uncertainty Factor Assessment Summary for Trough Subsidence due to BH Seam Instability at Mosbri Crescent

Uncertainty Source	Description	Assessed Information	Uncertainty Score (U)	Weighted Score (R1 x U1)
R1 (weighting of 2)	Geological Environment	No significant faulting or mine plan adjustments. Seam dip < 10º.	**1**	**2**
R2 (weighting of 2)	Level of Geotechnical Investigation	4 site-specific boreholes in north and southern areas of site including sonar to establish bord and pillar widths & 2 cored holes to establish seam thickness & mining height.	**1**	**2**
R3 (weighting of 3)	Type of coal mine plans	Hand worked, first working mine only with regular layout. It is unclear where the mining height changed from 3.75m (middle & bottom sections) in the south to 1.95m (middle section only) in the north, so maximum values have been assumed for the future subsidence assessment.	**2 - 3**	**6 - 9**
R4 (weighting of 3)	Method used to assess stability and impact	Detailed assessment using established empirical & numerical modelling methods to estimate FoS & subsidence effects. Previous pillar crush instability in workings to the east and north with possible yield of pillars in the southern area of the site requires abutment loads to be applied to pillars.	**1**	**3**
			Geotechnical Uncertainty Factor (GUF)	3 - 6 (Low - Moderate)

The GUF of 3 to 6 for the Borehole Seam mine workings indicates a ‘Low’ to ‘Moderate’ uncertainty in regard to long-term stability assessment criteria.

The following design constraints will subsequently be required for B3 Importance Level developments for a non-grouted solution to apply. According to *Table C3* of the SA NSW Guideline:

- Pillar FoS > 2.1
- Pillar w/h > 2
- Provide an independent peer review report on the stability assessment and worst-case subsidence predictions (this report).

- A structural engineer's reports that confirms the buildings and infrastructure will be 'safe' 'serviceable' and 'repairable' after Absolute Worst-Case conditions develop.[3]
- A number of permanent survey marks are established on the building and details of these and base-line levels (pre-mine subsidence) are provided to SA NSW.

- Verification of mine working remediation works and evidence that the structures have been constructed in accordance with all relevant building codes and standards are provided to SA NSW on completion of the development.

The pillar stability has subsequently been assessed in **Section 6** for B3 Importance Level and a 'Low' to 'Moderate' GU.

7.3.2 Pot-Hole Subsidence Risk

For assessment of the risk of pothole subsidence is usually only included in a desk top study when the cover depth is < 10 times the mining height and overburden conditions are poor.

For maximum likely mining heights of 0.91 m in the Yard Seam and 3.75 m in the Borehole Seam, the minimum rock cover depth required to invoke a 'pot-hole' risk assessment would be < 10 m and < 38 m for each seam respectively. It is noted that the rock cover depth is estimated to range between 38 m above the Yard Seam and 90 m above the Borehole Seam.

Based on the relatively small intersection spans of 5.5 m to 7.8 m and medium to high strength siltstone and sandstone (UCS > 40 MPa) it is assessed that risk of a pot-hole developing up to the surface is 'low'.

No further assessment or consideration of the potential for pot-hole impact on shallow or piled footing design for the site should therefore be required by SA NSW.

7.4 Structural Design Criteria

The following subsidence effect criteria have typically been adopted by SA NSW for B3 Importance Level structures in order to achieve "serviceability" and economic "repairability" and to assess whether there is a potential for significant impact due to a design subsidence event:

- Tilt < 3 mm/m
- Curvature < 0.15 km^{-1} (Radius > 7 km)
- Horizontal Strain < 2 mm/m;

[3] If it can be established that the site pillars have partially or fully failed, the AWC may be based on residual subsidence due to further crushing or closure of available void (if first workings only) or goaf consolidation (if second workings only).

Provided the average pillar FoS and w/h for the site exceed the minimum requirements indicated for the site Geotechnical Uncertainty Factor (GUF), the above criteria may be adopted as Serviceability Limits (SL) for the B3 structures.

The above SL values should be applied by structural engineers to limit the B3 Level building impacts to “Very Slight” (Category 1) in accordance with AS2870 - 2011.

If the FoS and w/h ratios for the site are **less than** nominated values in *Table C3*, it will be necessary to check whether the proposed structure will remain “Safe, Serviceable, and Repairable” after the Absolute Worst-Case event or need remediation grouting to control subsidence effects to the Serviceability Limits defined above.

8.0 Pillar Stability Assessment Review

8.1 General

Coffey, 2019a presents pillar stability calculations that differ in approach to DgS and the SA NSW Merit-based Guidelines. It was therefore considered necessary to present the following analysis that is consistent with the Guidelines and also enable comparison with the Coffey assessment outcomes.

The assessment of potential pillar instability based on RT plans of old mine workings should consider the following:

- effective cover depth and density of the overburden[4],
- RT tracing or scaling errors;
- whether the workings are flooded or dry and the potential for rib and roof deterioration[5];
- geological structure (faults, dykes, shear zones) which may reduce overburden stiffness;
- potential for unconfined clay rich strata to 'soften' and consolidate under applied loading (i.e. soft floor failure);
- unreported robbing of pillars (i.e. pillar dimensions scaled from RTs may not be accurate);
- the direction in which a pillar 'run' may approach the site will affect the magnitude of the applied pillar loading (i.e. the design action effect);
- the maximum load that may be applied to the pillars in the event of nearby pillar instability.

The probability of instability for the pillars beneath the site with respect to published cases in the Newcastle, Australian and South African Coalfields above bord and pillar panels have been assessed based on **UNSW, 1998**.

The empirical pillar strength formulae currently used in the Australian coal industry is based on a non-linear power law, which assumes that for a FoS of 1, the pillar panel will have a Probability of Failure (PoF) of 50%. The database includes 'failed' and 'unfailed' pillar panels from the South African and Australian Coal industries and is plotted in terms of pillar strength v. pillar load in **Figure 4a**.

4 - The empirical UNSW pillar strength formulae are based on an overburden density of 2.5 t/m^3 and acceleration constant 'g' of 10 m/s^2. The presence of significant depths of soil cover may therefore effectively reduce the pillar load;

5 - The database of pillar strengths has been derived from a 'dry' workings database, so it is recommended that the pillar loads also assume 'dry' conditions exist for FoS assessment;

It is also noted in **UNSW, 1996** that only 5 (26%) of the 'failed' Australian case studies were 'actual' pillar dimensions, with 14 (74%) being the design values (or scaled from the mine plans). The 'unfailed' pillar data base referred to 8 (50%) actual pillar dimensions with 8 (50%) taken 'off-the-plan'.

The South African database presented in **UNSW, 1996** acknowledges the following in regard to pillar dimensions due to difficulties with inspecting failed panels (which in a high proportion of cases, failed suddenly with little or no warning several months to years after their formation):

> "The mine dimensions in the database are unavoidably subject to some errors."

Over the past 20 years or more however, mine workings investigation work in the Newcastle CBD has significantly reduced the level of uncertainty when relying on scaled pillar measurements from the RTs due to the following:

- Video and sonar inspections of the Yard and Borehole Seams have repeatedly demonstrated that the standing pillar and ribs are in good condition with similar bord widths to RT records[6].

- The positive pressure head in the flooded workings probably has limited the rate of pillar deterioration and protected the workings from erosion impacts due to flowing ground water through dry workings.

- Any softening of mudstone/claystone beds that would have occurred after flooding is very likely to have ceased after 100 years.

8.2 Pillar Strength

Estimates of pillar strength have been based on the power rule formulae presented in **UNSW, 1998**. The strength of a pillar and its post-yielding behaviour are important properties to consider when assessing potential subsidence risks. Coal industry experience over the past 40 years has identified that both of the above properties are strongly influenced by the effective width and height of the pillars. The frictional contact strength between the coal seam roof and floor lithologies is also critical to pillar performance under load.

Bord and pillar panels with 'slender' pillar w/h ratios of < 3 have been found to collapse suddenly when overloaded with little residual strength. Pillars with 'squat' w/h ratios > 5 are able to develop greater core confinement under load and do not collapse in the commonly understood sense but tend to 'squeeze' slowly and strain harden when overloaded. Pillars with

[6] - *The generally meticulous nature in which the AA Mining Company's mining plans were recorded also allows a reasonably high degree of confidence in the accuracy of the RTs in the study area.*

w/h ratios between 3 and 5 are likely to exhibit transitionary-type behaviour between slender and squat pillars.

The two types of post-yielding behaviour have been discussed in **ACARP, 2005** and demonstrated in **Figure 4b** for pillar w/h ratios between 1 and 10. Several other studies by **Das, 1996** and **Zipf, 1999** demonstrate the 'strain-softening behaviour of 'slender' pillars with width to height ratios < 4; see **Figure 4c**. Zipf applied the w/h ratio to determine the rate of softening or the residual modulus of the pillars.

The **UNSW, 1998** strength formula adopted in this study for square-shaped 'slender' pillars with width, w, and height, h, is:

- $S_p = 8.6\ (w\sin\theta)^{0.51}/h^{0.86}$ and θ = angle between adjacent pillar rib sides (e.g. θ = 90° for square-shaped pillars);

The formula caters for rectangular pillars by modifying the pillar width to w_{eff} as follows:

- For pillars with w/h < 3, the length (l) of the pillar does not influence pillar strength and $w_{eff} = w\sin\theta$;

- For pillars with w/h > 6 then the length of the pillar effectively increases the strength of a square pillar to $w_{eff} = w\sin\theta\ [2l/(w+l)]$;

- For pillars with w/h between 3 and 6, the $w_{eff} = w[2l/(w+l)]^{(w/h-3)/3}$

A separate formula applies to 'squat' pillars with w/h > 5 and will not be required for this study.

8.3 Pillar Loading

The pillars within the panels were all considered to be subject to the weight of the full column of rock above the pillars and half the surrounding bords. This is known in the industry as 'full tributary area' (FTA) loading conditions as shown below and in **Figure 4d**.

σ_{FTA} = pillar load/pillar solid area = P/wl

where

P = full tributary area load of column of rock with a height, H, density, ρ, above each pillar with width, w, length, l and bord width, r;

= (l+ r)(w + r).ρ.g.H;

For long-term stability assessment purposes, it is considered reasonable to assume that the pillars adjacent to the area of instability could also be subject to a side-on or end-on abutment load as defined in **ACARP 1998**. Underground stress and surface subsidence monitoring around super-critical width longwall panels in the Newcastle Coalfield indicates that the additional load due to the crushing of adjacent pillars may be estimated based on an abutment angle of 21^o.

The distance (D) that the abutment load is likely to be distributed over adjacent pillars or solid coal may be estimated by the empirical formula presented in **Peng and Chiang, 1984**, as follows:

$$D = 5.13 \sqrt{H} = 50 \text{ m for the BH Seam at a depth of 95 m.}$$

The abutment load is also likely to be concentrated closer to the goaf or 'uncrushed' pillar line and calculated based on the parabolic stress distribution profile presented in **ACARP, 1998**; see **Figure 4e**.

The total increase in load/metre length (A) acting on the pillars adjacent to a crushed pillar area may be estimated as follows for a *critical* to *supercritical* panel with $W/H > 2\tan\theta$:

$A = 0.5\ \gamma\ H^2 \tan\theta$ where γ = unit weight of overburden (0.023 MPa/m)
θ = abutment angle (normally taken as 21^o)

The average stress acting on an adjacent standing pillar is then derived by multiplying 'A' by the pillar length (or width) that is perpendicular to the direction of loading plus the roadway or bord width. The load is then divided by the pillar area for the total abutment stress increase increment. Depending on the geometry of the pillar and direction of abutment loading, a proportion of the abutment load (1-R) may be distributed to adjacent 'inside' pillar by the cantilevering action of the overburden, as shown by the diagram in **Figure 4e**.

The proportion, R of the abutment load, 'A' that will load a goaf edge pillar may be estimated using the formula presented in **ACARP, 1998**:

$R = 1- [(D-w-r)/D]^3$ where D = distance that load distribution will extend from goaf edge.

w = goaf edge pillar width or dimension normal to the goaf edge.

The average pillar stress formula provided for loading from one side is as follows:

$$\sigma_{max} = \text{pillar load/pillar area} = (P+RA)/wl$$

The design abutment load for the site pillars has been assessed based on the known area of second workings with instability to the south of the site. For the assessment of the risk of a pillar run passing through the site, abutment loads from two alternative directions have been considered for all the site pillars based on RT and RT-0.5m pillar dimensions.

8.4 Pillar Stability Analysis Results

The long-term stability of Yard Seam and BH Seam workings pillars located below the site (see **Figure 2**) have been assessed for B3 Level buildings.

The results of the Yard and BH Seam pillar FoS under FTA and single direction abutment loading from pillar sides and ends are presented in **Tables 2A/B** and **3A/B** respectively. The pillar geometries selected were presented in **Coffey, 2019a** and represent the typical pillar sizes below the site.

Table 2A - Pillar Stability Review for FTA Loading Conditions in Yard Seam

Yard Seam Pillar No.	Pillar Width w (m)	Pillar Length l (m)	Bord Width b (m)	Cut-through Width r (m)	Pillar height h (m)	Pillar w/h	e (%)	Pillar Strength S_p (MPa)	FTA Load (MPa)	FTA FoS
Likely Case (Assumed Pillar Side Dimensions; Mining height h = effective seam thickness; Cover depth = 42 m)										
1	1.6	16.0	5.4	3.0	1.1	1.45	80.8	10.09	5.46	**1.85**
2	1.9	16.0	5.4	3.0	1.1	1.73	78.1	11.01	4.79	2.30
3	2.7	40.0	5.4	3.0	1.1	2.45	69.0	13.17	3.39	3.89
Credible Worst-Case (Pillar side dimensions = Assumed Dimensions - 0.5 m; Mining Height h = Seam thickness + 0.5 m)										
1	1.1	15.5	5.9	3.5	1.6	0.69	87.2	6.08	8.19	**0.74**
2	1.4	15.5	5.9	3.5	1.6	0.88	84.4	6.88	6.79	**1.03**
3	2.2	39.5	5.9	3.5	1.6	1.38	75.1	8.66	4.21	**2.06**

Bold - Pillar FoS or w/h < minimum required by *Table C3* in Merit Based Guidelines (refer **Section 7**);

Table 2B - Pillar Stability Review for FTA Loading Conditions in Borehole Seam

BH Seam Pillar No.	Pillar Width w (m)	Pillar Length l (m)	Bord Width b (m)	Cut-through Width r (m)	Pillar height h (m)	Pillar w/h	e (%)	Pillar Strength S_p (MPa)	FTA Load (MPa)	FTA FoS
Likely Case (Assumed Pillar Side Dimensions; Mining height h = effective seam thickness; Cover depth = 94 m)										
1	8.8	27.9	5.4	4.05	4.35	2.02	45.9	7.58	4.34	**1.75**
3	10.5	28.3	5.4	4.60	4.35	2.41	43.2	8.30	4.14	**2.01**
5	11.7	30.4	5.7	4.30	4.35	2.69	41.1	8.77	3.99	2.20
2	10.0	29.4	5.5	3.85	6.15	1.63	43.0	6.05	4.12	**1.47**
4	12.3	28.2	5.3	3.75	6.15	2.00	38.3	6.73	3.81	**1.77**
Mean	10.7	28.8	5.5	4.1	5.10	2.10	42.1	7.35	4.10	**1.79**
Credible Worst-Case (Pillar side dimensions = Assumed Dimensions - 0.5 m; Mining Height h = Seam thickness + 0.5 m)										
1	8.3	27.4	5.9	4.55	4.85	1.71	49.9	6.72	4.69	**1.43**
3	10.0	27.8	5.9	5.10	4.85	2.06	46.9	7.39	4.42	**1.67**
5	11.2	29.9	6.2	4.80	4.85	2.31	44.5	7.83	4.24	**1.85**
2	9.5	28.9	6.0	4.35	6.65	1.43	46.7	5.52	4.41	**1.25**
4	11.8	27.7	6.8	4.25	6.65	1.77	41.9	6.17	4.04	**1.53**
Mean	10.2	28.3	6.0	4.6	5.6	1.82	45.8	6.63	4.34	**1.53**

Shaded **-** northern area pillars; **Bold** - Pillar FoS or w/h < minimum required by *Table C3* in Merit Based Guidelines (refer **Section 7**);

Table 3A – Pillar Stability Review for Single Abutment Loading Conditions in the Yard Seam

Yard Seam Pillar No	Pillar Width w (m)	Pillar Length l (m)	Abutment Load Influence Distance from Instability Limits D (m)	Single Direction Abutment Load Cases – Load Perpendicular to Bords: Proportion of Abutment Load Applied to Pillar R_{side}	A_{side}	Total Pillar Load (MPa)	Pillar FoS	Load Parallel to Bords: Proportion of Abutment Load Applied to Pillar R_{end}	A_{end}	Total Pillar Load (MPa)	Pillar FoS
Likely Case (RT Pillar Side Dimensions; Mining height h = seam thickness)											
1	1.6	16.0	33	0.51	6.28	8.65	**1.17**	0.92	2.31	7.59	**1.33**
2	1.9	16.0	33	0.53	5.29	7.57	**1.46**	0.92	2.03	6.66	**1.65**
3	2.7	40.0	33	0.57	3.37	5.30	2.49	1.00	0.63	4.02	3.28
Credible Worst-Case (Pillar side dimensions = RT Dimensions - 0.5 m; Mining Height h = Seam thickness + 0.5 m)											
1	1.1	15.5	33	0.51	9.43	12.98	**0.47**	0.92	3.48	11.39	**0.53**
2	1.4	15.5	33	0.53	7.41	10.60	**0.65**	0.92	2.85	9.33	**0.74**
3	2.2	39.5	33	0.57	4.19	6.58	**1.32**	1.00	0.79	5.00	**1.73**

Bold - Pillar FoS or w/h < minimum required by *Table C3* in Merit Based Guidelines (refer **Section 7**);

Table 3B – Pillar Stability Review for Single Abutment Loading Conditions in the BH Seam

BH Seam Pillar No	Pillar Width w (m)	Pillar Length l (m)	Abutment Load Influence Distance from Instability Limits D (m)	Single Direction Abutment Load Cases – Load Perpendicular to Bords: Proportion of Abutment Load Applied to Pillar R_{side}	A_{side}	Total Pillar Load (MPa)	Pillar FoS	Load Parallel to Bords: Proportion of Abutment Load Applied to Pillar R_{end}	A_{end}	Total Pillar Load (MPa)	Pillar FoS
Likely Case (RT Pillar Side Dimensions; Mining height h = seam thickness)											
1	8.8	27.9	50	0.64	5.52	0.97	**0.97**	0.95	2.45	6.68	**1.13**
3	10.5	28.3	50	0.69	4.69	1.13	**1.13**	0.96	2.27	6.32	**1.31**
5	11.7	30.4	50	0.73	4.14	1.25	**1.25**	0.97	2.07	6.01	**1.46**
2	10.0	29.4	50	0.67	4.79	0.82	**0.82**	0.96	2.24	6.27	**0.96**
4	12.3	28.2	50	0.73	3.91	1.01	**1.01**	0.95	2.15	5.86	**1.15**
Mean	10.7	28.8	50	0.69	4.64	1.01	**1.01**	0.96	2.27	6.28	**1.17**
Credible Worst-Case (Pillar side dimensions = RT Dimensions - 0.5 m; Mining Height h = Seam thickness + 0.5 m)											
1	8.3	27.4	50	0.64	5.96	0.79	**0.79**	0.95	2.65	7.21	**0.93**
3	10.0	27.8	50	0.69	5.02	0.94	**0.94**	0.96	2.42	6.75	**1.09**
5	11.2	29.9	50	0.73	4.39	1.05	**1.05**	0.97	2.20	6.38	**1.23**
2	9.5	28.9	50	0.67	5.13	0.70	**0.70**	0.96	2.39	6.72	**0.82**
4	11.8	27.7	50	0.73	4.14	0.87	**0.87**	0.95	2.28	6.22	**0.99**
Mean	10.2	28.3	50	0.69	4.85	0.86	**0.86**	0.96	2.37	6.62	**1.00**

Shaded **-** northern area pillars; **Bold** - Pillar FoS or w/h < minimum required by *Table C3* in Merit Based Guidelines (refer **Section 7**);

The results in **Tables 2A/B** and **3A/B** indicate that the pillars in both seams under a range of possible loading conditions do not satisfy the minimum SA NSW pillar FoS and w/h ratio values considered necessary for long-term stability. Similar outcomes were also assessed in **Coffey, 2109a**.

Based on the stability analysis results, the probability of failure under credible worst-case conditions have been assessed in **Section 8.5**.

8.5 Pillar Failure Probability for FTA and Abutment Loading Conditions

The probability of pillar failure (p_f) for a super-critical width panel of pillars may be estimated from the Standard Log-Normal probability density function of critical FoS values presented in **UNSW, 1998** as follows:

$$1 - p_f = P(\ln(FoS)/\sigma)$$

where P(.) = standard cumulative normal probability distribution with a mean FoS of 1.
σ = standard deviation = 0.156

The probability of a panel failure for the bord and pillar mine workings in the Yard Seam under FTA loading conditions ranges between 97% (0.97) and < 1 in 1 million (10^{-6}); see **Figure 5a**. For the Borehole Seam workings, the probability of a panel failure ranges between 99% (0.99) and 2.4 in 10,000 (2.4×10^{-4}); see **Figure 5b**.

Due to the likely presence of abutment stress conditions to the deeper east, north and south of the site, it is considered that a pillar run, if it does eventuate, would approach the site from these directions and apply side or end on abutment loads to the pillars.

It is similarly noted in **Coffey 2019a** that the FoS of the pillars is approximately 1 and that the stability of the mine workings beneath the site is marginal.

As the analysis outcomes are significantly lower than the recommended minimum value of 2.1[7], it will be necessary to remediate the mine workings in each seam by strategically placing grout to encapsulate the sides of several key pillars. The grout design will be required to raise the pillar FoS under abutment loading to at least 1.6 and reduce subsidence effects to B3 Level building design Serviceability Limits.

The assessment of worst-case subsidence for the site pillars under abutment loading conditions is presented in **Section 9.0**.

[7] The minimum required FoS of 2.1 for long-term stability has a probability of failure of 1 in 1 million.

9.0 Worst-Case Subsidence Assessment Review

9.1 General

Coffey 2019a estimates maximum subsidence for the site based on existing void heights above the collapsed rubble; see **Section 9.3.4**. DgS has prepared separate subsidence estimates for elastic and full pillar crush responses under dry and flooded conditions based on the following methodology presented below.

The subsidence effect contours (subsidence, tilt, curvature, horizontal displacements and strains) for the various pillar instability cases have been derived using the SDPS® (Surface Deformation Prediction System). SDPS® was developed in the US Coalfields by **Karmis *et al*, 1990** based on longwall and pillar panel data.

SDPS® is an influence function-based model that may be used to estimate worst-case subsidence profiles and contours above a range of coal mine workings from longwalls to failed bord and pillar panels. The influence of an extracted element of coal or standing pillar of coal is transmitted to the surface via a 3-D Gaussian (bell-shaped) function. The program allows the extraction limits of the various mining areas, intra-panel pillars and surface topography to be imported from Autocad.

The model may be calibrated to measured or predicted subsidence profiles over bord and pillar panels of known width, cover depth, mining height and panel extraction ratio. The shape of the subsidence profile may be manipulated by adjusting the influence angle (approximate complement to the angle of draw) and inflexion point location; see **Figure 6a**.

The model may also be used to predict the effect of stable pillars surrounded by failing ones, which makes it suitable for assessing the subsidence mitigating potential of the proposed grouting strategy.

The maximum subsidence over crushed bord and pillar panels has been estimated based on reference to published subsidence data in the Newcastle CBD and mining examples from the Australian and South African Coal Fields; see **Figure 6b**.

In general, the maximum subsidence over a crushed bord and pillar panel will be controlled by:

- the available void in the workings after bulking of fallen roof rubble;
- the residual strength of the crushed pillar and strain hardening properties of the collapsed roof and yielded pillar material;
- the load transfer capability of the overburden, which decreases the applied pillar loadas the pillar crushes and loses stiffness (see **Figure 6c**);
- the potential buoyancy affects in flooded mine workings to reduce subsidence.[8]

[8] Predictions for total (dry) and effective (buoyant) stress conditions acting on the failing pillars have been provided to give an upper and lower limit for the worst-case subsidence predictions.

The SDPS® 3-D influence function program was used to estimate the subsidence contours with failing pillar panel by linking it to the pillar FoS. An effective in-panel goaf edge may be assumed where the pillar FoS under AWC conditions is sufficient to provide an appropriate boundary between elastic and yielding response. This approach may also be applied around an area where grout (of a minimum strength and stiffness) has been introduced into the workings to increase the likelihood that the pillars will not yield under the applied loads.

9.2 Elastic Compression Response under Design Loading

The initial elastic settlement of the pillars (before crushing) or where pillars remain elastic under the worst-case design loading condition (i.e. the pillar FoS is > minimum required for long-term stability), may be estimated using elastic solid mechanics theories as follows:

$$s_{max} = s_{pillar} + s_{roof} + s_{floor}$$ [9]

where

s_{pillar} = $\sigma_{net}\, h/E_{coal}$ = compression of pillar

s_{roof} = $\sigma_{net}\, I(1-\nu^2)[t_1/E_{roof1} + (w-t_1)/E_{roof2}]$ = compression roof strata units

s_{floor} = $\sigma_{net}\, I(1-\nu^2)[t_2/E_{floor1} + (w-t_2)/E_{floor2}]$ = compression of floor strata units

σ_{net} = pillar stress increase (design pillar stress - pre-mining stress)

E_{coal} = Young's Modulus for coal (default 2000 MPa)

$E_{roof1,2}$ = Average Young's Modulus for the immediate & upper roof strata units within one pillar width of the mine roof

$E_{floor1,2}$ = Average Young's Modulus for the immediate & lower floor strata units with one pillar width of the mine floor.

$t_{1,2}$ = thickness of immediate roof and floor strata units (if weaker than upper & lower strata units otherwise $t_{1,2} = w$)

ν = Poisson's Ratio = 0.25 is the default value for roof and floor strata

I = shape factor for square footing = ~ 1.5 (for a semi-rigid footing and rectangular pillars based on **Das, 1998**)

w = pillar width

h = pillar height

The material properties for elastic analysis are defined in **Table 4** and considered to be representative of the conditions in the Yard and Borehole Seam mine workings.

[9] Assumes pillars have same size and stiffness. Numerical modelling approaches improve accuracy when irregular pillar geometries are present.

Table 4 - Rock Mass Strength and Modulus Estimates

Stratigraphic Units	In-situ UCS+ (mean) (MPa)	E_{lab}/UCS^	E_{lab} (GPa)	Geological Strength Index# (GSI)	E_{rm}/ E_{lab}*	Rock Mass Moduli E_{rm} (GPa)
Tighes Hill Sandstone and siltstone	21 - 65 (40)	300	12	65	0.5	6
Shale	1 - 16 (4)	300	1.2	40	0.33	0.4
Borehole Seam	15 - 25 (20)	300	6	40	0.33	2
Waratah Sandstone	25 - 65 (50)	300	15	65	0.5	7.5

+ - UCS values derived from bore core samples in Newcastle CBD & Honeysuckle Precinct by several geotechnical consultants; (brackets) - mean values used for modulus estimates;
^ - Young's Modulus (E) derived from rock mass UCS, E_{lab} = 300 x UCS; # - refer **Hoek and Diederichs, 2005**;
* - $E_{rm}/E_{lab} = 0.02+1/(1+e^{(60-GSI)/11})$.

The worst-case subsidence for elastic pillar-roof/floor strata performance under FTA, side-on and end-on abutment loading case scenarios for dry mine workings conditions are summarised in **Table 5A for Yard Seam and 5B for the Borehole Seam**.

Table 5A - Analytical Maximum Subsidence Predictions for the Yard Seam due to Credible Worst-Case Conditions

Pillars	Cover Depth H (m)	CWC Pillar Width w (m)	Mining Height h (m)	CWC e %	Effective Mining Height h' = h.e (m)	Pillar Stress (MPa)	Pillar Stress Increase# (MPa)	Pillar FoS	Subsidence Predictions Based on Analytical Pillar-Roof & Floor Strata System Compression^ (mm)				
									Pillar	Roof$	Floor	Total (mean)	2 × Total (design worst-case)
FTA Loading													
1	42	1.1	0.91	87	0.79	8.19	7.14	**0.74**	6	31	1	**37**	**75**
2	42	1.4	0.91	84	0.77	6.71	5.66	**1.03**	4	26	1	31	62
3	42	2.2	0.91	75	0.68	4.21	3.16	2.06	2	16	1	19	37
Side-On Abutment Loading*													
1	42	1.1	0.91	87	0.79	12.98	11.93	**0.47**	9	52	1	**63**	**125**
2	42	1.4	0.91	84	0.77	10.60	9.55	**0.65**	7	44	1	**52**	**105**
3	42	2.2	0.91	75	0.68	6.58	5.53	1.32	4	27	1	32	64
End-On Abutment Loading**													
1	42	1.1	0.91	87	0.79	11.39	10.34	**0.53**	8	45	1	**54**	**108**
2	42	1.4	0.91	84	0.77	9.33	8.28	**0.74**	6	38	1	**45**	**91**
3	42	2.2	0.91	75	0.68	5.00	3.95	1.73	3	19	1	23	46

e = extraction ratio for reduced pillar geometry; # - stress increase (total stress - pre-mining stress of 1.05 MPa);
^ - Effective mining height based on mining height x extraction ratio (i.e. available void volume);
* - Side-On Abutment Load (perpendicular to the pillar length) = FTA + RA(l+r)/(wl);
** - End-On Abutment Load (parallel to the pillar length) = FTA + RA(w+b)/(wl);
$ - 1 m of weak shale in immediate roof; **Bold -** Pillars expected to yield under applied loading (i.e. elastic subsidence only is unlikely).

Table 5B - Analytical Maximum Subsidence Predictions for the Borehole Seam due to Credible Worst-Case Conditions

Pillars	Cover Depth H (m)	CWC Pillar Width w (m)	Mining Height h (m)	CWC e %	Effective Mining Height h' = h.e (m)	Pillar Stress (MPa)	Pillar Stress Increase# (MPa)	Pillar FoS	Subsidence Predictions Based on Analytical Pillar-Roof & Floor Strata System Compression^ (mm)				
									Pillar	Roof$	Floor	Total (mean)	2 × Total (design worst-case)
FTA Loading													
1	94	8.3	1.95	50	0.97	6.72	4.86	1.43	5	15	2	22	44
3	94	10.0	1.95	47	0.91	7.39	4.40	1.67	5	14	2	21	42
5	94	11.2	1.95	45	0.87	7.89	4.03	1.85	4	13	2	20	40
2	94	9.5	3.75	47	1.75	5.52	4.37	1.25	6	14	2	22	44
4	94	11.8	3.75	42	1.57	6.17	3.87	1.53	5	12	2	20	39
Side-On Abutment Loading*													
1	94	8.3	1.95	50	0.97	8.47	6.12	**0.79**	14	38	7	58	**116**
3	94	10.0	1.95	47	0.91	7.86	5.51	**0.94**	13	36	7	56	**111**
5	94	11.2	1.95	45	0.87	7.42	5.07	1.05	12	35	7	53	106
2	94	9.5	3.75	47	1.75	7.87	5.52	**0.70**	17	36	7	59	**119**
4	94	11.8	3.75	42	1.57	7.07	4.72	**0.87**	15	33	7	54	**109**
End-On Abutment Loading**													
1	94	8.3	1.95	50	0.97	7.21	4.86	**0.93**	11	30	5	46	**92**
3	94	10.0	1.95	47	0.91	6.75	4.40	**1.09**	10	29	6	44	**89**
5	94	11.2	1.95	45	0.87	6.38	4.03	1.23	9	28	6	42	85
2	94	9.5	3.75	47	1.75	6.72	4.37	**0.82**	14	28	6	47	**94**
4	94	11.8	3.75	42	1.57	6.22	3.87	**0.99**	12	27	5	45	**89**

e = extraction ratio for reduced pillar geometry; # - stress increase (total stress - pre-mining stress of 2.35 MPa);
^ - Effective mining height based on mining height x extraction ratio (i.e. available void volume);
* - Side-On Abutment Load (perpendicular to the pillar length) = FTA + RA(l+r)/(wl);
** - End-On Abutment Load (parallel to the pillar length) = FTA + RA(w+b)/(wl);
$ - 1 m of weak shale in immediate roof; **Bold -** Pillars expected to yield under applied loading (i.e. elastic subsidence only is unlikely); shaded - northern pillars

Based on the results in **Tables 5A and 5B**, the elastic response subsidence for the site pillars under long-term abutment loading conditions is unlikely to exceed 130 mm.

The assessment of worst-case subsidence due to a full pillar crushing event is assessed in **Section 9.3**.

9.3 Maximum Potential Subsidence Prediction

9.3.1 Empirical Model Background

The prediction of maximum subsidence over bord and pillar and partial pillar extraction panels with moderate extraction ratios of 40% to 70% is generally difficult in Australia because survey data is scarce for these cases. This has usually resulted in the need to use high extraction ratio pillar panels and longwall data and adjusting the mining height for the extraction ratios to make subsidence predictions instead.

A previous subsidence study of the Newcastle CBD crush events by **Hawkins and Ramage, 2004** noted that the measured subsidence was significantly less than maximum subsidence values predicted using the longwall and total pillar extraction curve presented in **Holla, 1987** and also after adjusting for the effective mining height (which is equal to the true mining height multiplied by the panel extraction ratio); see **Figure 6d**.

The reason for the above discrepancy is considered to be caused by the fundamental differences in subsidence development mechanics between longwalls and bord and pillar workings. The former mining method results in the development of a much thicker rubble than the latter and is due to the large differences in roof span left between solid pillars or ribs in the panels after mining. The presence of remnant pillars in pillar extraction panels also reduces subsidence.

The collapsed rubble in both cases will probably be subject to the same stress and have similar stiffness properties (i.e. the strains under load will be the same), however, the rubble thickness differences will result in a proportionally greater seam roof convergence and surface subsidence to develop above a longwall. A schematic diagram, which demonstrates these fundamental differences in subsidence mechanics, is presented in **Figure 6e**.

The figure indicates that the subsidence for a longwall panel is likely to be derived from a rubble thickness that ranged from 4 to 6 times the seam thickness. However, a bord and pillar panel that crushes with extraction ratios of 40% and 55% may only have maximum caving heights of about 7.5 to 8.3 m, which is assessed to be 1.2 to 1.4 times the seam thickness (including the pillars with an original mining heights of 4.2 to 5.5 m).

If a longwall or total extraction database is referred to, the predicted outcomes usually indicate a maximum subsidence of 0.5 to 0.6 times the effective mining height (i.e. actual mining height x pillar extraction ratio (e) above a super-critical[10] panel geometry. The measured subsidence above the 'super-critical' pillar panel crushes in the Newcastle CBD have only ranged between 0.3 and 0.45 times the effective mining height, with the lower value (Creep 3) possibly a case of incorrect mining height estimate, incomplete crush or pillar 'punching' failure into the roof; see **Figure 6f**.

10 - Supercritical panels occur when the mined panel is wider than it is deep (W/H>1.2 to 1.4), and usually results
in complete failure of the overburden and maximum subsidence for a given mining height.

It is assessed from **Figure 6f** that the maximum subsidence above dry mine workings below the site is likely to range between 0.35 and 0.45 times the effective mining height (h' = true mining height x extraction ratio) or 0.4h' +/- 0.05h'.

The predicted v. measured ranges of maximum subsidence (S_{max}) in the old mine workings for dry conditions are shown in **Table 6**.

Table 6 - Predicted v. Measured Subsidence for AAC & W&BI/Ferndale Mine Workings

Mine Workings	Cover Depth H (m)	Mining Height, h (m)	Extraction Ratio e (%)	Effective Mining Height h' = he (m)	Measured Subsidence S_{max} (m)	Predicted Dry S_{max} 0.4h' +/- 0.05h'
New Winning	115 - 110	5.5	39	2.15	0.825 - 0.775	0.75 - 0.97 (0.86)
	77	2.2 - 2.5	39	0.86 - 0.98	*0.30*	0.28 - 0.41 (0.34)
W&BI	60	4.8	55	2.64	1.2	0.92 - 1.19 (1.06)
Ferndale	40	2.0	63	1.26	N.M.	0.44 - 0.57 (0.50)

(brackets) - mean predictions; *italics* - measured subsidence estimated indirectly from building damage reports (**To, 1987**).

It is considered that this model will provide an upper bound subsidence prediction for the site if the pillars in each seam have not yet crushed.

9.3.2 Overburden Buoyancy Effects on Subsidence

Based on FLAC3D modelling, **Mackenzie & Clark, 2005** adopted a pillar loading life-cycle approach that considered initial dry conditions in the workings followed by the effects of buoyancy after flooding.

Assuming the maximum subsidence is a function of the overburden stress, the maximum subsidence (S_{max}') for buoyant overburden conditions may be estimated as follows for a future pillar crush event:

$$S_{max}' = [(\gamma H - \gamma_w H_w)/\gamma H]S_{max}$$

where γ = dry unit weight of rock (default 0.025 MN/m^3)
γ_w = unit weight of water (default 0.01 MN/m^3)
H_w = head of water above mine workings (default H - depth to sea level)

For a surface level of RL 32 m (AHD) and a water table level of RL 3 m (AHD), the water pressure head in the Yard Seam will be approximately 13 m and 65 m in the Borehole Seam.

Buoyant mine workings conditions will result in reduced subsidence that is estimated to be approximately 88% to 72% of the dry workings' subsidence due to pillar failure in the Yard and Borehole Seam's respectively. The predicted flooded mine workings values are presented in **Table 7**.

9.3.3 Empirical Model Results

Predicted maximum subsidence due to a pillar crush has been assessed using the empirical model presented in **Section 9.3.1** for the pillars below the site and pillar extraction area to the south for dry and flooded conditions. The results are summarised in **Table 9**.

Table 7 - Predicted Maximum Subsidence (Upper Bound) due to Full Pillar Crush in Yard and Borehole Seams

Seam	**Cover Depth H (m)**	**Mining Height, h (m)**	**Extraction Ratio e (%)**	**Effective Mining Height h' = he (m)**	**Predicted S_{max}/he**		**Predicted S_{max} (m)**	
					Dry	Flooded	Dry	Flooded
Yard (north)	42	0.91	80	0.73	0.4	0.35	0.29	0.26
Yard (south)	42	0.91	80	0.73	0.4	0.35	0.29	0.26
Borehole (north)	**94**	**1.95**	**42**	**0.82**	**0.4**	**0.29**	**0.33**	**0.24**
Borehole (south)	**94**	**3.75**	**42**	**1.575**	**0.4**	**0.29**	**0.63 (0.43)**	**0.46 (0.26)**
Yard + Borehole (north)	Cumulative Subsidence due to pillar crush in both seams						0.62	0.50
Yard + Borehole (south)	Cumulative Subsidence due to pillar crush in both seams (modified subsidence due to previous crush event)						0.92 (0.72)	0.72 (0.52)

Bold - Maximum subsidence range for AWC if Yard Seam Workings are bulk grouted.

The results indicate that the maximum subsidence at the site due to a pillar crush event in the Yard Seam only will range between 0.26 m to 0.29 m.

A review of the borehole data and stability analysis results suggests that the southern area pillars in the Borehole Seam have partially yielded or crushed more than 200 mm. On-going pillar failure in the Borehole Seam only could therefore range between 0.26 m to 0.63 m.

For both seam's workings to crush, maximum subsidence is estimated to range between 0.50 m and 0.62 m in the northern area and 0.72 m to 0.92 m in the southern area.

As the geotechnical uncertainty for the Yard Seam is 'High' it will be necessary to grout these workings to lower the GUF to an acceptable level (Low to Moderate). This will therefore leave only the mine subsidence risk in the Borehole Seam to be considered for the development (i.e. maximum subsidence ranging from 0.43 m to 0.63 m).

An alternative approach to estimating potential subsidence for the site has been to assume the pillars can only crush into the available void along the bords (**Coffey 2019a**). Residual subsidence values for current conditions are estimated in **Section 9.3.4**.

9.3.4 Coffey Residual Subsidence due to Pillar Crush into available void

Coffey have introduced a method of estimating future subsidence (Δ) based on pillar failure into the available void as follows:

$$\Delta = [(w+b)h_v - h_p.\psi.w]/(w+b)$$

where w = pillar width
b = bord width
h_v = void above rubble
h_p = section of exposed pillar failing into void (default is h_v)
ψ = crushed pillar bulking factor (default is 1.3)

The predicted residual subsidence values for the Yard Seam and Borehole Seam workings has been assessed by DgS and presented in **Table 8**.

Table 8 - Predicted Maximum Subsidence due to Residual Pillar Crush into Available Voids in Yard and Borehole Seams

Seam	Pillar Width w (m)	Bord Width b (m)	Void Above Rubble h_v (m)	Bulking Factor	Predicted S_{max} (m)	
					Dry	Flooded
Yard (north)	1.6	5.4	0.50	1.3	0.35	0.31
Yard (south)	1.6	5.4	0.33	1.3	0.23	0.20
Borehole (north)	**10.3**	**5.5**	**0.55**	**1.3**	**0.08**	**0.06**
Borehole (south)	**11.15**	**5.4**	**1.65**	**1.3**	**0.20**	**0.15**
Yard + Borehole (north)	Cumulative Subsidence due to pillar crush in both seams				0.43	0.37
Yard + Borehole (north)	Cumulative Subsidence due to pillar crush in both seams				0.43	0.35

Coffey, 2019a estimated a maximum subsidence for the site could range between 150 mm and 300 mm, which are similar to the **Table 8** values. The subsidence values and cover depth of 93 m were then used to derive differential subsidence effects using **Holla, 1987**, which indicated maximum tilts between 3 and 6 mm/m, curvatures from 0.07 km-1 to 0.2 km-1 and strains from 0.7 mm/m and 2 mm/m. Based on these values, it is assessed that further instability in the Borehole Seam workings is likely to exceed the B3 Level Serviceability Limit States for tilt and curvature.

Coffey 2019a also states that "the above estimates do not include the mine subsidence numerical modelling that is currently underway". The subsequent modelling results in **Coffey 2019b** and **Coffey 2019c** indicate worst case subsidence of approximately 450 mm for dry workings conditions, which is consistent with the full crush model less previous subsidence of 200 mm.

It is also apparent that the 'balanced void' model predicts lower subsidence than the full pillar crush model. It is therefore considered appropriate that the full crush model be adopted at this stage until further borehole data can be obtained to establish the mining (or available void height and extent of pillar crush between the north and southern areas in the Borehole Seam below the site.

A maximum potential subsidence of 630 mm under dry conditions has therefore been adopted for the CWC Subsidence value for the site.

9.4 Calibration of SDPS for AWC Subsidence Effect Contours

The following SDPS model input parameters were used to estimate the AWC Subsidence effects due to full pillar crush events in the Yard and Borehole Seam workings below the Mosbri Crescent site:

- Maximum supercritical subsidence/effective mining height ratio, S_{max}/he = 0.4
- Supercritical inflexion point distance from mining limits/cover depth ratio, d/H = 0.25 (d = 10.5 m in the Yard Seam and 23.5 m in the Borehole Seam)[11]
- Tangent of the Influence Angle, tan(β) = 1.8
- Horizontal Strain = 10 x Curvature

The parameters have been derived from subsidence data presented in **Coffey, 2009** for the Wickham and Bullock Island pillar crush event in 1896; see **Figures 6g** and **6h**.

9.5 Predicted Subsidence Effect Contours and Maximum Site Parameters

The predicted subsidence effects for the absolute worst-case (AWC) pillar crush conditions for dry and flooded cases in the Borehole Seam have been assessed for and summarised in **Table 9**.

AWC Subsidence effect contours, including tilt, curvature and horizontal strain have then been derived for dry workings conditions using Surfer12® kriging software; see **Figures 7a-d**.

[11] The inflexion point represents the distance to maximum tilt from the limits affected by pillar instability or mine subsidence in general. The Influence Angle is also measured from this point and towards the limits of mining.

Table 9 - Predicted Absolute Worst-Case Subsidence Effect Parameters for Mosbri Crescent due Borehole Seam Failure

Parameter	Dry Conditions	Flooded Conditions
Cover Depth, H (m)	94	94
Mining Height, $h^{\&}$ (m)	3.75	3.75
Seam Thickness, T (m)	6.1	6.1
Inflection point, d (m)	23.5	23.5
Predicted d/H	0.25	0.25
Angle of draw to 20 mm subsidence contour (o)	<26.5°	<26.5°
Maximum Subsidence, S_{max} (mm)	630	460
Maximum Tilt, T_{max} (mm/m)	13	10
Maximum Curvature*, C_{max} (km^{-1})	-0.45 to +0.45	-0.3 to +0.3
Maximum Horizontal Strain^, E_{max} (mm/m)	-4.5 to +4.5	+3 to -3

& - Maximum mining height assumed; * - Hogging curvature is positive; ^ - tensile strain is positive; E_{max} = 10 x C_{max}.

As discussed in **Section 7.3**, it will be necessary for B3 structures to remain "safe, serviceable, and economically "repairable" after the AWC scenario. The predicted subsidence effects after the BH Seam crushes are likely to exceed the SLR values for the structures.

It will therefore be necessary to remediate the mine workings with grout to fill or reduce existing voids to ensure building serviceability (and safety) will be maintained in the event of a pillar crush event within and or around the site limits.

DgS generally concurs with the recommended grouting solutions for the Yard and Borehole Seams presented in **Coffey, 2019b**; see **Figures 8a** and **8b** respectively. The solutions recommended are:

(i) a bulk grouting solution for the Yard Seam workings due to the marginal FoS and absence of a record tracing for the workings (due to a High GUF);

(ii) a strategic grouting solution for the Borehole Seam workings (due to a Low to Moderate GUF).

An indicative assessment of strategic grout locations in the Borehole Seam to control subsidence effects to the required magnitudes, as previously discussed, is presented in **Section 10**.

10.0 Grout Design Review

10.1 Coffey FLAC3D Model

As discussed earlier in **Section 7.3**, DgS concurs with the proposal by Coffey to bulk grout the Yard Seam with low strength (1 MPa UCS) flyash-cement grout, with strategic grout placed in the Borehole Seam.

The Borehole Seam grout design in **Coffey, 2019b** (Layout 1) follows the pillar encapsulation approach applied elsewhere in the Newcastle CBD and has been modelled using FLAC-3D V6. The model has been developed from the geotechnical data in **Coffey 2019a**. The program provides several constitutive models that allow reasonably accurate modelling of the pillar response to overburden loading.

The overburden has been modelled as a Ubiquitous Joint model which combines an elastic-plastic Mohr-Coulomb model of rock mass with limited joint slip allowed within elements. Based on recommendations in **DgS, 2018**, Coffey have also applied slip planes or elasto-plastic (Mohr-Coulomb) Interfaces between the coal pillars, roof, floor and grout contact surfaces to allow realistic stress re-distribution to occur between elements during subsidence development.

Coal pillars have been modelling using a Mohr-Coulomb Strain Softening/hardening model that allows pillars to crush to a residual strength value and subsequently strain harden to limit subsidence development to expected magnitudes. The softening phase assumes a reduction of pillar cohesion to 0.1 MPa over a plastic strain of 3.5%, which is consistent with slender pillar behaviour. The strain hardening phase then commences at a total strain of 5% with maximum pillar crush limited to approximately 0.5 m.

Elastic moduli and material strength input parameters were then selected based on calibration to **UNSW, 1998** empirical pillar strength formulae values for pillar strength and estimates of worst-case subsidence (see **Section 9**). The long-term stability of the mine workings was assessed by reducing the coal cohesion in 5% increments to indirectly model pillar spalling and local roof failure until the pillars failed below the site.

The initial results indicated that the pillars below the site should have already failed if the assumed mining geometry was present. Historical pillar failures to the east and borehole data indicate that the majority of pillars below the site are still standing. It was then decided to increase the strength of the site pillars by decreasing the pillar height until the site pillars stopped failing. A pillar height of 5.1 m was found to support the applied loading.

Five (5) MPa UCS grout was then placed in the model at the locations shown in **Figure 8b** (Borehole Seam) and the strength of the pillars decreased until the onset of pillar yielding (with grout confinement). For an effective grout strength of 1 MPa in the rubble and 2 MPa above the rubble (to allow for loss of strength during placement under water apparently) the model started crushing below the site once the pillar strengths were reduced to ~ 70% of the pre-grouting values (suggesting a post-grouted FoS of 1.43).

The grouting design proposed (Layout 1) required two-sided encapsulation of one to two pillars at eight locations around the boundary of the site at a clear spacing of 30 m to 50 m. Two internal pillars were also encapsulated leaving un-grouted spans of 35 m to 70 m between the external grouted pillar groups. The external pillar groups were also placed approximately 28 m outside of the site boundary to control tilts and curvatures at the proposed building locations.

While DgS was comfortable with the approach used by Coffey to limit external pillar instability effects on the site, the un-grouted internal spans did appear excessive should internal pillar instability eventuate.

Supplementary analysis of un-grouted spans and an alternative grouting arrangement was subsequently assessed by DgS in the following sections.

10.2 Voussoir Beam Analysis

The borehole data provided in **Coffey, 2018a** indicates 40 m to 50 m of high strength siltstone and sandstone with UCS ranging between 15 MPa and 150 MPa (Mean of 50 MPa).

A 2D-Voussoir Beam analysis based on **Diedrichs and Kaisser, 1999** was completed on 'strong' beam thicknesses of 25 m, 35 m and 50 m with their bases located 2 m above the seam roof. The results indicate un-grouted spans between 50 m and 60 m in the mine workings will limit subsidence to < 100 mm should local instability occur within the site; see **Figures 8c** and **8d**.

The analysis assumed a design UCS of 25 MPa (Class I/II Sandstone in **Bertuzzi & Pells, 2002**) and GSI of 65. A rock mass modulus (parallel to bedding) of 4.7 GPa was derived based on **Hoek and Deidrichs, 2006**.

Empirical subsidence data for longwalls also indicate that 'natural arching' will develop for spans < 60 m (regardless of strong beam thickness) and assuming a span/rock thickness ratio of 0.5 to 0.6 to achieve the same outcome; see **Figure 8e**.

The proposed grouting scheme presented in **Coffey, 2018a** has therefore been adjusted to satisfy the above spanning criteria with a preliminary check completed in the following sections. Coffey were advised on this issue and verified the stability of the proposed scheme in **Coffey, 2019**.

10.3 Amended Grouting Scheme in the Borehole Seam

The proposed grouting scheme to limit internal spans to <60 m is shown in **Figure 8f**.

The following design criteria for the grouting scheme will be required to satisfy SANSW 'SSR' performance limits:

(i) the strength of the encapsulated pillars must be greater than the applied internal and external loading, and

(ii) the system stiffness is sufficient to limit subsidence to within SSR limits for the proposed structures.

The placement of grout onto the collapsed roof rubble in their current ‘standing’ condition will allow the passive development of horizontal confining pressure as the pillar compresses vertically (and expands laterally) under additional load; see **Figure 9a**.

The modified strength of the pillars and their subsidence reducing capability under design loading conditions will also depend on the strength and stiffness of the grouted rubble and the proportion of un-grouted rubble. Cement modified flyash with a 90-day UCS of 5 MPa has been assumed to demonstrate how the peak and residual strength properties of the pillar elements that will benefit from the proposed grout confinement.

Pillar strength after placement of grout may be computed from the following equation for biaxial stress conditions (**Donovan and Karfakis, 2004**).

$$S_p' = S_p + K_{pp} \times \sigma_h$$

where S_p' is the modified pillar strength after the placement of backfill grout on two sides[12], S_p is the original pillar strength that can be estimated based on the UNSW approach, K_{pp} is a coefficient that depends on the characteristics of coal pillar, and σ_h is the horizontal pressure acting on pillars.

The reciprocal of K_{pp} is the commonly understood K factor that refers to the ratio of horizontal stress to vertical stress (σ_h/σ_v). Due to the difference in material stiffness or elastic modulus between the coal pillar and grout, the K values for the grout will be different to the values for the coal pillar. The design passive grout pressures have been estimated from horizontal grout pressure v. vertical pillar stress increase charts developed with FLAC3D and presented in **DgS, 2018**; see **Figure 9b**.

It is considered that the non-grouted and grout-modified strengths of the pillars below the site should be based on the credible worst-case pillar geometries scaled from the RT less 0.5 m with an effective height equal to the available seam thickness + 0.5 m.

Based on a review of UCS v. Modulus data for cement stabilised fly-ash grout samples (**ACARP, 2001**), a base grout modulus/UCS ratio of 300 has been adopted, see **Figure 9c**.

The elastic modulus (stiffness) of the grouted rubble has then been weighted to reflect the possibility that not all the rubble will accept grout from a tremie lowered into the rubble. The effective modulus of the grouted void and non-grouted section of rubble has therefore been determined using the following algorithm:

[12] The grout pressure should be halved if placed on one side only. The formula assumes the grout is placed in the bords that provide confinement to the pillar width. Pillar strength is not increased significantly if grout is also placed in cut-throughs as slender pillar strengths (w/h<3) are not affected by the pillar length dimension according to **UNSW, 1998**.

E' = $\sum_{i=1}^{n} Ei.ti$ / t where E' = Effective grouted modulus
t = thickness of rubble and overlying void
E_i = Modulus of layer (grout or rubble)
t_i = thickness of layer

The effective modulus for the 5 MPa UCS grout (90-day strength) placed in a bord with 1 m of un-grouted and grouted rubble for the balance is summarised in **Table 10** for the northern and southern mine workings below the site. The insitu grout modulus has been reduced to 80% above the rubble and 67% of the laboratory results within the rubble.

Table 10 - Grouted Rubble Properties

Parameter	**Layer Thickness t_i (m)**	**Layer Modulus E_i (MPa)**	**Product E_i t_i**
Northern Pillar Grout Strength (UCS) = 5 MPa & E_g = 300UCS = 1500 MPa			
Ungrouted Void	0.10	0	0
Grouted Void above Rubble	0.45	1200	540
Grouted Rubble	3	1000	3000
Un-Grouted Rubble (dense)	1	100	100
Bord Height	**4.55**		**3640**
Effective Grout Modulus		**E'=**	**800 MPa**
Southern Grout Strength (UCS) = 5 MPa & E_g = 300UCS = 1500 MPa			
Ungrouted Void	0.10	0	0
Grouted Void above Rubble	1.55	1200	1860
Grouted Rubble (50% of rubble)	4	1000	4000
Un-Grouted Rubble (dense)	1	100	100
Bord Height	**6.65**		**5960**
Effective Grout Modulus		**E'=**	**900 MPa**

A grouted rubble modulus of 800 MPa has been adopted for design purposes in both the north and south areas of the mine. It is assessed that a modulus of 550 MPa was adopted by Coffey based on an 8 m high bord with 2 m of dense, un-grouted floor rubble with a modulus of 120 MPa overlain by 4 m of grouted rubble with a modulus of 500 MPa and 2 m of void grout with a modulus of 1000 MPa. It is assessed that the Coffey model has assumed in-situ grout strengths and moduli of 67% and 33% of the surface values (i.e. UCS of 5 MPa and E of 1500 MPa) for void and rubble grout respectively.

Based on the likely strength and stiffness increases due to backfilling of grout to the roof and actual grout confinement extending beyond the design lines shown, it considered reasonable to adopt an un-adjusted grout strength of 5 MPa and weighted modulus of 80% and 67% for the void and rubble grout properties (see **Table 10**). Any reduction in grout strength during underwater placement is likely to be recovered by (i) roof contact with grout under load that will effectively increase the grouted prism strength due to lateral confinement and (ii) the grout is likely to extend beyond the minimum design limits specified, resulting in additional confinement of the pillar and increase in pillar strength.

By adopting an in-situ grout UCS of 5 MPa with a modulus of 800 MPa, the modified pillar strength v. strain curves are presented in **Figures 9d** and **9e** in the northern and southern areas respectively.

The design abutment loading for the pillars has been estimated with reference to **ACARP, 1998** at the northern and southern boundaries of the site by adopting side-on and end on abutment loading conditions that will occur simultaneously after the CWC subsidence event.

A summary of the modified pillar strengths for proposed grout confinement of key pillars bellow the site are provided in **Table 11**.

Table 11 - Summary of Modified Pillar Strengths and FoS for the Site due to 5 MPa Grout Confinement

Grout UCS (MPa)	Effective Grout Modulus Eg' (MPa)	Existing Pillar Strength^ S_p (MPa)	Modified* Pillar Strength S_p (MPa)	Modified* Residual Strength@ 100mm Subsidence S_p' (MPa)	Design Pillar Loading (MPa)				Modified Pillar FoS$
					FTA	Side on	End on	Total	
Northern CWC Pillar Dimensions (w' = 11.6 m, l' = 28.2 m; bord width = 6 m, cut-through width = 3.8 m; Effective Pillar Height, T'= 4.85 m)									
Nil	100	7.97	7.97	1.59	4.05	3.03	2.18	9.26	**1.16**
5	800	-	11.55	17.45	4.05	3.03	2.18	9.26	1.89
Southern CWC Pillar Dimensions (w = 11.3 m, l = 30.5 m; bord width = 5.5m, cut-through width = 3.8 m; Effective Pillar Height, T'= 6.65 m)									
Nil	100	6.04	6.04	1.21	4.39	3.4	2.47	10.26	**0.59**
5	800	-	9.09	16.45	4.39	3.4	2.47	10.26	1.51

^ - Pillar strengths according to **UNSW (1998)**. Shaded - ungrouted pillars based on CWC pillar side dimensions (i.e. RT - 0.5 m); **Bold** - Pillar FoS < 1.5 under the design abutment loading case.

The results indicate that the proposed grouting arrangement is likely to support the design load cases (side-on + end-on Abutment Loading (including FTA)).

It is considered that fully encapsulated pillars below the site may have a lower FoS than then minimum required for the non-grouted case due to (i) the increased confidence in the mine plan after grouting; (ii) the reduction in void beneath the site due to the grouting, and (iii) the post-yielding response of the grout confined pillars will have changed from strain-softening to strain-hardening system if overloaded at some stage in the future.

Coffey 2019 has added a similar layout (Layout 2) to the arrangement presented in **Figure 8f** and verified the pillar loads, strength and subsidence is consistent with this report.

10.4 Modified Subsidence Effects due to Amended Grouting Strategy

The results of the subsidence effect contouring exercise for the proposed grout arrangement modification summarised in **Table 12**.

Table 12 - Maximum Subsidence Effect Summary for Proposed DgS Grouting Arrangement Modification to Layout 1 in the BH Seam Workings below the Mosbri Crescent Site Footprint

Case	Location	S_{max} (m)		Tilt (mm/m)		Curvature* (1/km)		Horizontal Strain** (mm/m)	
		Dry	**Flooded**	**Dry**	**Fld.**	**Dry**	**Fld.**	**Dry**	**Fld.**
Grouted	North	0.03 - 0.07	0.02 - 0.05	< 3	< 2	+/-0.15	+/-0.10	+/-2	+/-1.5
	South	0.03 - 0.07	0.02 - 0.05	< 3	< 2	+/-0.15	+/-0.10	+/-2	+/-1.5

* - hogging curvatures are positive and sagging curvatures are negative; ** - tensile strains are positive and compressive strains are negative; Maximum average strain appropriate for design may be derived by multiplying the assessed curvatures by 10 (**Holla, 1987**); Strain concentrations due to surface cracking may double the strains locally.

The Credible Worst-Case subsidence effect contours (subsidence, tilt, curvature and strain) for the grout confined pillar cases under dry conditions are presented in **Figures 9a** to **9d**. The contours indicate that the predicted worst-case subsidence effect contours with 5 MPa grout will be unlikely to exceed structural design tolerances.

The subsidence effects predicted in the Coffey models are summarised in **Table 13** and again indicate the FLAC3D model is more conservative than the DgS model estimates.

Table 13 - Maximum Subsidence Effect Summary for Coffey Grouting Arrangements AAC Mine Workings below the Mosbri Crescent Site Footprint

Case	Location	S_{max} (m)		Tilt (mm/m)		Curvature* (1/km)		Horizontal Strain** (mm/m)	
		Dry	**Flooded**	**Dry**	**Fld.**	**Dry**	**Fld.**	**Dry**	**Fld.**
Grouted	Layout 1	<160	-	<4	-	<0.100	-	<1	-
	Layout 2 (DgS)	<160	-	<4	-	<0.125	-	<1.25	-

11.0 Conclusions and Recommendations

The review of the predicted subsidence effects and proposed rehabilitation modelling by Coffey indicates outcomes that are consistent with an independent assessment by DgS.

The following outcomes have been identified by the review:

- The existing mine workings in the Yard and Borehole Seams currently have an FoS of around 1 under a range of likely loading and pillar w/h < 2 mining geometry scenarios.

- The probability of pillar failure is therefore ~50% based on **UNSW, 1998** probability of pillar failure curves.

- The geotechnical uncertainty for a trough subsidence impact assessment is 'high' for the Yard Seam workings (due to the lack of a mine plan) and 'low' to 'moderate' for the Borehole Seam mine workings (due to the variable mining height indicated).

- The Merit-based Guidelines will require the proposed 'B3 Importance Level' development to remain 'safe, serviceable and readily repairable' after an Absolute Worst-case subsidence event.

- Estimates of future AWC subsidence events are likely to result in subsidence below the site of between 0.43 m to 0.63 m. Maximum tilts are estimated to range between 3 - to 13 mm/m; curvatures of +/- 0.45 km^{-1} and strains of +/- 4.5 mm/m.

- The predicted subsidence effects after the BH Seam crushes are likely to exceed the SLR values for the proposed structures.

- It will therefore be necessary to remediate the mine workings with grout to fill or reduce existing voids to ensure building 'serviceability' (and 'safety') will be maintained in the event of a pillar crush event within and or around the site limits.

- DgS generally concurs with the recommended grouting solutions for the Yard and Borehole Seams presented in **Coffey, 2019b** (Layout 1). However, it is recommended that the internal un-grouted distances between grout confined pillars in the BH Seam be limited to < 60 m to ensure 'natural' arching of the high strength overburden, located between the Yard and Borehole Seams and between the grouted areas.

- The grouting arrangement assessed in this report and **Coffey, 2019c** for Layout 2 is the preferred option with assessed modified grout pillar stress and FoS estimates likely to be > 1.5.

- Proposed structures will need to be designed by structural engineers to tolerate residual subsidence effects after grouting works are completed in both seams. The Serviceability limits (SL) will need to be limited the tilts < 3 mm/m, curvatures < 0.15 km^{-1} (or > 7 km radius of curvature) and horizontal strains < 2 mm/m after failure of the mine workings roof.

- The impacts caused by the SL values should not exceed Category 1 damage (very slight) as defined in **AS2870 - 2011**.

12.0 References

ACARP, 1998. **Chain Pillar Design (Calibration of ALPs)**. M. Colwell. ACARP Report No. C6036 (October).

ACARP, 2001. **Utilising Flyash Paste Backfill**. Golder Associates Pty Ltd & UNSW School of Mining. ACARP Report No. C7033 (August).

ACARP, 2005. **Systems Approach to Pillar Design**. Strata Control Technologies Pty Ltd, UNSW School of Mining, Coffey Geosciences Pty Ltd. ACARP Project No. C9018. (May).

AS2870 - 2011. **Australian Residential Slabs and Footing Design Guidelines**.

Bertuzzi, R. and Pells, P.J.N., 2002. **Geotechnical Parameters of Sydney Sandstone and Shale**. Australian Geomechanics, 37 (5).

Coffey, 2009. **Consultancy for Mine Subsidence, Cottage Creek Precinct, Honeysuckle Drive, Wickham**. Coffey Geotechnics Report No. GEOTWARA20878AA-AC (March).

Coffey, 2018. **Mine Subsidence Report - Proposed Residential Development at 108 Church St, The Hill**. Coffey Report No 754-NTLGE220504-AI (9 May 2018).

Coffey, 2019a. **Mine Subsidence Investigation Report - Proposed Multi-Building Residential Development, 11-17 Mosbri Crescent, Cooks Hill**. Coffey Report No 754-NTLGE220504-AH (Rev 3) (14 January).

Coffey, 2019b. **Mine Subsidence Investigation Report - Proposed Multi-Building Residential Development, 11-17 Mosbri Crescent, Cooks Hill**. Coffey Report No 754-NTLGE220504-AI (18 January).

Coffey, 2019c. **Mine Subsidence Investigation Report - Proposed Multi-Building Residential Development, 11-17 Mosbri Crescent, Cooks Hill**. Coffey Report No 754-NTLGE220504-AI (12 March).

Das, 1986. **Influence of Width/Height Ratio on Post Failure Behaviour of Coal**. M.N. Das. Institution Journal of Mining and Geological Engineering Vol 4.

Das, B.M. 1998. **Principles of Geotechnical Engineering** (4th Edition). PWS Publishing Company.

DgS, 2018. **Preparation of Pillar Stability and Potential Subsidence Contours due to the Borehole Seam Mine Workings below the Newcastle CBD & Wickham - Stage 1 of the Grouting Strategy Project**. DgS Report No WSP-001/1 (31/07/18).

Diedrichs M.S. & Kaiser P.K., 1999. **Stability of Large Excavations in Laminated Hard Rock Masses: The Voussoir Analogue Revisited**. International Journal of Rock Mechanics and Mining Sciences 36.

Donovan J.G. & Karfakis M.G., 2004. **Design of Backfilled Thin-Seam Coal Pillars Using Earth Pressure Theory**. Geotechnical and Geological Engineering 22. Kulwer Academic Publishers, Netherlands.

Hawkins G. & Ramage R., 2004. **A Synthesis of Results of Sub-Surface Investigation of Abandoned Mine Workings with Reference to the Borehole Seam Workings under Newcastle**. 6th Triennial MSTS Conference on Buildings and Structures, Maitland (November).

Karmis M., Agioutantis Z. & Jarosz A., 1990. **Recent Developments for the Application of the Influence Function Method for Ground Movement Predictions in the US**. US mining Science and Geotechnology. Vol 10. pp 223-245.

Mackenzie S. & Clark I. H., 2005. **Three-Dimensional Geotechnical Modelling of Abandoned Bord and Pillar Workings**. Australian Geomechanics Vol 40 No 1 (March).
Holla L. 1987. **Mining Subsidence in NSW 2. Surface Subsidence Prediction in the Newcastle Coalfield**. Department of Mineral Resources.

Peng S.S. & Chiang, H.S. 1984. **Longwall Mining**. Chiang. Wiley.

SA NSW, 2018. Merit Based Guidelines for Building over Abandoned Mines in NSW. Subsidence Advisory (May).

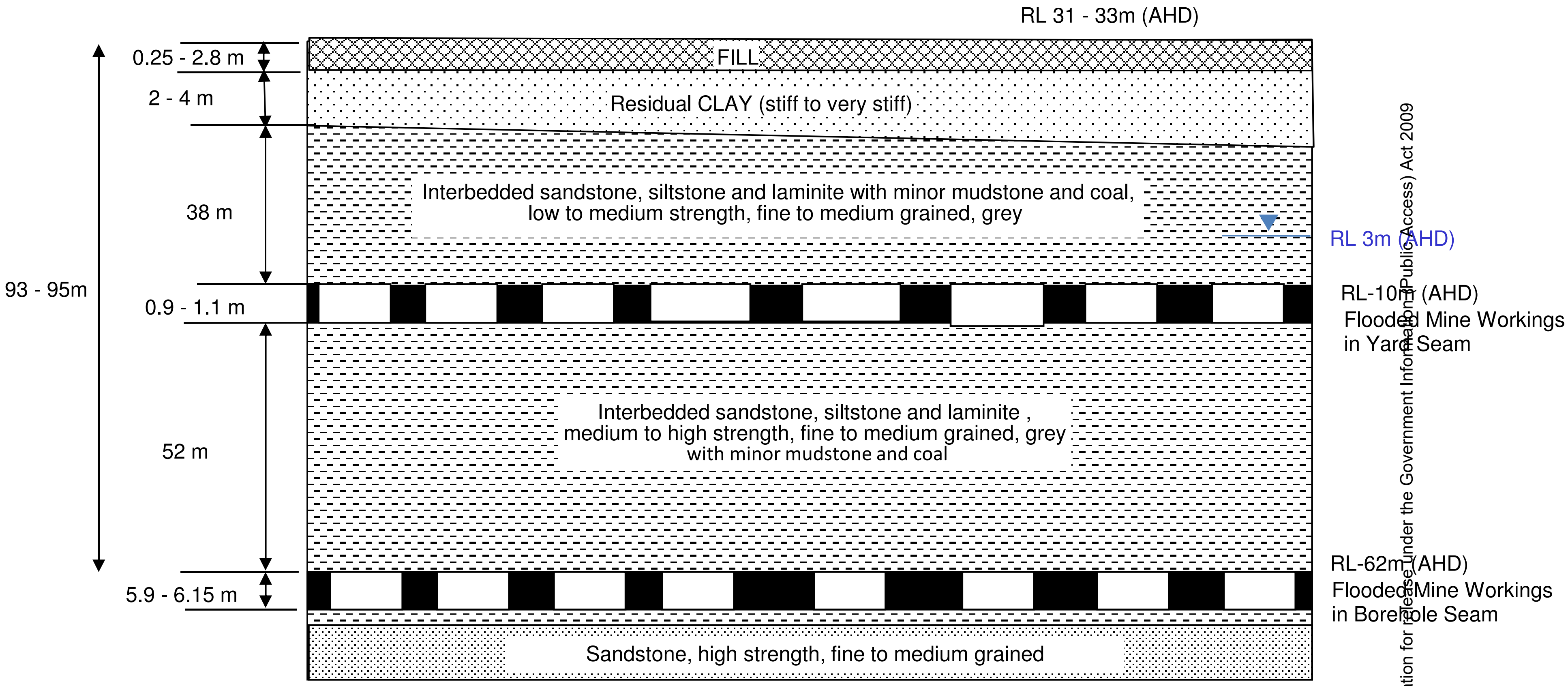
To, E. 1988. **1908 Royal Commission Revisited**. Published proceedings of 1st Triennial Conference on Buildings and Structures Subject to Mine Subsidence, August.

Trove, 1925. **Sydney newspaper article (5/2/1925)**. National Library of Australia. https://trove.nla.gov.au/newspaper/article/117983671?searchTerm=earth%20creep%20newcastle&searchLimits=sortby=dateAsc|||l-australian=y|||dateFrom=1925-01-01|||dateTo=1925-12-31

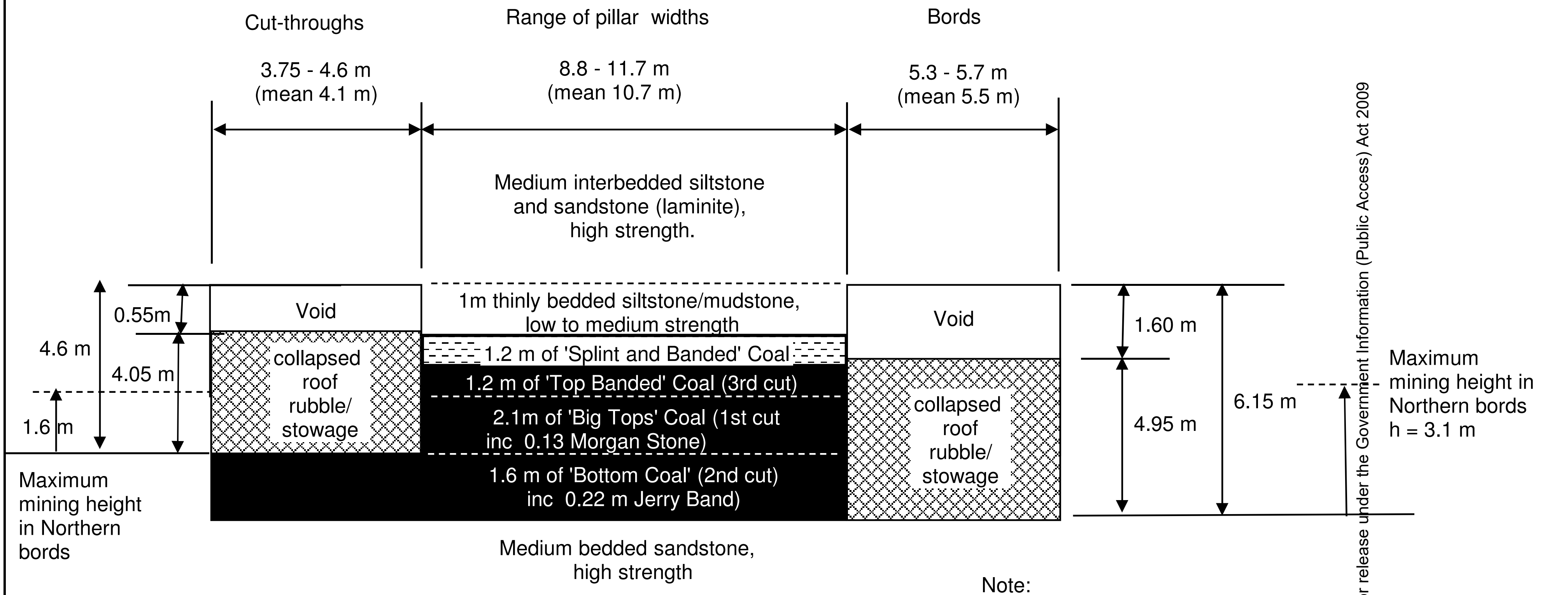
UNSW, 1996. **Coal Pillar Strength from Back-Calculation**. Salamon, M. D. G., Galvin J. M., Hocking G. and Anderson I. University of NSW Research Project Report RP 1/96.

UNSW, 1998. **Establishing the Strength of Irregular and Rectangular Pillars**. J.M. Galvin, B.K. Hebblewhite, M.D.G. Salamon, B.B. Lin. ACARP Report No. C5024, UNSWUMRC Research Report RR3/98. (December).

Zipf, R.K. Jnr 1999. **Using a Post-Failure Stability Criterion in Pillar Design**. Proceedings of Second International Workshop on Coal Pillar Mechanics, NIOSH IC 9448 (June).

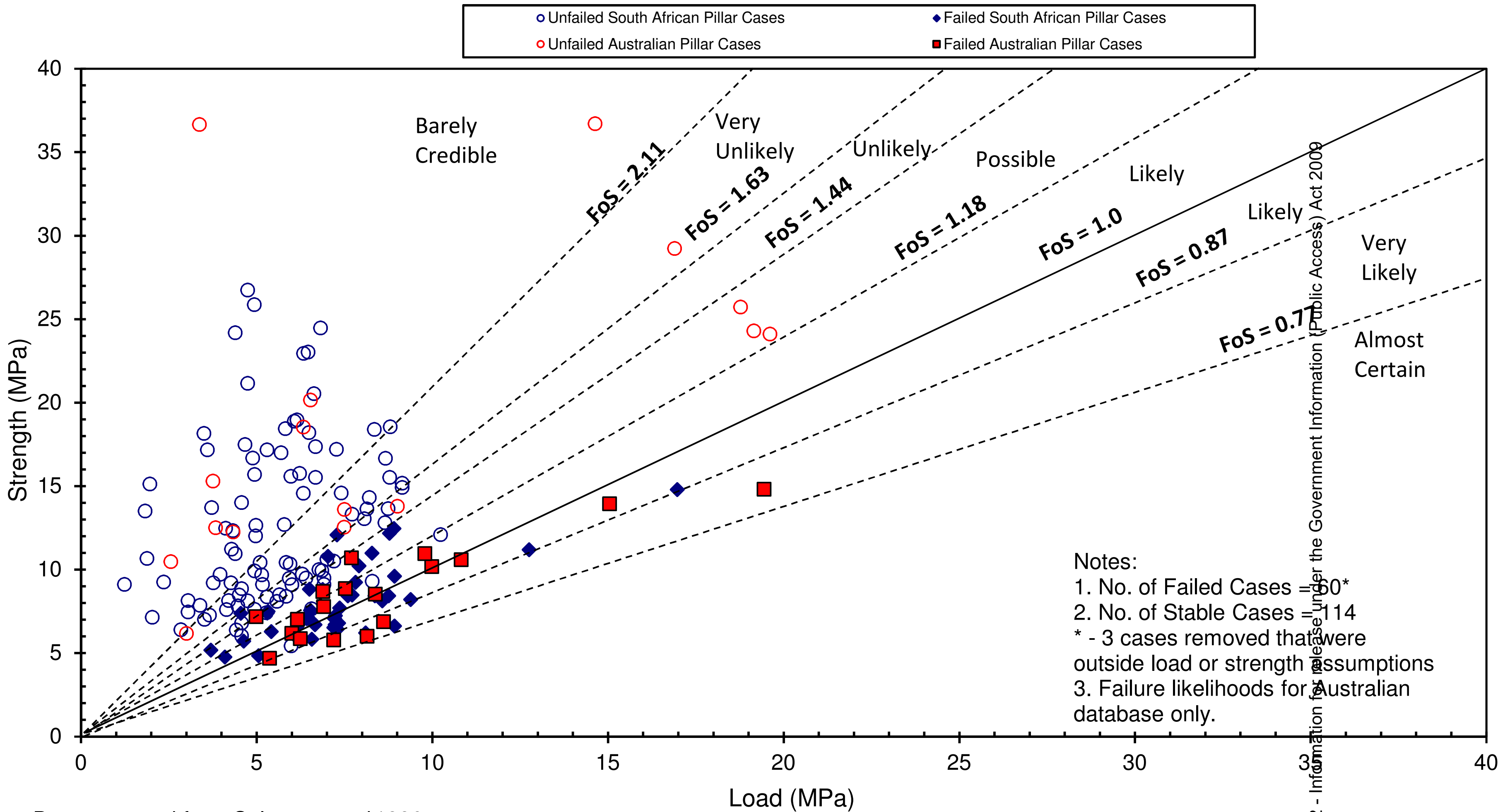


DgS	Engineer:	S. Ditton	Client:	Coffey COF-009/1		
	Drawn:	S. Ditton				
	Date:	28.02.19	Title:	Overburden Conditions Assumed Beneath 130 Parry St, Newcastle West		
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS	Figure No:	3a



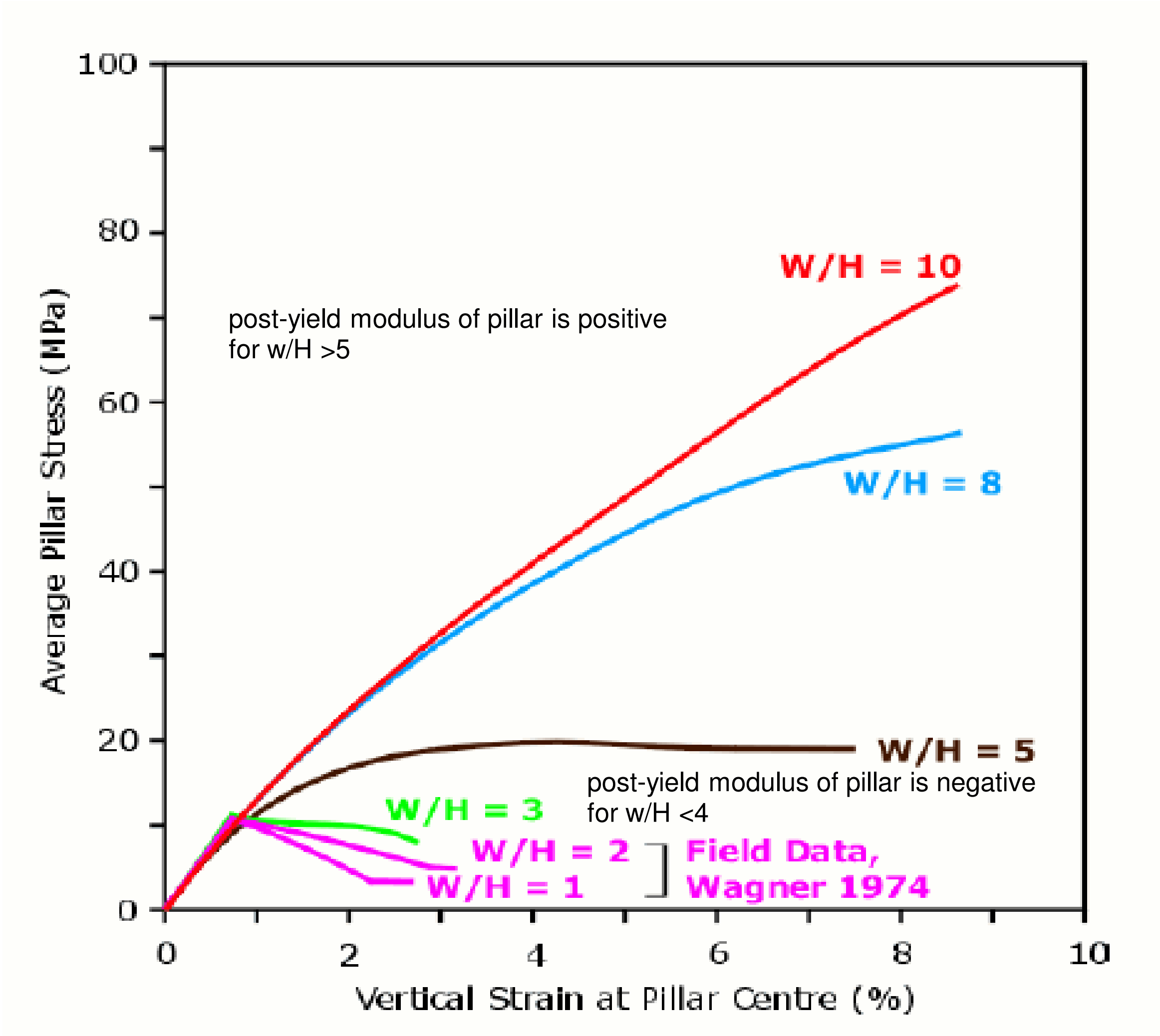
Note:
1. Workings are flooded and under maximum of 61.5 m head of pressure (WT @ 3.5 m below surface).
2. Pillar lengths range from 24 to 57 m (mean 46.2m).
3. Two small pillars 5 x 20 m exist between the larger pillars.

DgS	Engineer:	S.Ditton	Client:	Coffey COF-009/1
	Drawn:	S.Ditton		
	Date:	18.02.19	Title:	Interpreted Conditions in Workings in the Borehole Seam below Mosbri Crescent, The Hill
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS
			Figure No:	3b



Data extracted from Salamon, *et al* 1996.

DgS	Engineer:	S.Ditton	Client:	Coffey COF-009/1
	Drawn:	S.Ditton		
	Date:	28.02.19	Title:	Database of Failed and Unfailed Bord and Pillar Panels from Australian and South African Coal Mines: Pillar Strength v. FTA Load
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS
			Figure No:	4a



Ref: ACARP, 2005

DgS	Engineer:	S.Ditton	Client:	Coffey	
	Drawn:	S.Ditton		COF-009/1	
	Date:	28.02.19	Title:	In-situ Pillar Stress v. Strain Behaviour for a Range of Pillar Width/Height Ratios	
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS	Figure No: 4b

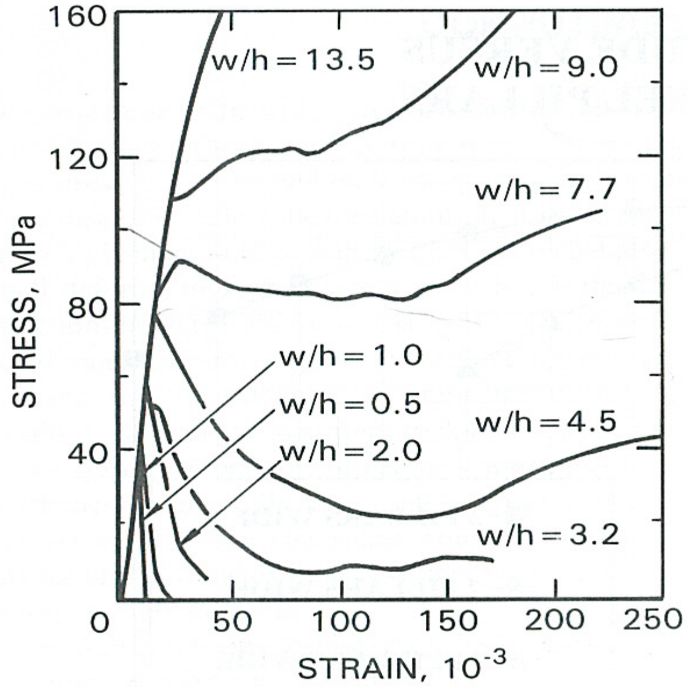


Figure 4.—Complete stress-strain curves for Indian coal specimens showing increasing residual strength and postfailure modulus with increasing w/h (after Das [1986]).

Ref: Das, **1996**

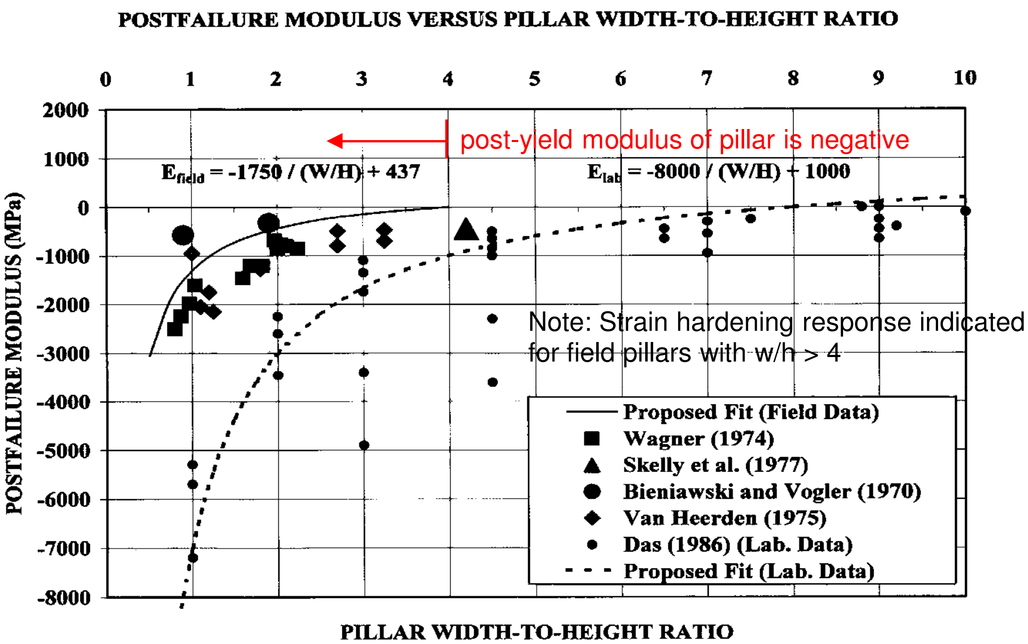
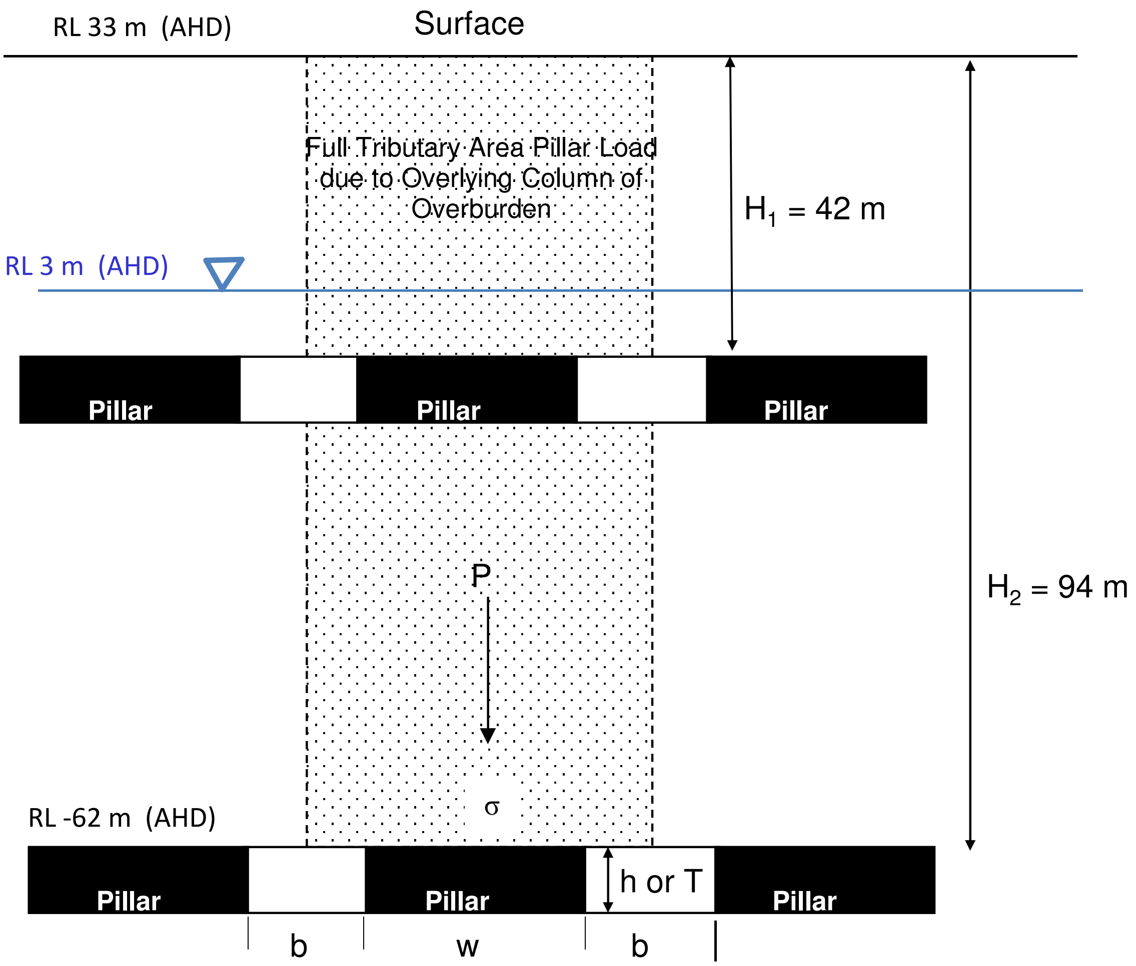


Figure 5.—Summary of postfailure modulus data for full-scale coal pillars and laboratory specimens. Also shown is proposed approximate equation for E_p.

Ref: **Zipf, 1999**

DgS	Engineer:	S.Ditton	Client:	Coffey		
	Drawn:	S.Ditton		COF-009/1		
	Date:	28.02.19	Title:	Post-yielded Modulus & Laboratory Stress - Strain Curves for a range of pillar w/h Ratios		
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS	Figure No:	4c

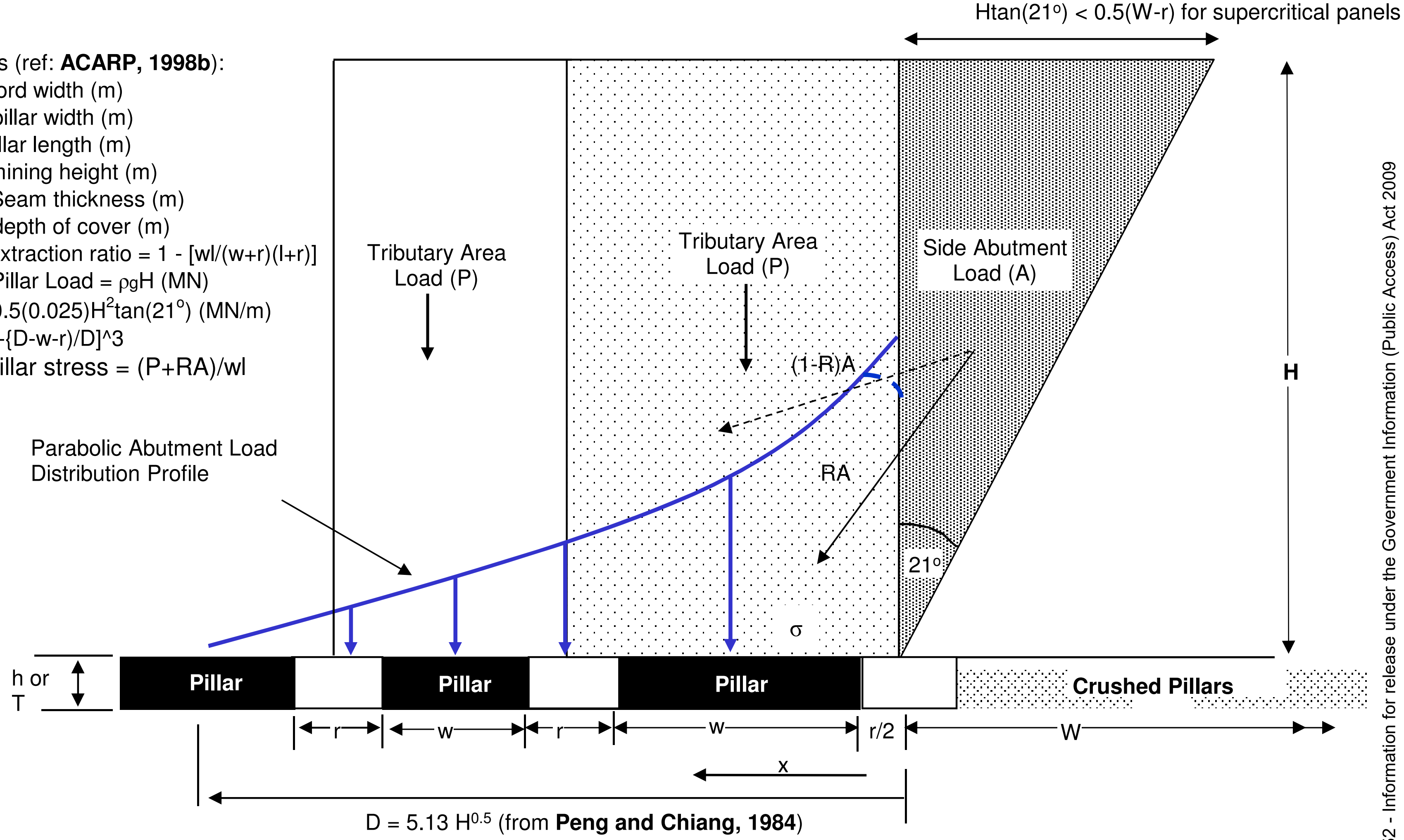


Notes:

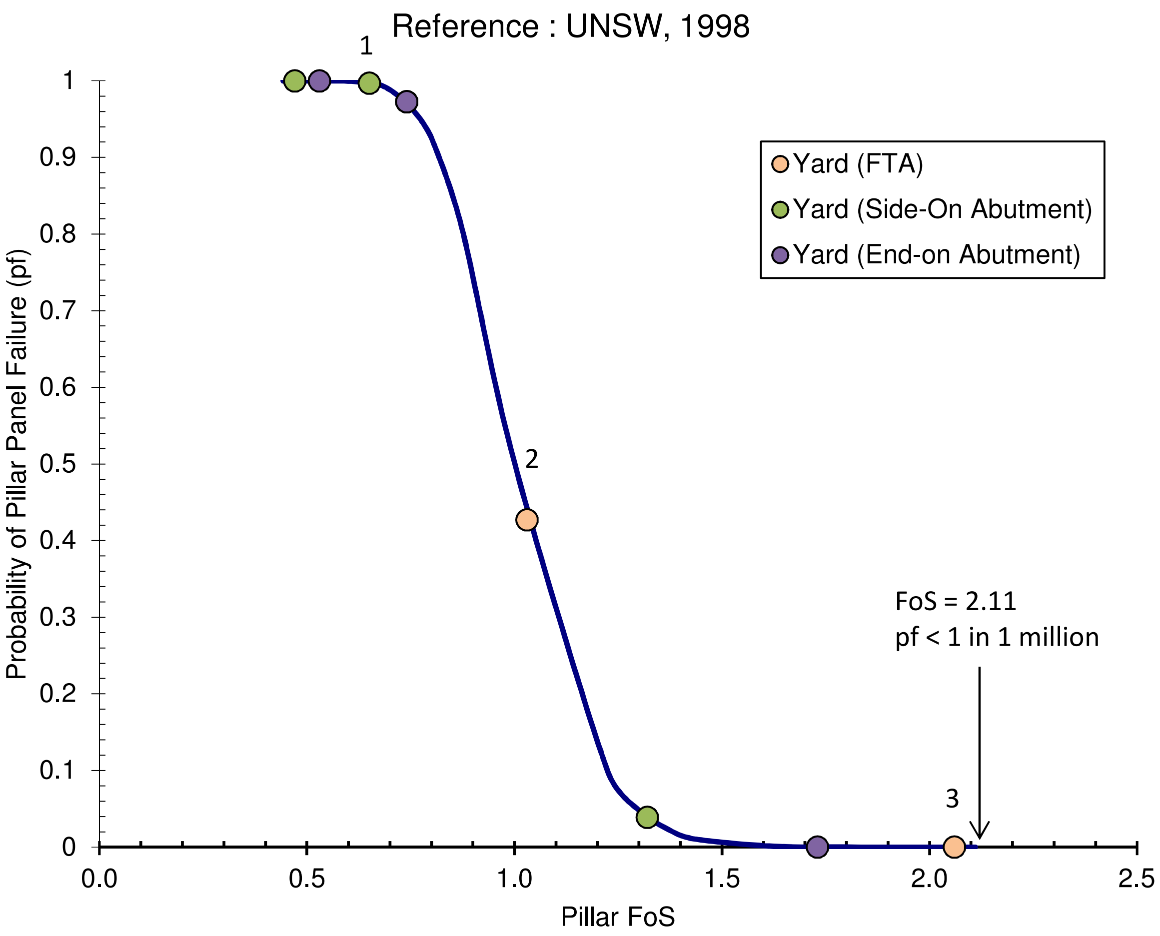
- w = pillar width (m)
- l = pillar length
- b = bord width (m)
- r = cut-through width (m)
- h = mining height (m)
- T = Seam thickness (m)
- H = depth of cover (m)
- ρ = overburden density (t/m3)
- g = gravity acceleration = 10 m/s^2
- P = Full Tributary Area (FTA) Pillar Load = $\rho gH(w+b)(l+r)$ (MN)
- σ = FTA pillar stress = $P/(wl)$ (MPa)
- e = extraction ratio = $1 - [wl/(w+b)(l+r)]$

DgS	Engineer:	S.Ditton	Client:	Coffey	
	Drawn:	S.Ditton		COF-009/1	
	Date:	28.02.19	Title:	Conceptual Model of Full Tributary Area Loading	
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS	Figure No: 4d

Notes (ref: **ACARP, 1998b**):
r = bord width (m)
w = pillar width (m)
l = pillar length (m)
h = mining height (m)
T = Seam thickness (m)
H = depth of cover (m)
e = extraction ratio = 1 - [wl/(w+r)(l+r)]
P = Pillar Load = $\rho g H$ (MN)
A = $0.5(0.025)H^2\tan(21^o)$ (MN/m)
R =1-{D-w-r)/D]^3
σ= pillar stress = (P+RA)/wl



DgS	Engineer: S.Ditton	Client:	Coffey COF-009/1	
	Drawn: S.Ditton			
	Date: 28.02.19	Title:	Conceptual Model of Abutment Load Acting on Site Pillars Due to Pillar Run Scenario	
	Ditton Geotechnical Services Pty Ltd	Scale:	NTS	Figure No: 4e



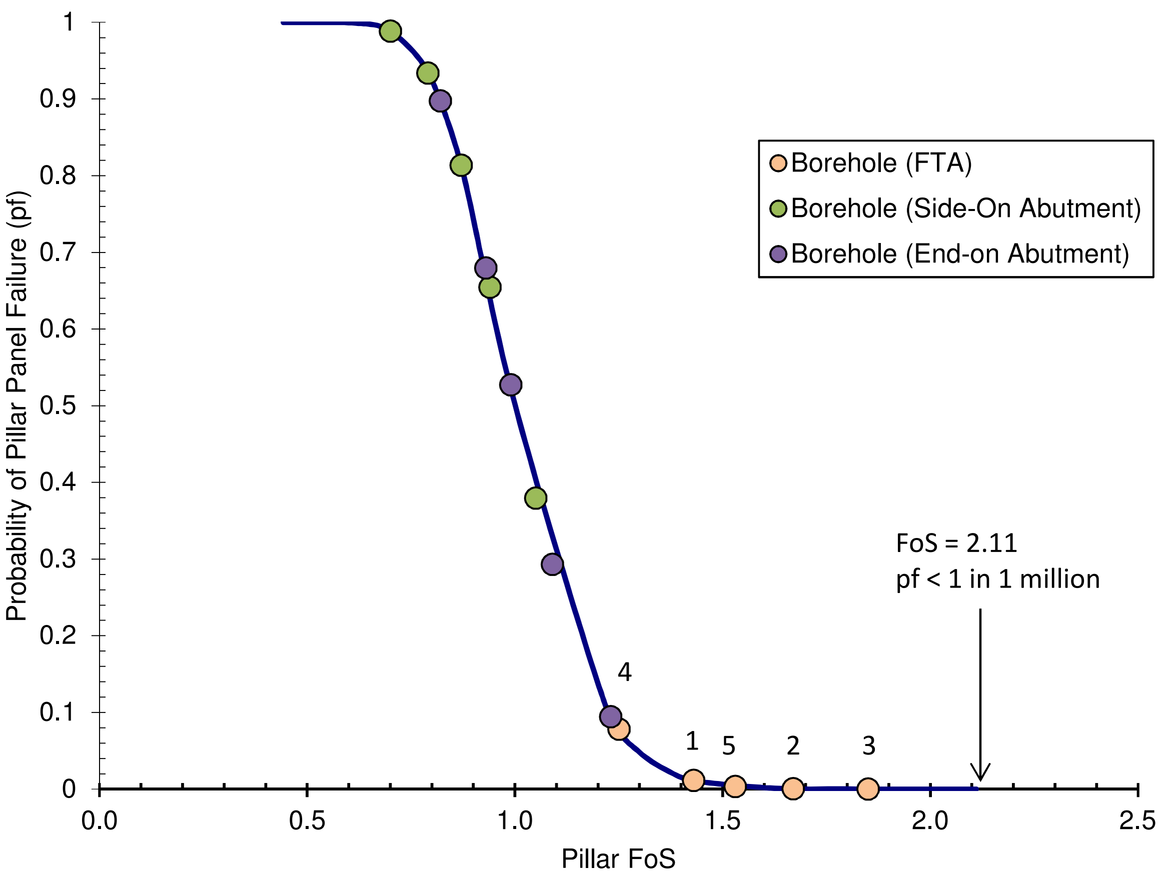
pf	1-pf	lnFoS	FoS
0.9	**0.1**	**-0.19**	**0.83**
0.8	0.2	-0.13	0.87
0.5	0.5	0.00	1.00
0.1	0.9	0.20	1.22
0.05	0.95	0.26	1.30
0.02	0.98	0.32	1.38
0.01	0.99	0.37	1.44
0.001	0.999	0.49	1.63
0.0001	0.9999	0.58	1.79
0.00001	0.99999	0.67	1.95
0.000001	**0.999999**	**0.75**	**2.11**

Estimated log-normal pdf parameters:

Parameter	Value
μ	1.014
sigma	0.157

DgS	Engineer:	S.Ditton	Client:	Coffey	
	Drawn:	S.Ditton		COF-009/1	
	Date:	28.02.19	Title:	Probability of Australian Bord and Pillar Panel Failure v. FoS under Design Loading Conditions in Yard Seam Workings	
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS	Figure No: 5a

Reference : UNSW, 1998

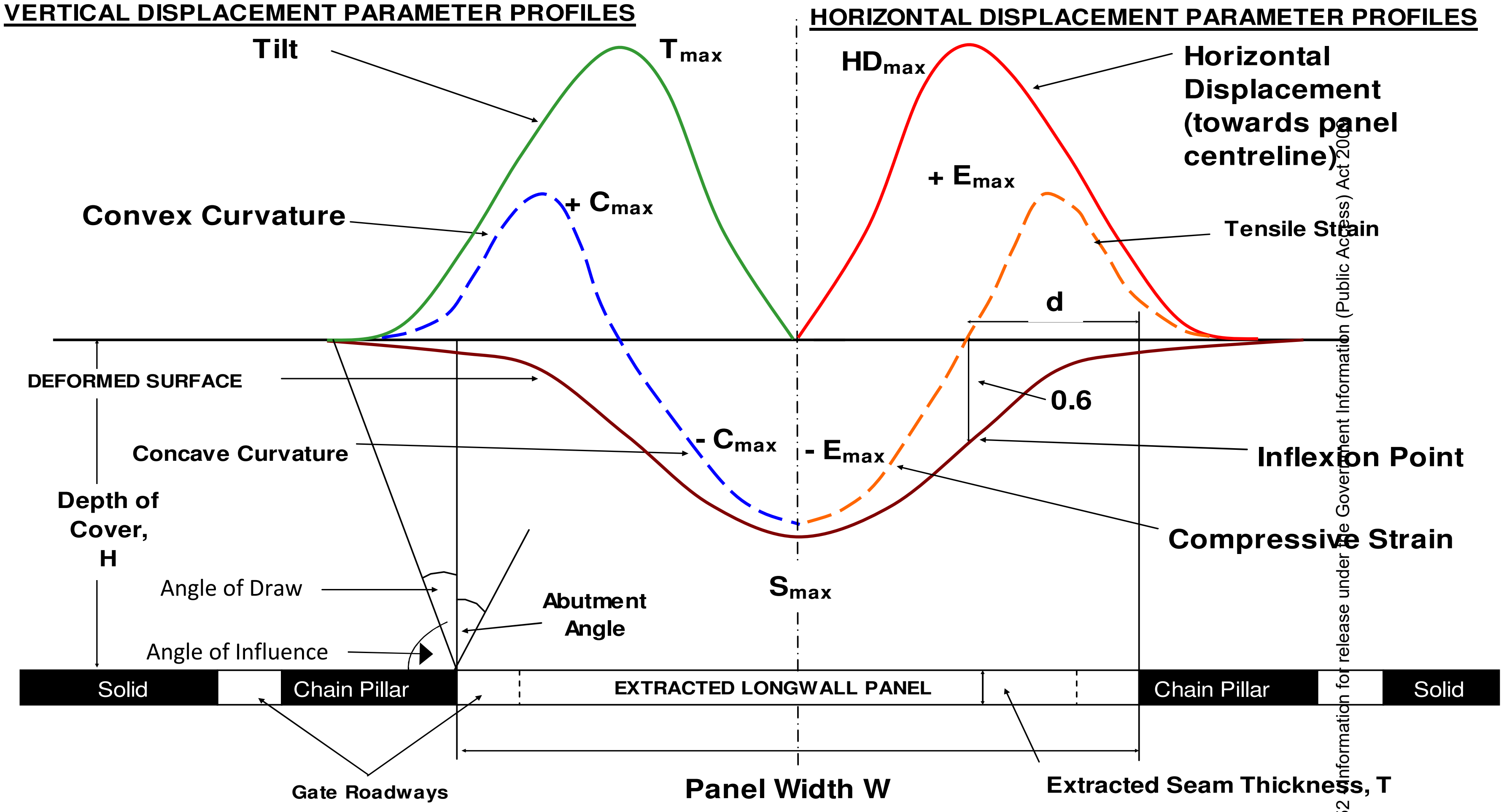


pf	1-pf	lnFoS	FoS
0.9	**0.1**	**-0.19**	**0.83**
0.8	0.2	-0.13	0.87
0.5	0.5	0.00	1.00
0.1	0.9	0.20	1.22
0.05	0.95	0.26	1.30
0.02	0.98	0.32	1.38
0.01	0.99	0.37	1.44
0.001	0.999	0.49	1.63
0.0001	0.9999	0.58	1.79
0.00001	0.99999	0.67	1.95
0.000001	**0.999999**	**0.75**	**2.11**

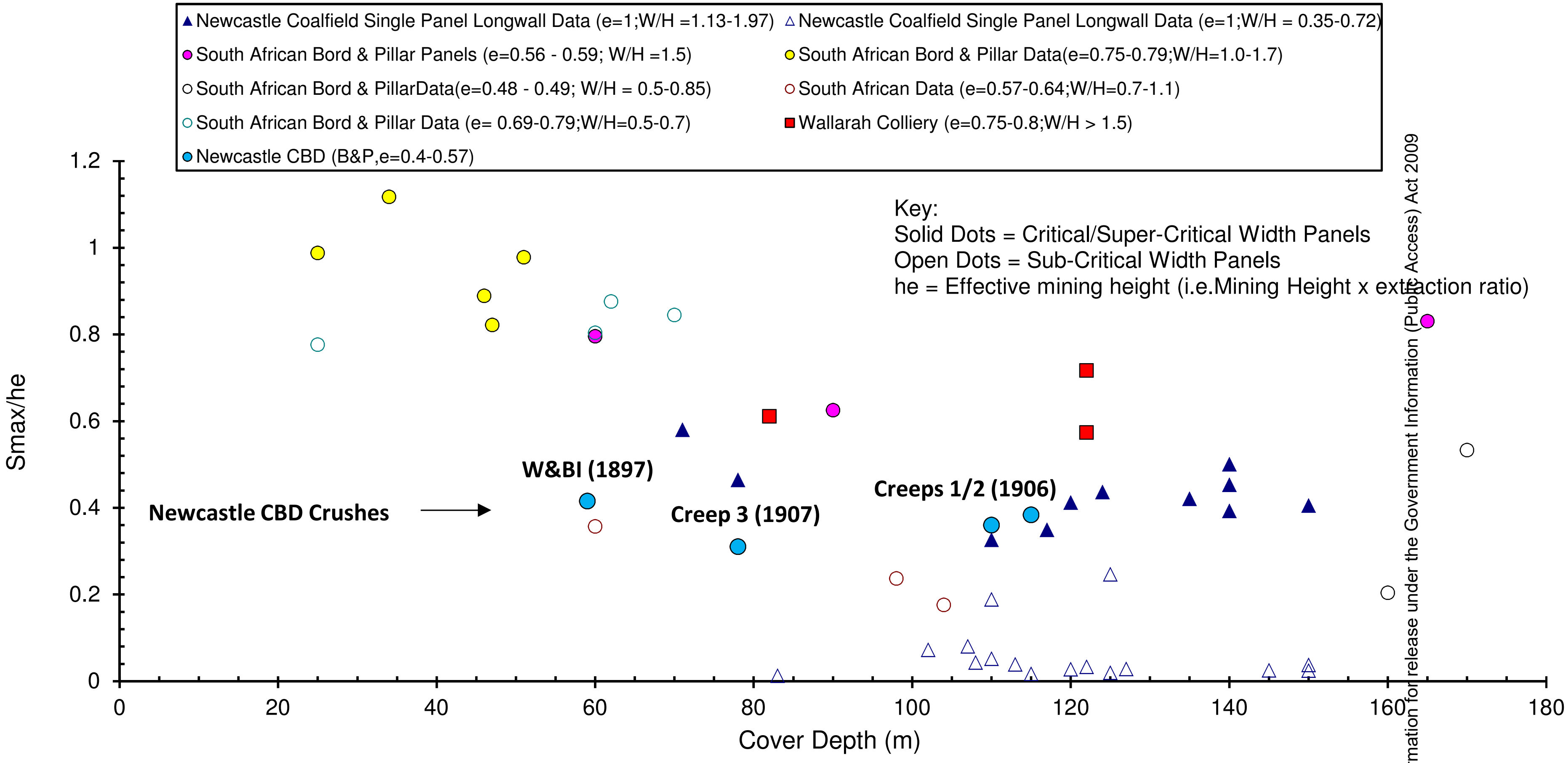
Estimated log-normal pdf parameters:

Parameter	Value
μ	1.014
sigma	0.157

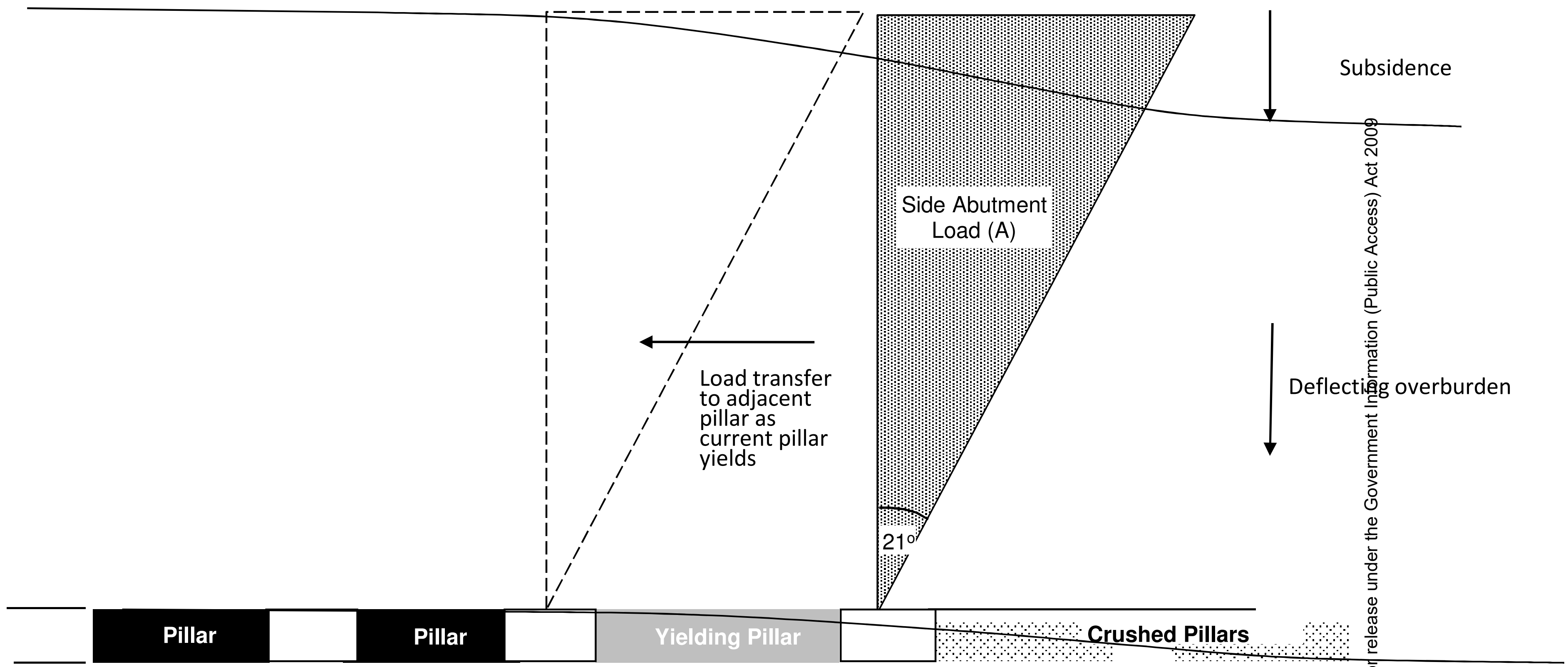
DgS	Engineer: S.Ditton	Client:	Coffey	
	Drawn: S.Ditton		COF-009/1	
	Date: 28.02.19	Title:	Probability of Australian Bord and Pillar Panel Failure v. FoS under Design Loading Conditions in Borehole Seam Workings	
	Ditton Geotechnical Services Pty Ltd	Scale:	NTS	Figure No: 5b



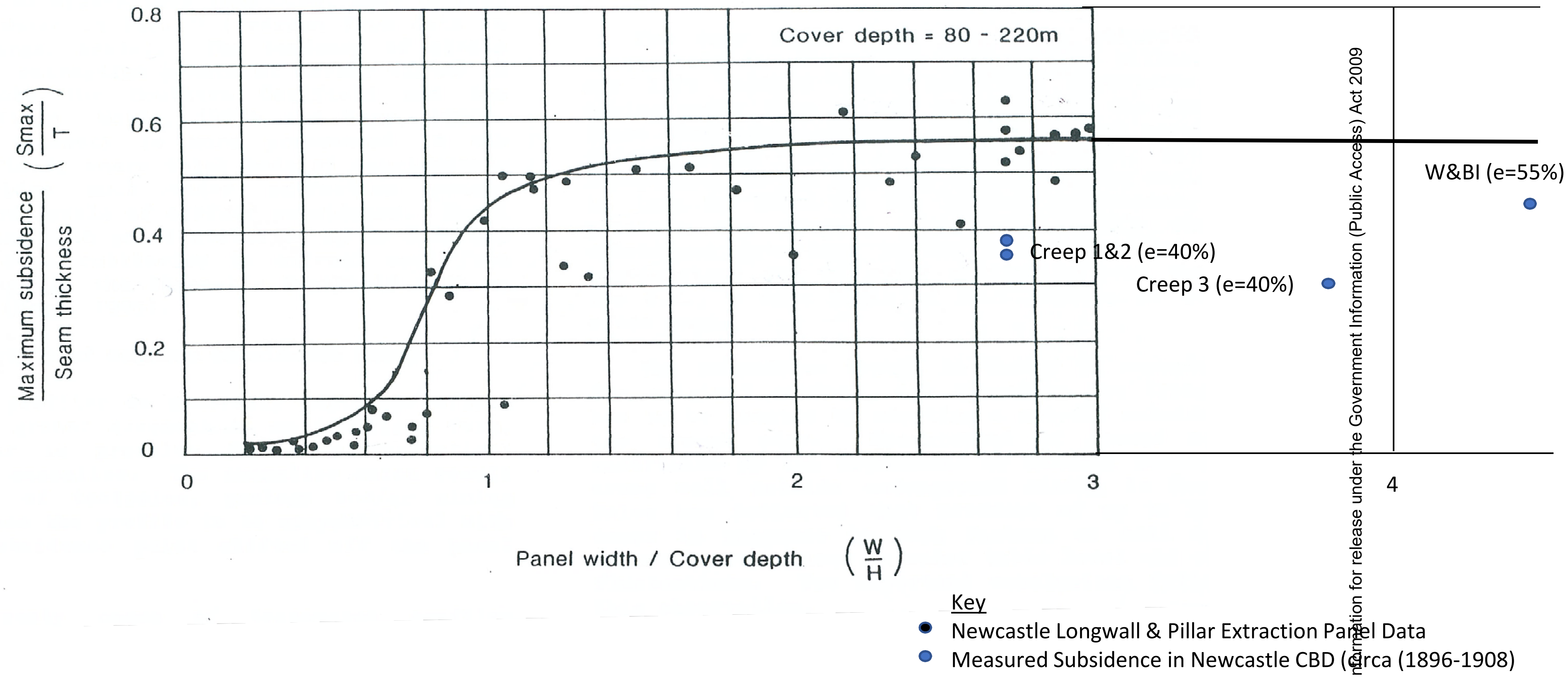
DgS	Engineer:	S.Ditton	Client:	Coffey COF-009/1			
	Drawn:	S.Ditton					
	Date:	18.02.19	Title:	Mine Subsidence Trough Deformation Parameters (adapted from Holla, 1987)			
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS		Figure No:	6a



DgS	Engineer:	S.Ditton	Client:	Coffey COF-009/1		
	Drawn:	S.Ditton				
	Date:	06.11.18	Title:	Database of Smax/he above Failed Bord and Pillar Panels from South Africa & Newcastle Coalfield		
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS	Figure No:	6b

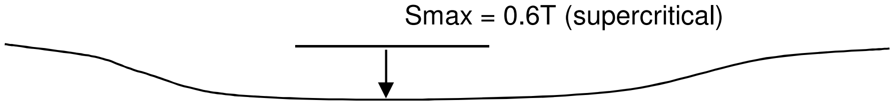


DgS	Engineer:	S.Ditton	Client:	Coffey		
	Drawn:	S.Ditton		COF-009/1		
	Date:	18.02.19	Title:	Conceptual Model of Abutment Load Transfer to Adjacent Pillars Due to Pillar Run Scenario		
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS	Figure No:	6c



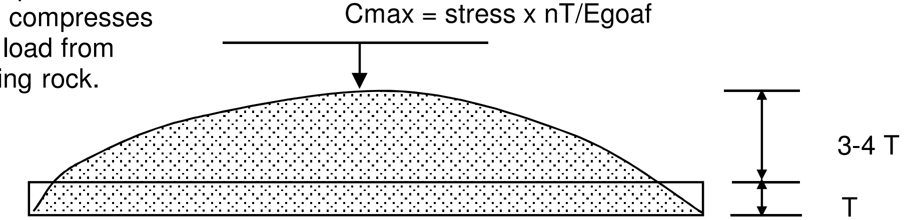
DgS	Engineer:	S.Ditton	Client:	Coffey
	Drawn:	S.Ditton		COF-009/1
	Date:	06.11.18	Title:	Longwall v. Bord and Pillar Crush Subsidence data in Newcastle Coalfield (ref **Holla, 1987**)
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS — Figure No: 6d

3. Seam/rubble convergence is then transferred to surface and is usually defined as a proportion (a) of the mining height (the overburden stiffness may be ignored for super-critical width panels).



a = 0.6 (but probably a function of cover depth or goaf stress)

2. Collapsed roof rubble compresses under load from overlying rock.

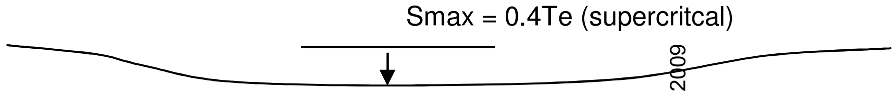


1. Coal seam is extracted and immediate roof falls into void behind face

Longwall Mining Subsidence Mechanics

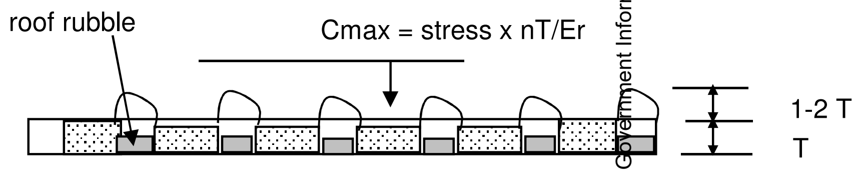
Key:
T = Mining Height.
Egoaf = Young's Modulus of collapsed roof material.
Cmax = Seam Roof convergence.
n = rubble height/mining height factor (ranges from 4 to 6).
Smax = Maximum surface subsidence.
a = subsidence factor, which relates maximum subsidence to mining thickness.

3. Seam/rubble convergence is then transferred to surface and is usually defined as a proportion (b) of the effective mining height (T x extraction ratio) The overburden stiffness may be ignored for super-critical width panels.



a = 0.4 assumed above B& P workings

2. Pillars and immediate mine roof deteriorates after mining and overburden compresses (and sometimes crushes) the remnant coal pillars and collapsed roof rubble along the bords.

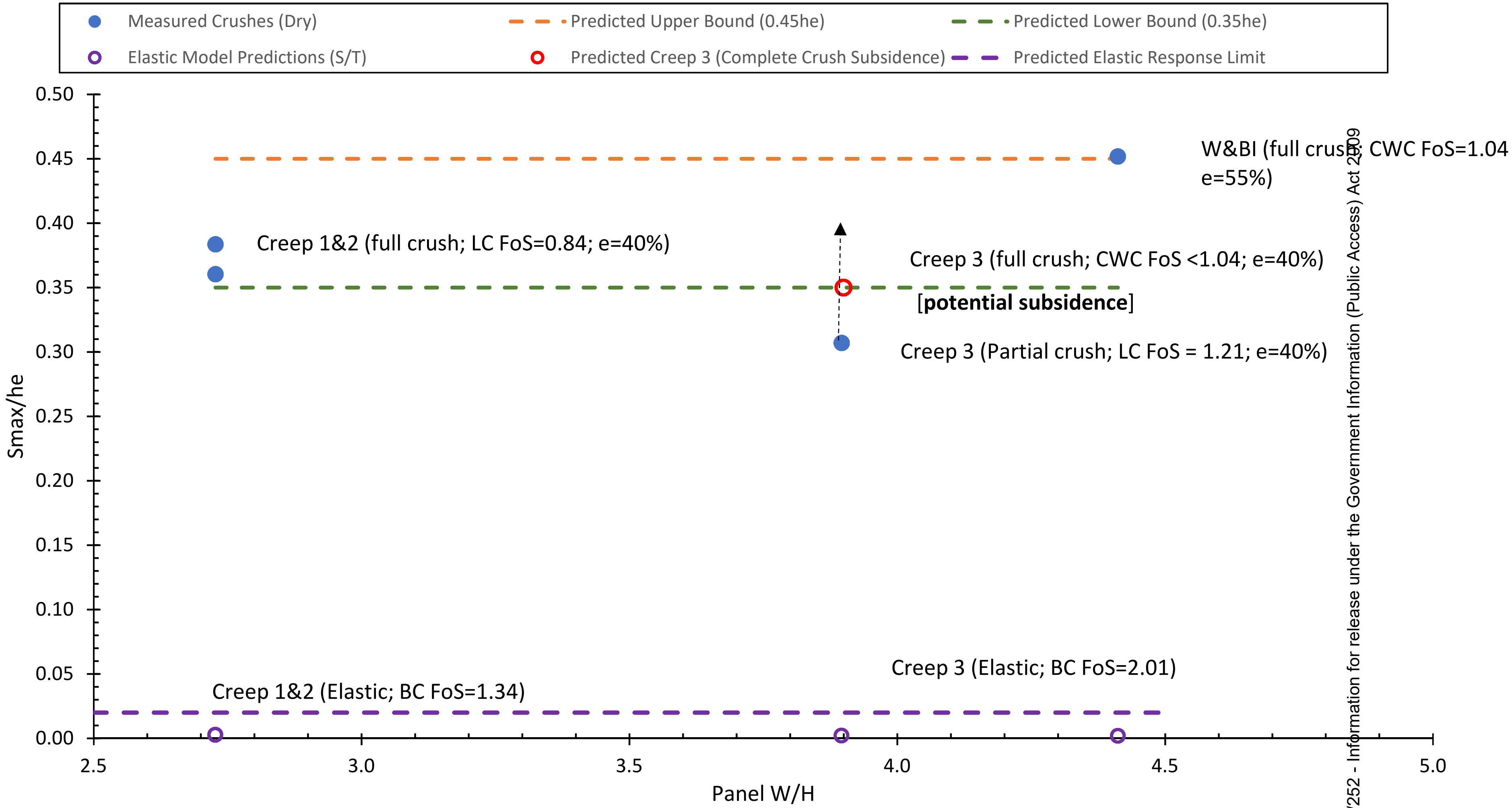


1. Bord and Pillars are formed in the coal seam.

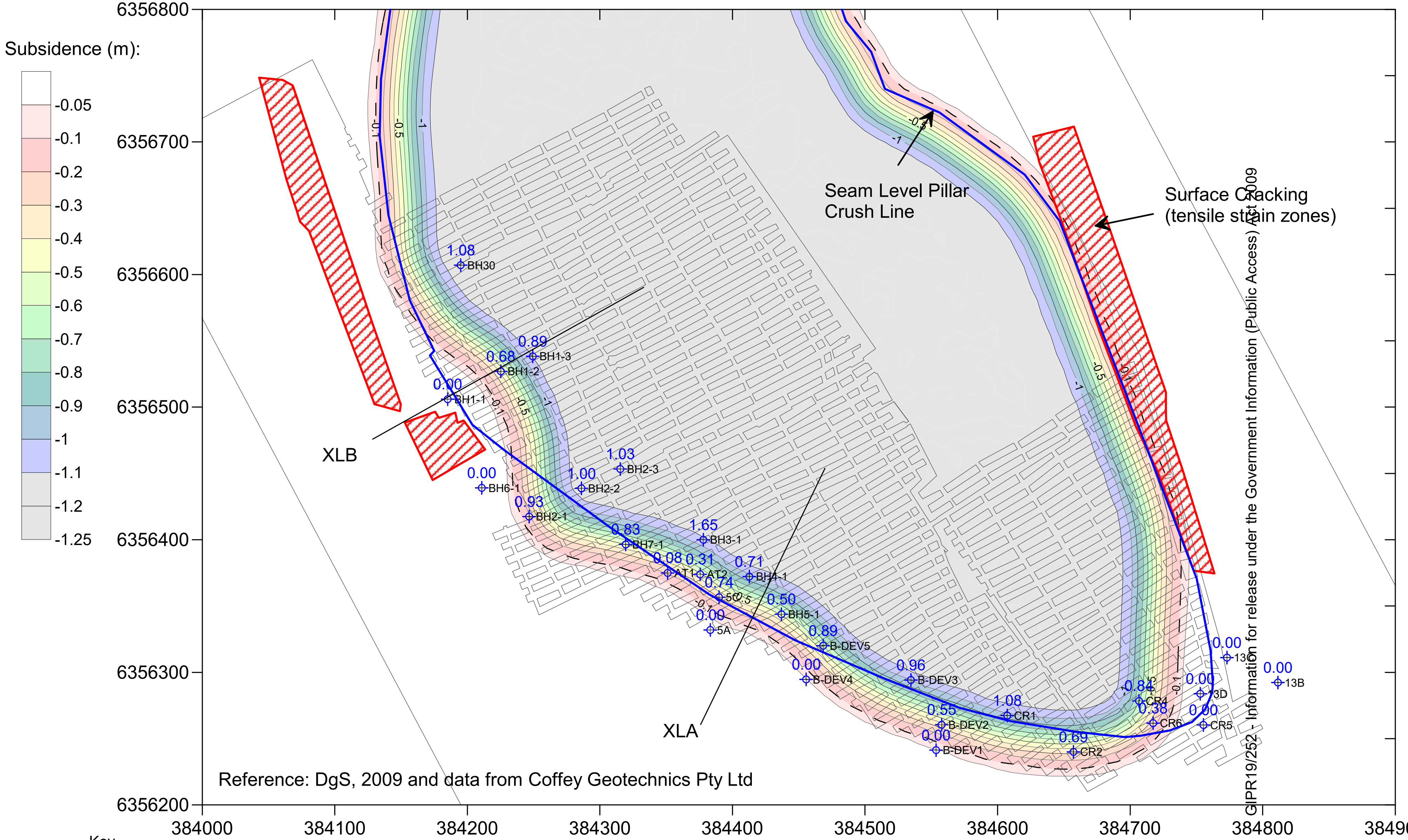
Bord and Pillar Workings Subsidence Mechanics

Key:
T = Mining Height.
Er = Young's Modulus of yielded pillar and collapsed roof material.
Cmax = Seam Roof convergence.
n = rubble height/mining height factor (ranges from 1 to 2)
Smax = Maximum surface subsidence.
a = subsidence factor, which relates maxium subsidence to mining thickness.

DgS	Engineer:	S.Ditton	Client:	Coffey COF-009/1		
	Drawn:	S.Ditton				
	Date:	18.02.19	Title:	Fundamental Differences between Longwall Subsidence Mechanics and Bord & Pillar Panels (Supercritical Width Panels Only)		
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS	Figure No:	6e



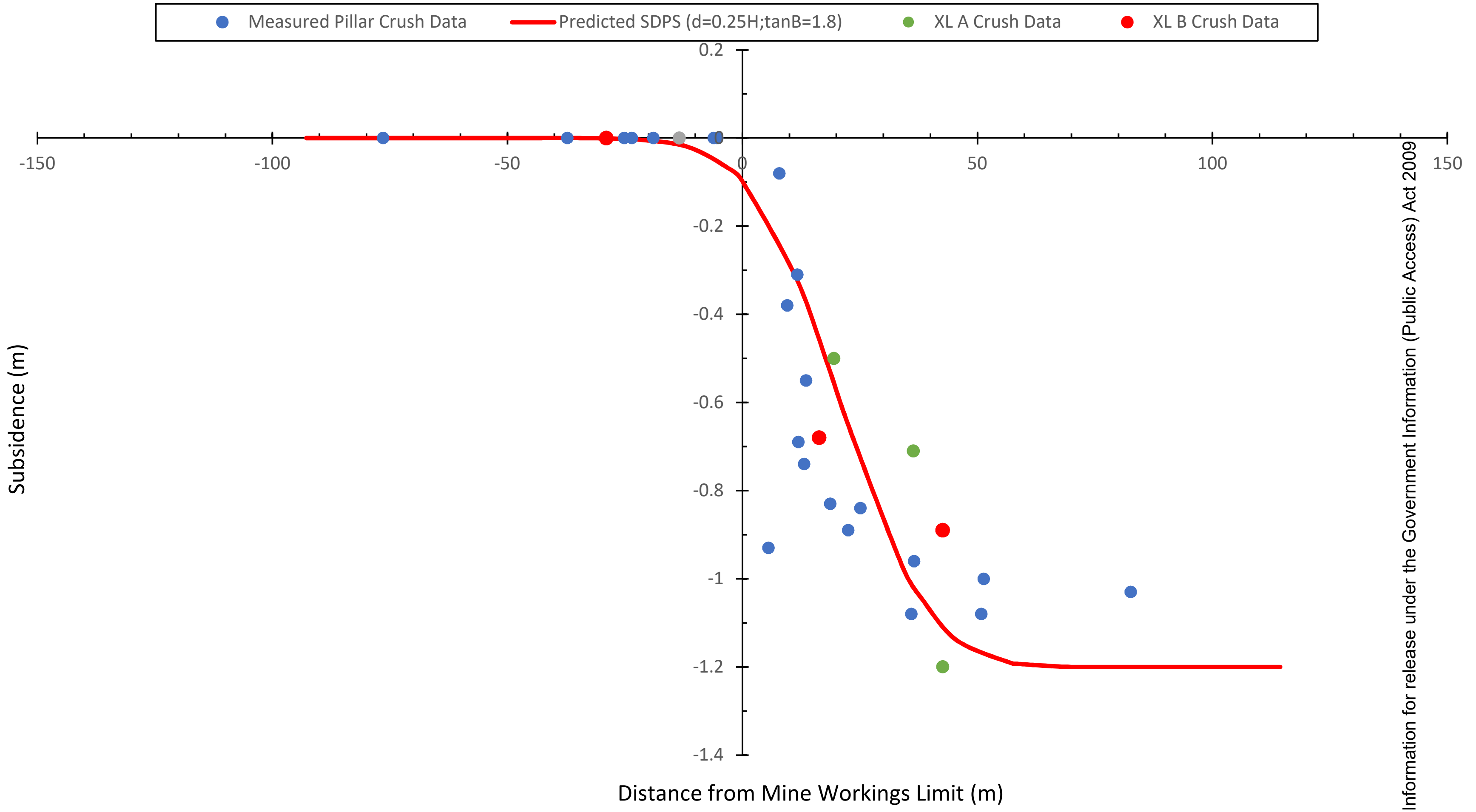
DgS	Engineer:	S.Ditton	Client:	Coffey COF-009/1
	Drawn:	S.Ditton		
	Date:	18.02.19	Title:	Maximum Pillar Crush Subsidence Prediction Model for Dry Bord & Pillar Mine Workings in Newcastle CBD
	Ditton Geotechnical Services Pty Ltd			
			Scale:	NTS
			Figure No:	6f



Key

- Historical Crush Line (Atkins, 1908)
- 0.60 BH# Seam Crush Thickness (m)
- Assessed Crush Line Limit @ 100 mm subsidence

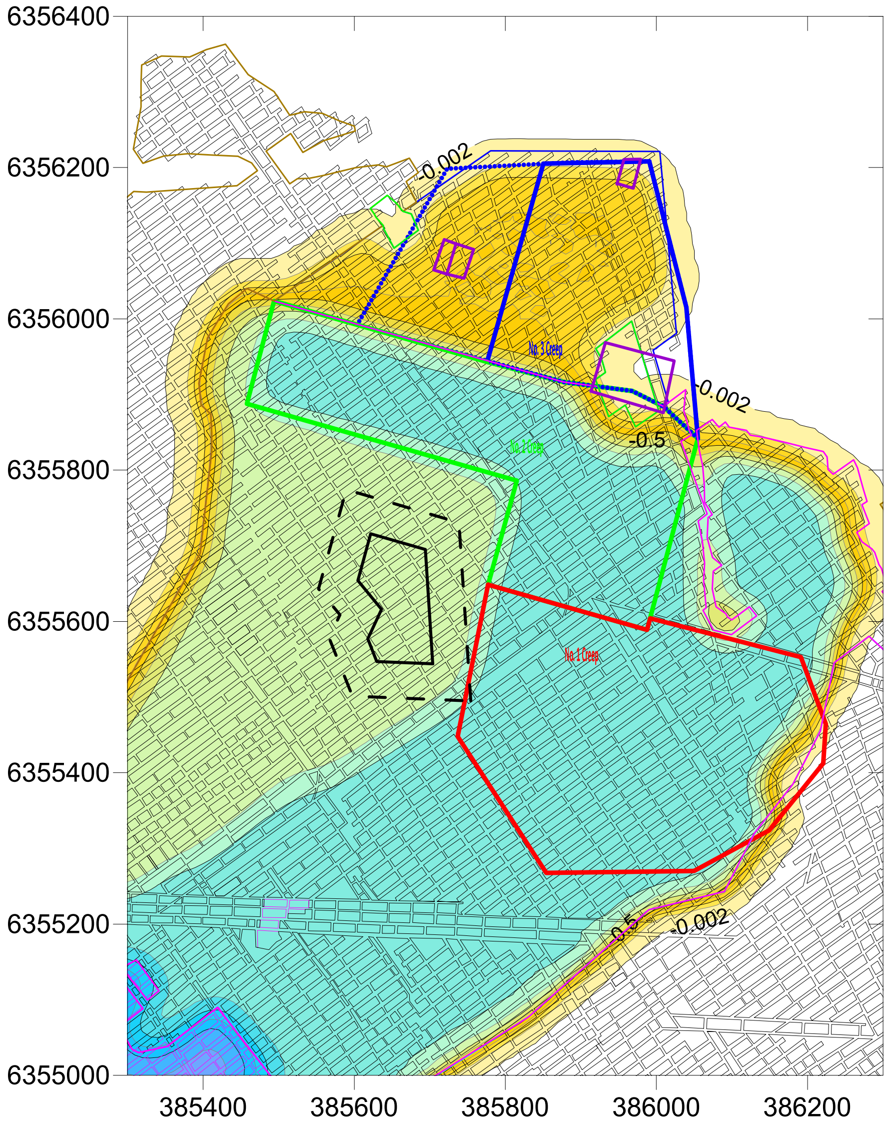
DgS Ditton Geotechnical Services Pty Ltd	Engineer:	S.Ditton	Client:	Coffey COF-009/1		
	Drawn:	S.Ditton				
	Date:	18.02.19	Title:	Predicted SPDS Subsidence Contours v. Measured Borehole Seam Crush Line in W&BI Coal Company Mine Workings, Honeysuckle		
			Scale:	1:4,000	Figure No:	6g



DgS	Engineer: S.Ditton	Client:	Coffey COF-009/1	
	Drawn: S.Ditton			
	Date: 18.02.19	Title:	Subsidence Model (SDPS) Calibration to Honeysuckle Crush Data from Coffey Geotechnics, 2009	
	Ditton Geotechnical Services Pty Ltd	Scale:	NTS	Figure No: 6h

Subsidence (m):

-0.002
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1
-1.1
-1.2
-1.3
-1.4
-1.5



Note: Yard Seam subsidence included

Key

Site Boundary

Angle of Draw (26.5°)

Interpreted Panel Creep Boundaries

Buildings damaged by Creeps 2-3

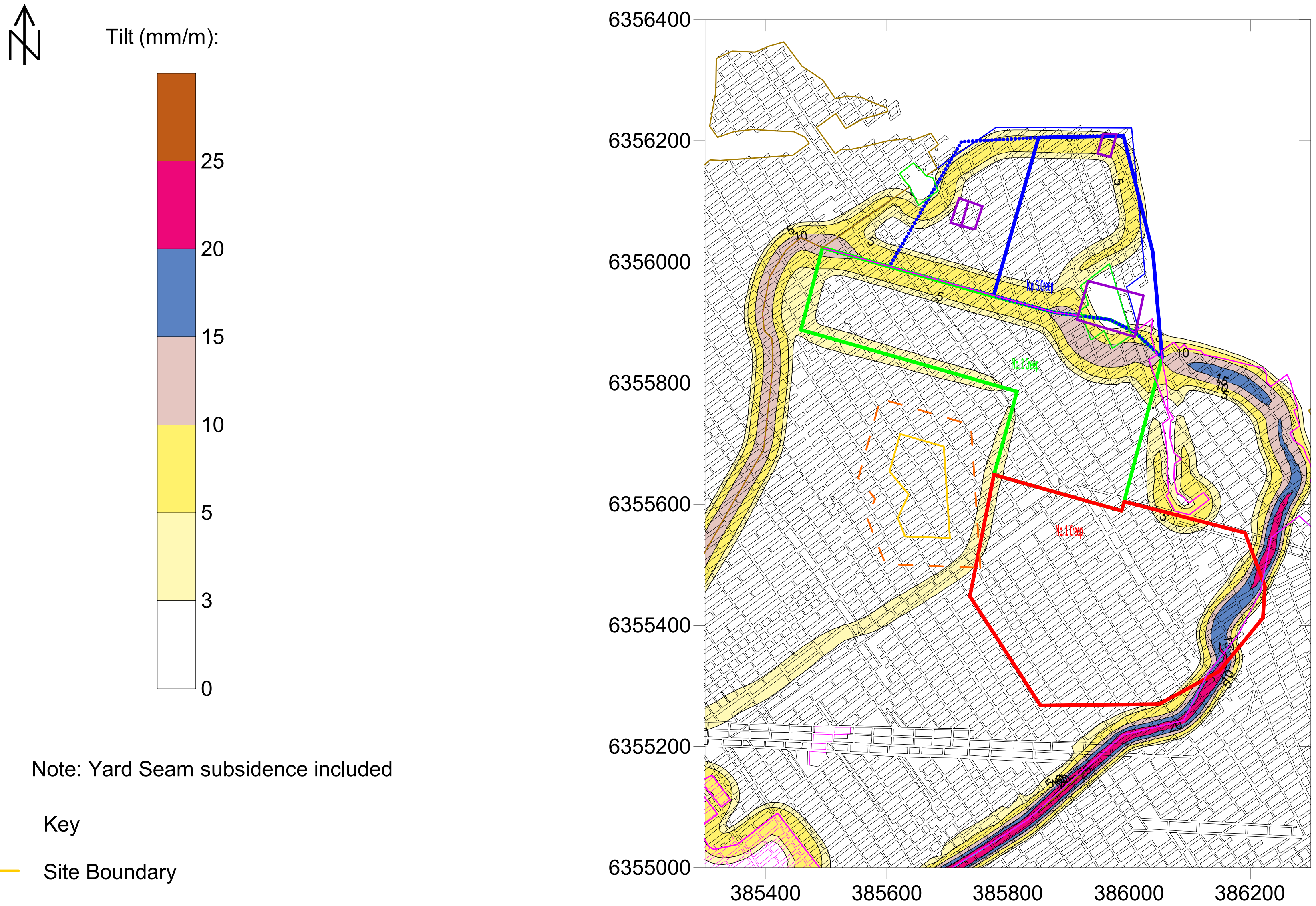
AAC Mine Workings Pillars in Borehole Seam

DgS

Ditton Geotechnical Services Pty Ltd

Engineer:	S.Ditton
Drawn:	S.Ditton
Date:	08.03.19

Client:	Coffey COF-009/1
Title:	Predicted Final Subsidence Contours (Credible Worst Case) to Minimum Pillar FoS of 2.1 under Dry Conditions
Scale:	1:10,000 (A4)
Figure No:	7a



Note: Yard Seam subsidence included

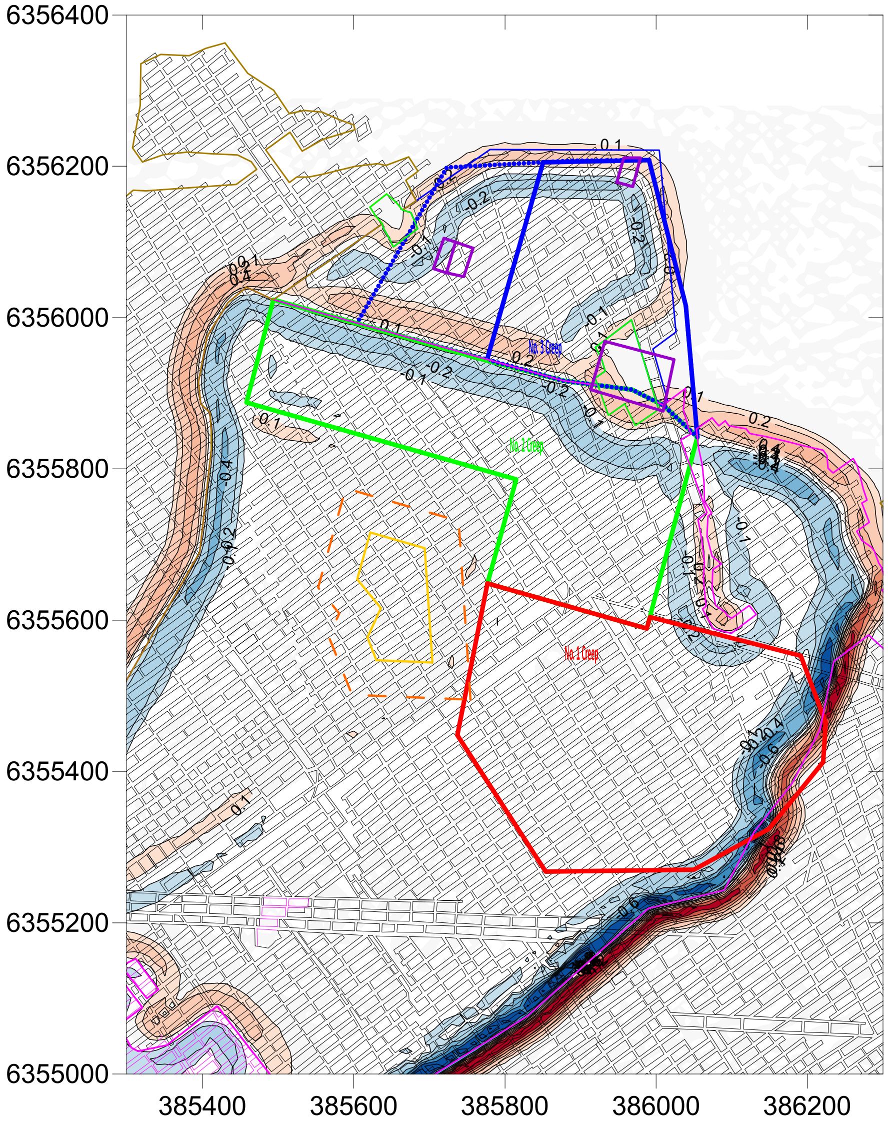
Key

- Site Boundary
- Angle of Draw (26.5°)
- Interpreted Panel Creep Boundaries
- Buildings damaged by Creeps 2-3
- AAC Mine Workings Pillars in Borehole Seam

DgS	Engineer:	S.Ditton	Client:	Coffey COF-009/1		
	Drawn:	S.Ditton				
	Date:	20.02.19	Title:	Predicted Final Tilt Contours (Credible Worst Case) to Minimum Pillar FoS of 2.1 under Dry Conditions		
	Ditton Geotechnical Services Pty Ltd		Scale:	1:10,000 (A4)	Figure No:	7b

Curvature (km-1):

1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0.1
0
-0.1
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
-1.6



Note: Yard Seam subsidence included

Key

Site Boundary

Angle of Draw (26.5°)

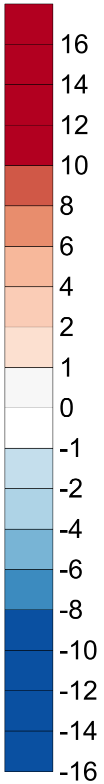
Interpreted Panel Creep Boundaries

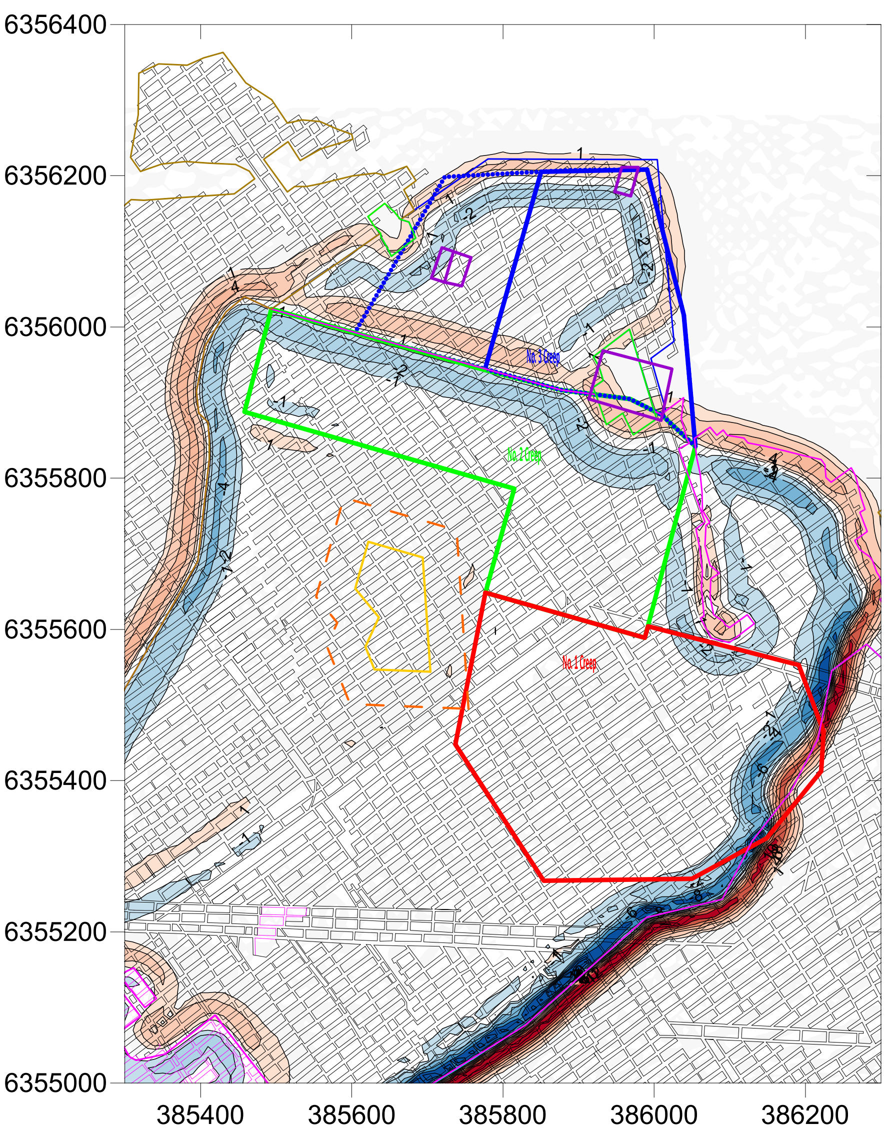
Buildings damaged by Creeps 2-3

AAC Mine Workings Pillars in Borehole Seam

DgS	Engineer:	S.Ditton	Client:	Coffey COF-009/1		
	Drawn:	S.Ditton				
	Date:	20.02.19	Title:	Predicted Final Curvature Contours (Credible Worst Case) to Minimum Pillar FoS of 2.1 under Dry Conditions		
Ditton Geotechnical Services Pty Ltd			Scale:	1:10,000 (A4)	Figure No:	7c

Horizontal Strain (mm/m):





Note: Yard Seam subsidence included

Key

Site Boundary

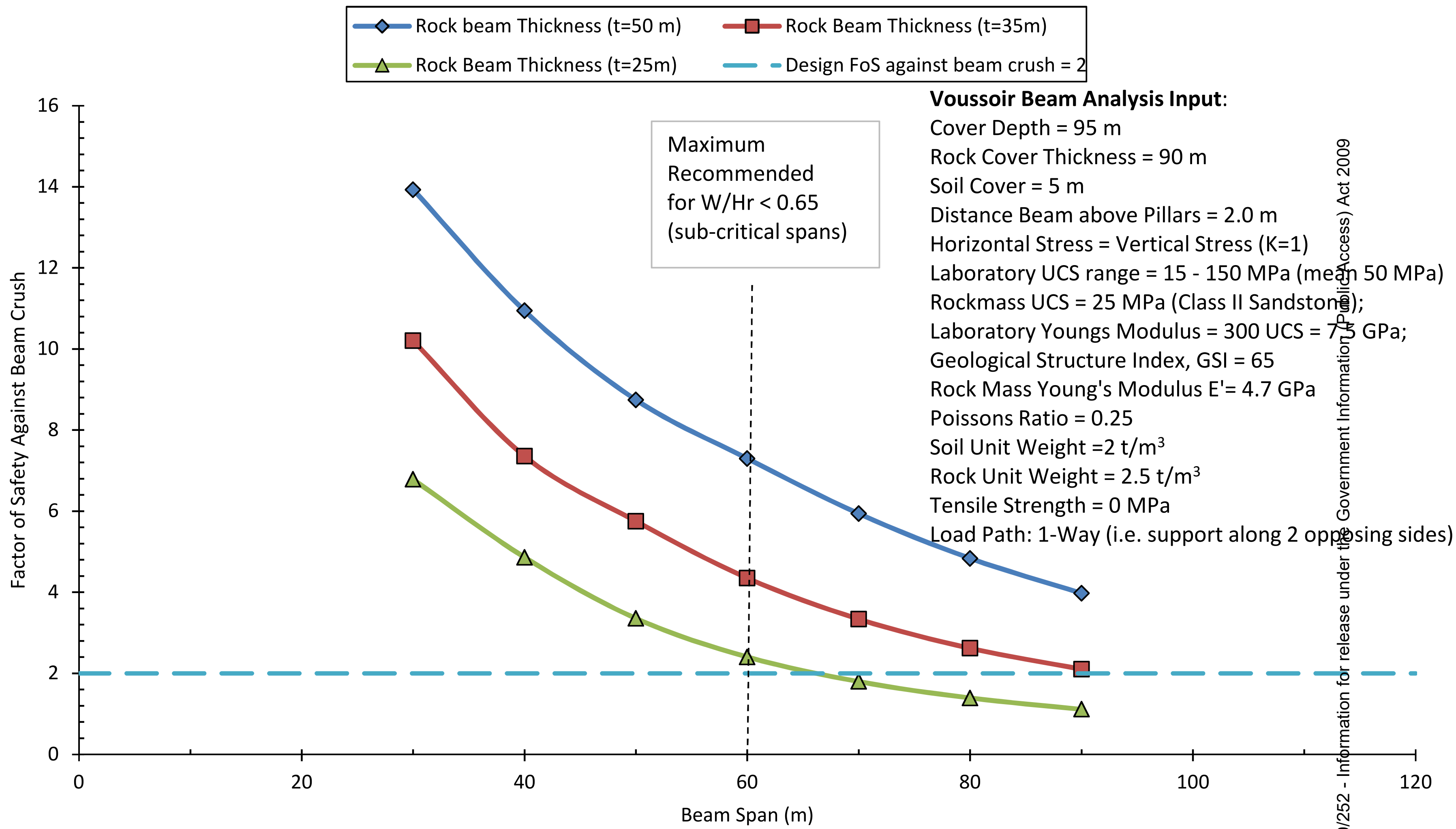
Angle of Draw (26.5°)

Interpreted Panel Creep Boundaries

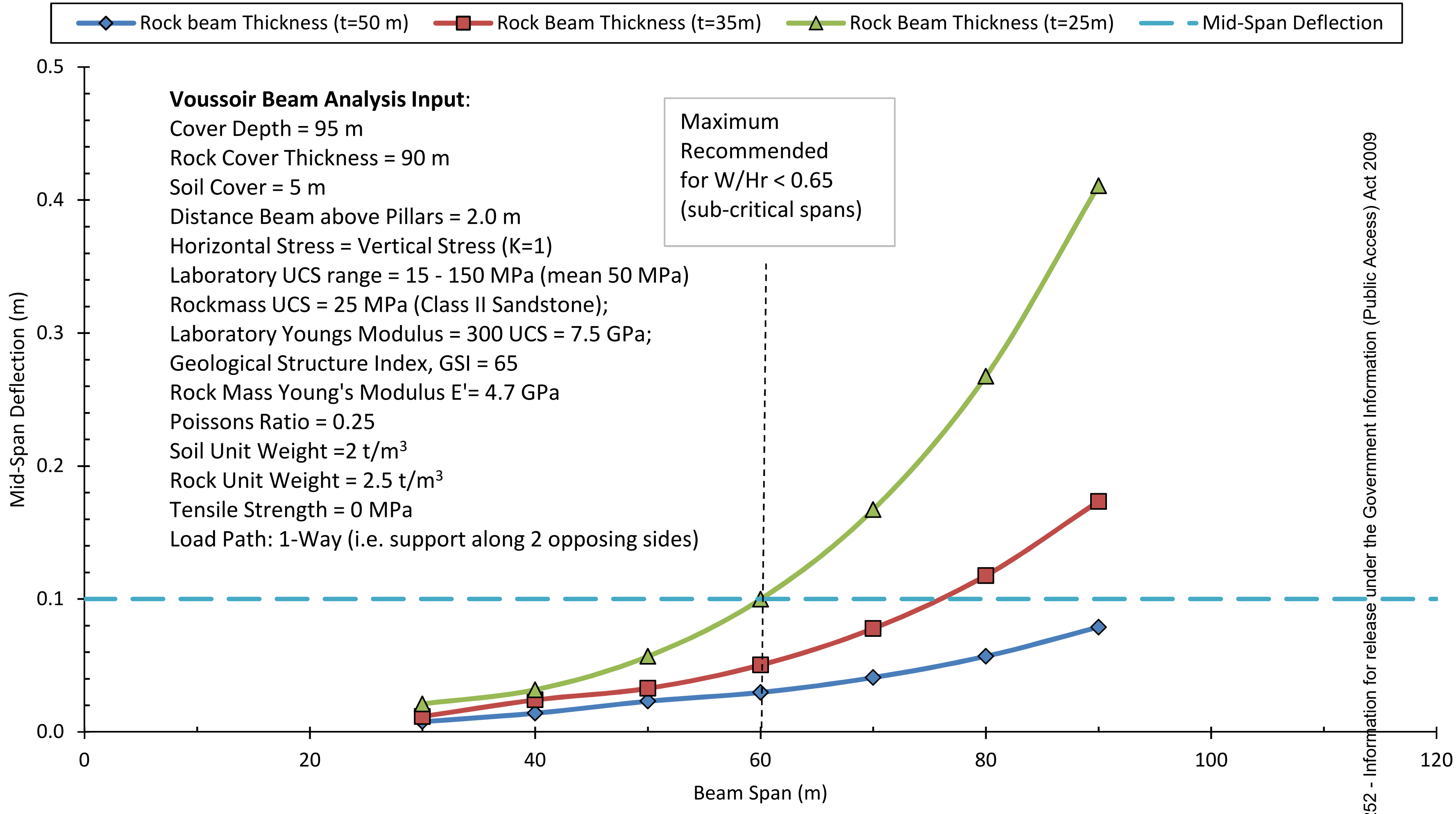
Buildings damaged by Creeps 2-3

AAC Mine Workings Pillars in Borehole Seam

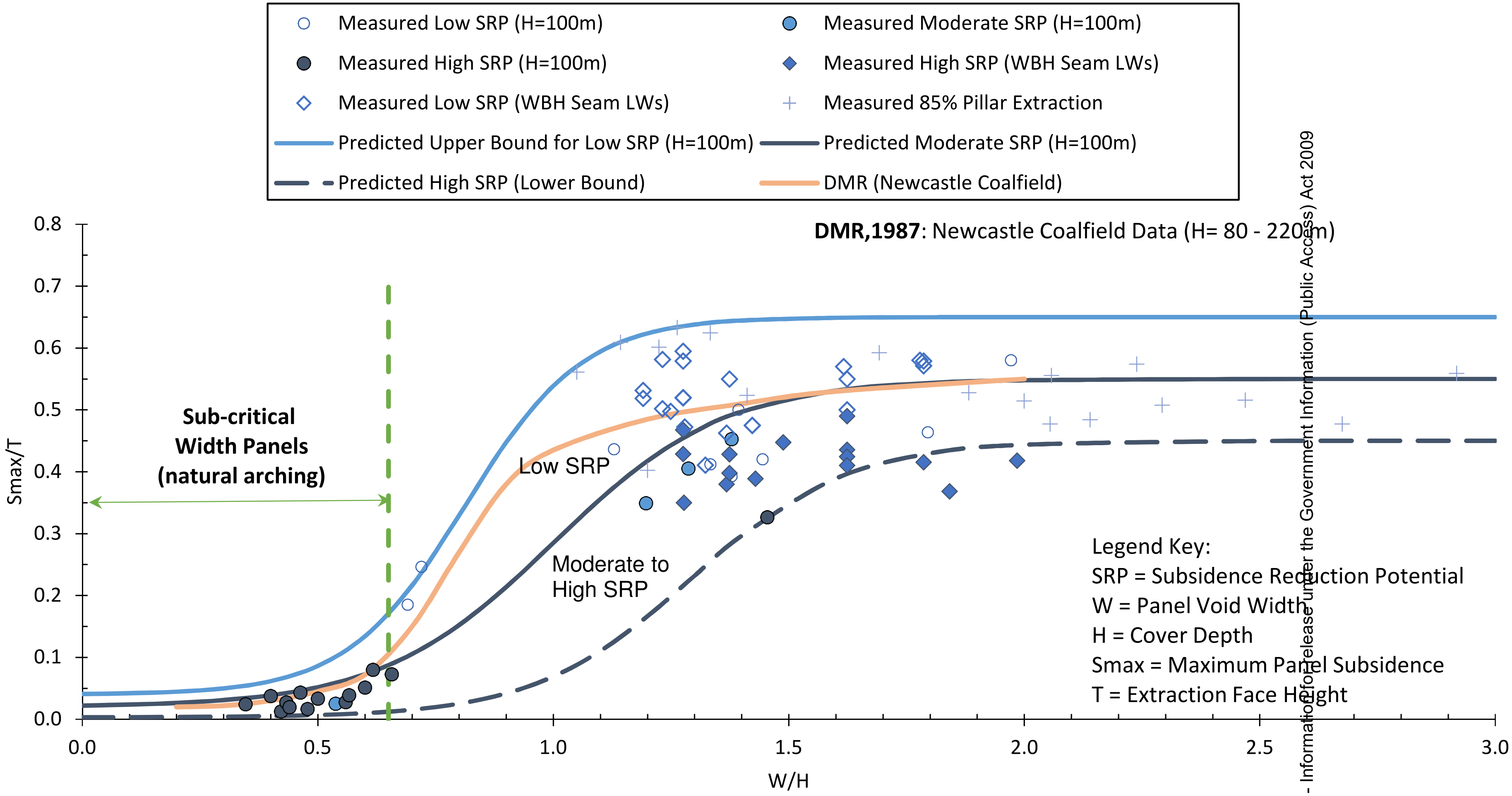
DgS	Engineer: S.Ditton	Client:	Coffey COF-009/1
	Drawn: S.Ditton		
	Date: 20.02.19	Title:	Predicted Final Horizontal Strain Contours (Credible Worst Case) to Minimum Pillar FoS of 2.1 under Dry Conditions
	Ditton Geotechnical Services Pty Ltd	Scale:	1:10,000 (A4) — Figure No: 7d



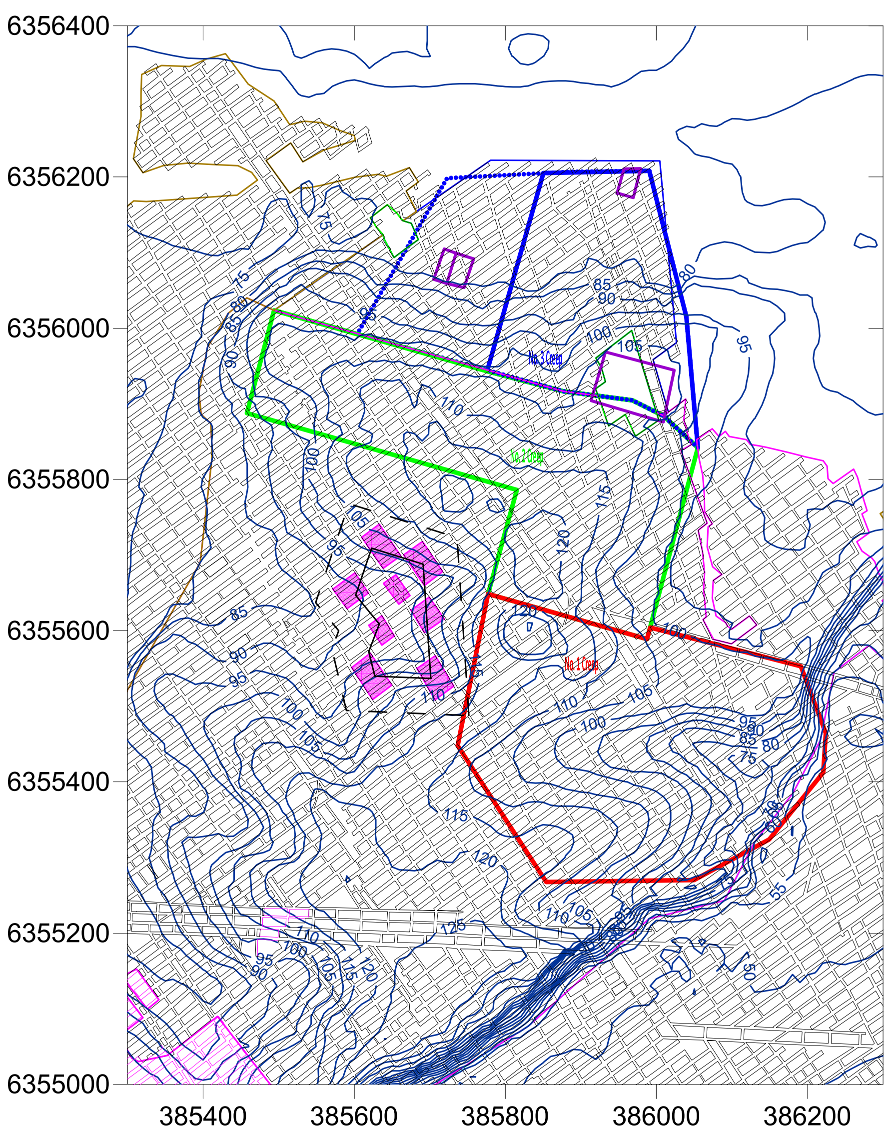
DgS	Engineer:	S.Ditton	Client:	Coffey COF-009/1
	Drawn:	S.Ditton		
	Date:	06.03.19	Title:	Predicted Overburden Spanning Capability between Grouted Areas in AAC Mine: FoS against Beam crush v. Span
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS
			Figure No:	8c



DgS	Engineer:	S.Ditton	Client:	Coffey COF-009/1		
	Drawn:	S.Ditton				
	Date:	06.03.19	Title:	Predicted Overburden Spanning Capability between Grouted Areas in AAC Mine: Mid-Span Deflection v. Span		
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS	Figure No:	8d



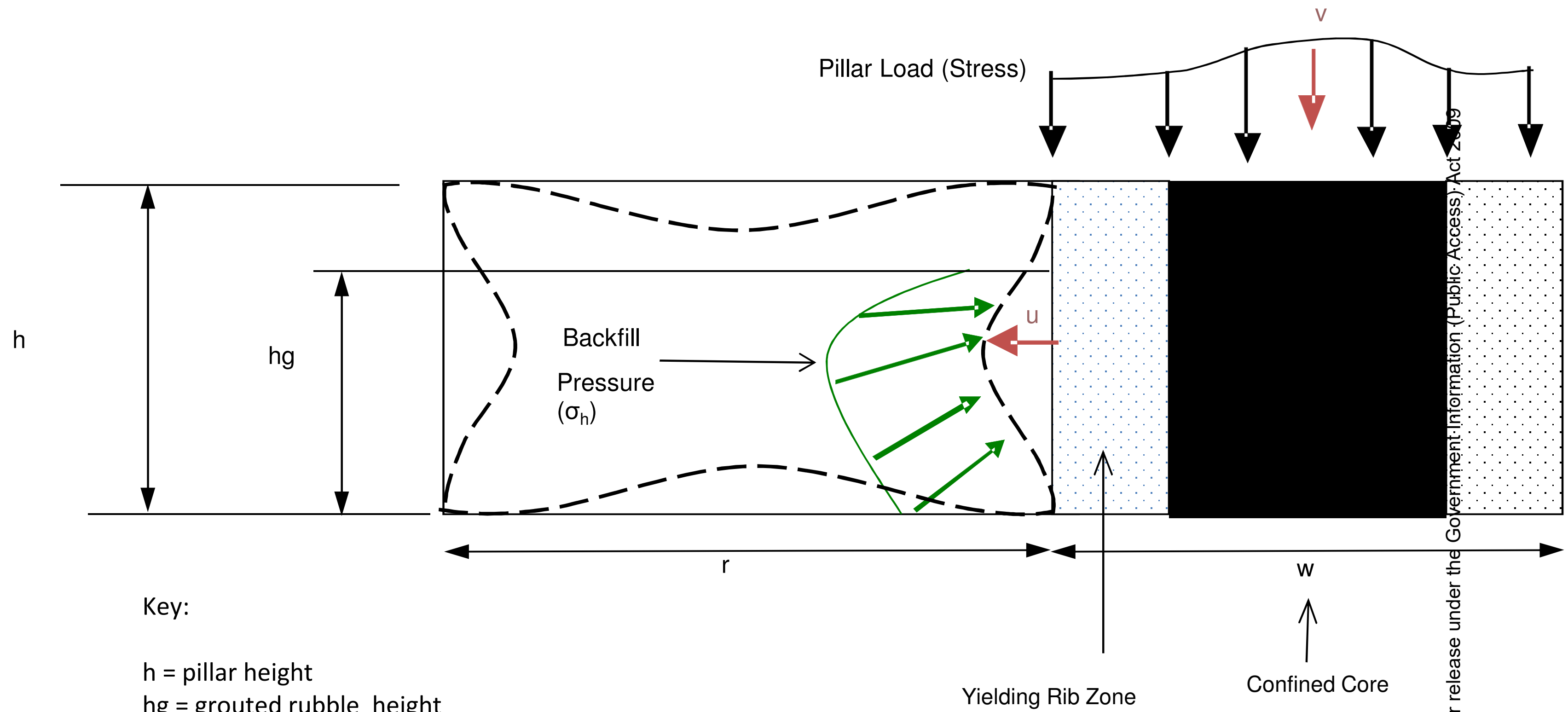
DgS	Engineer:	S.Ditton	Client:	Coffey COF-009/1		
	Drawn:	S.Ditton				
	Date:	06.03.19	Title:	Predicted Maximum Single Panel Subsidence for Miniwalls, Longwalls & Pillar Extraction Panels in Newcastle Coalfield with Cover Depths between 50 m and 150 m		
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS	Figure No:	8e



Key

- Site Boundary
- Angle of Draw (26.5°)
- Interpreted Panel Creep Boundaries
- Buildings damaged by Creeps 2-3
- AAC Mine Workings Pillars in Borehole Seam
- Grout Modified Pillars

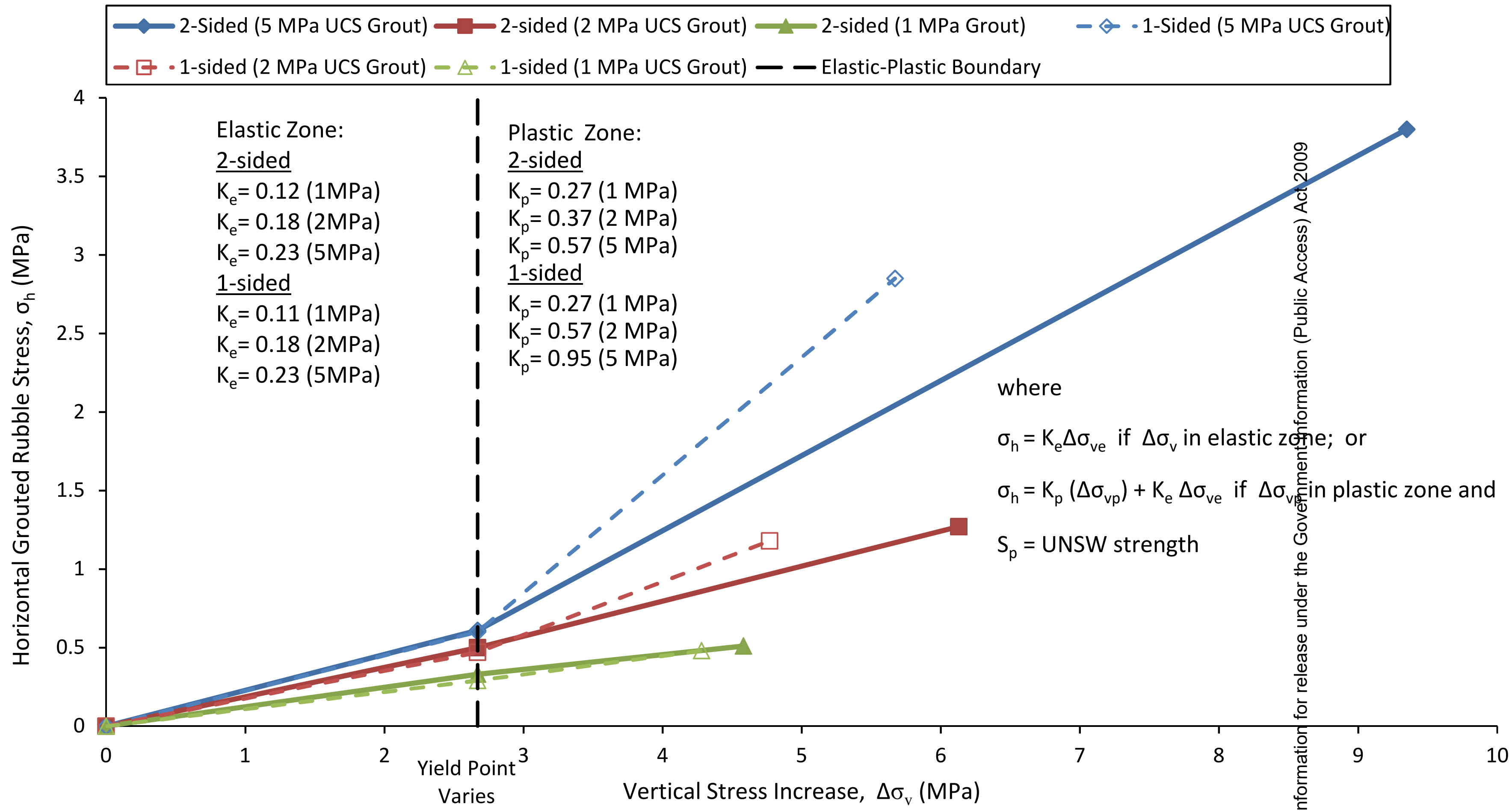
DgS	Engineer:	S.Ditton	Client:	Coffey COF-009/1
	Drawn:	S.Ditton		
	Date:	13.03.19	Title:	Proposed Strategic Grouting in the Borehole Seam with 5 MPa Grout to satisfy Internal and External Pillar Instability Control for the Mosbri Crescent Site
	Ditton Geotechnical Services Pty Ltd		Scale:	1:10,000 (A4)
			Figure No:	8f



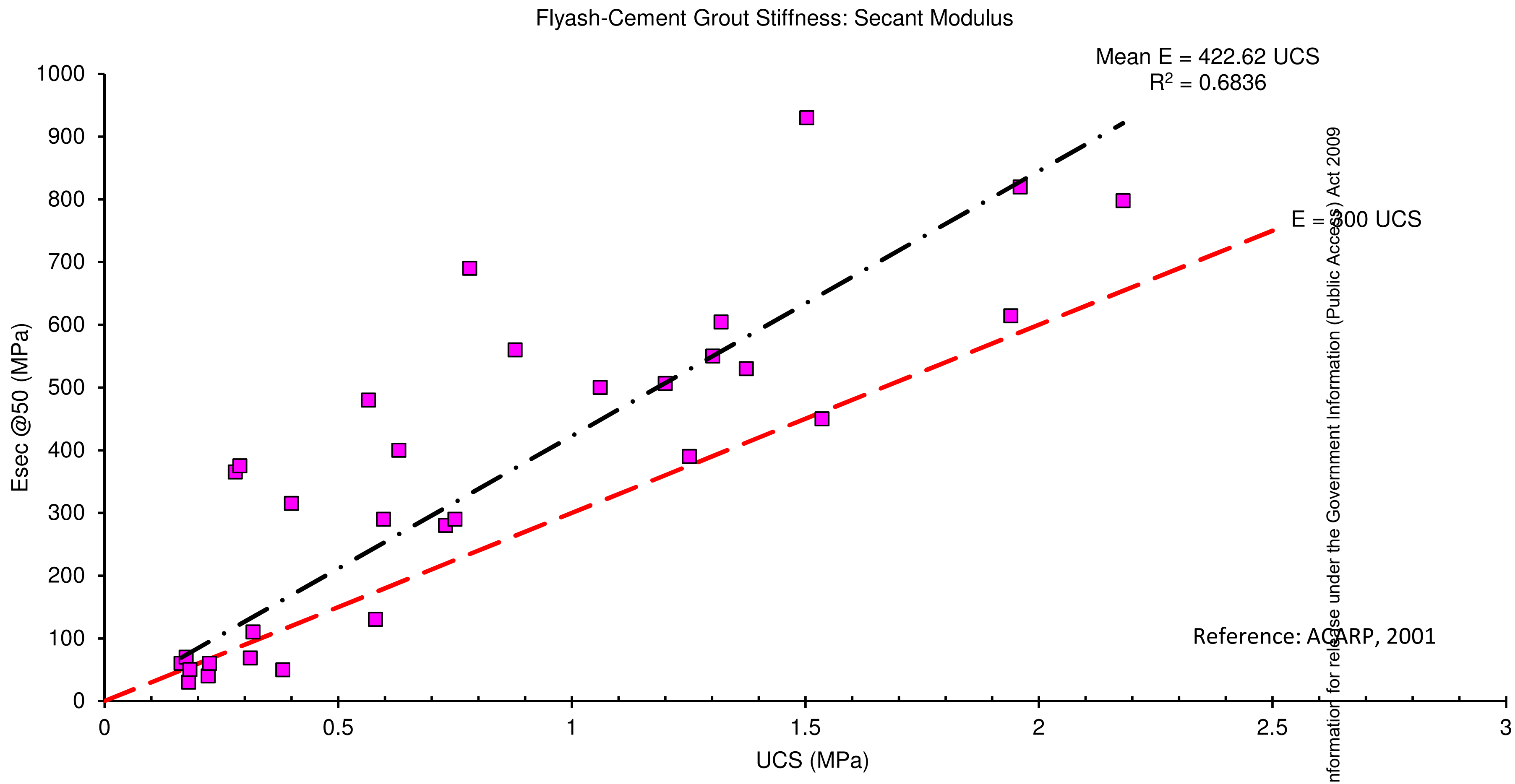
Key:

h = pillar height
hg = grouted rubble height
r = bord width
w = pillar width
u = lateral displacement
v = vertical displacement

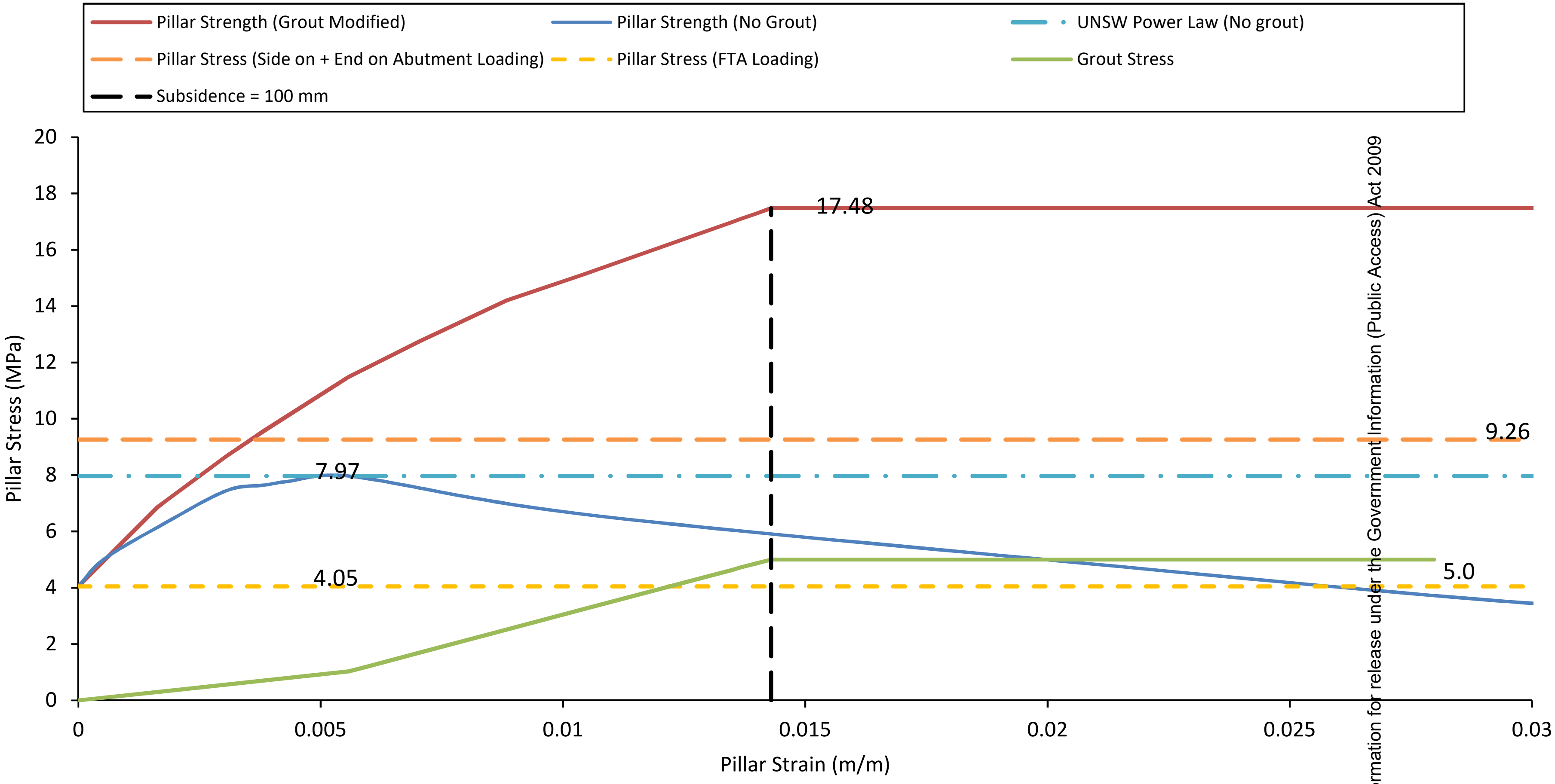
DgS	Engineer:	S.Ditton	Client:	Coffey COF-009/1		
	Drawn:	S.Ditton				
	Date:	10.03.19	Title:	Conceptual Model of Maximum Passive Pressure that Develops in Grouted Rubble due to an Expanding Pillar Under Abutment Loading (based on FLAC3D Modelling)		
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS	Figure No:	9a



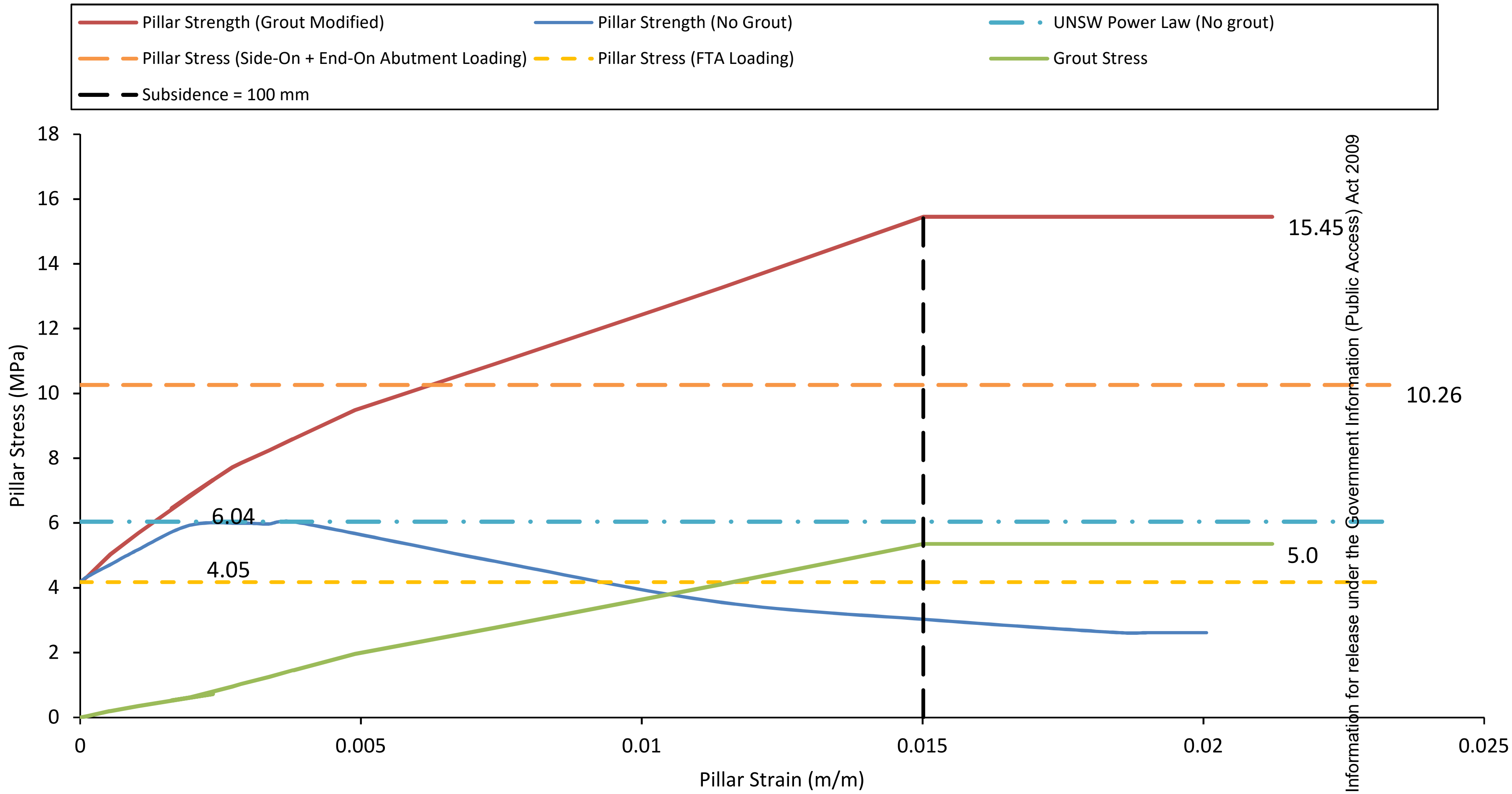
DgS				
	Engineer:	S.Ditton	Client:	Coffey COF-009/1
	Drawn:	S.Ditton		
	Date:	10.03.19	Title:	Horizontal Back Pressure in Grouted Rubble due to Pillar Stress Increases in the Elastic and Plastic Zones: Grout UCS = 1, 2 & 5 MPa
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS
			Figure No:	9b



DgS	Engineer:	S.Ditton	Client:	Coffey COF-009/1		
	Drawn:	S.Ditton				
	Date:	10.03.19	Title:	Grout UCS v. Youngs Modulus Laboratory Test Results		
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS	Figure No:	9c



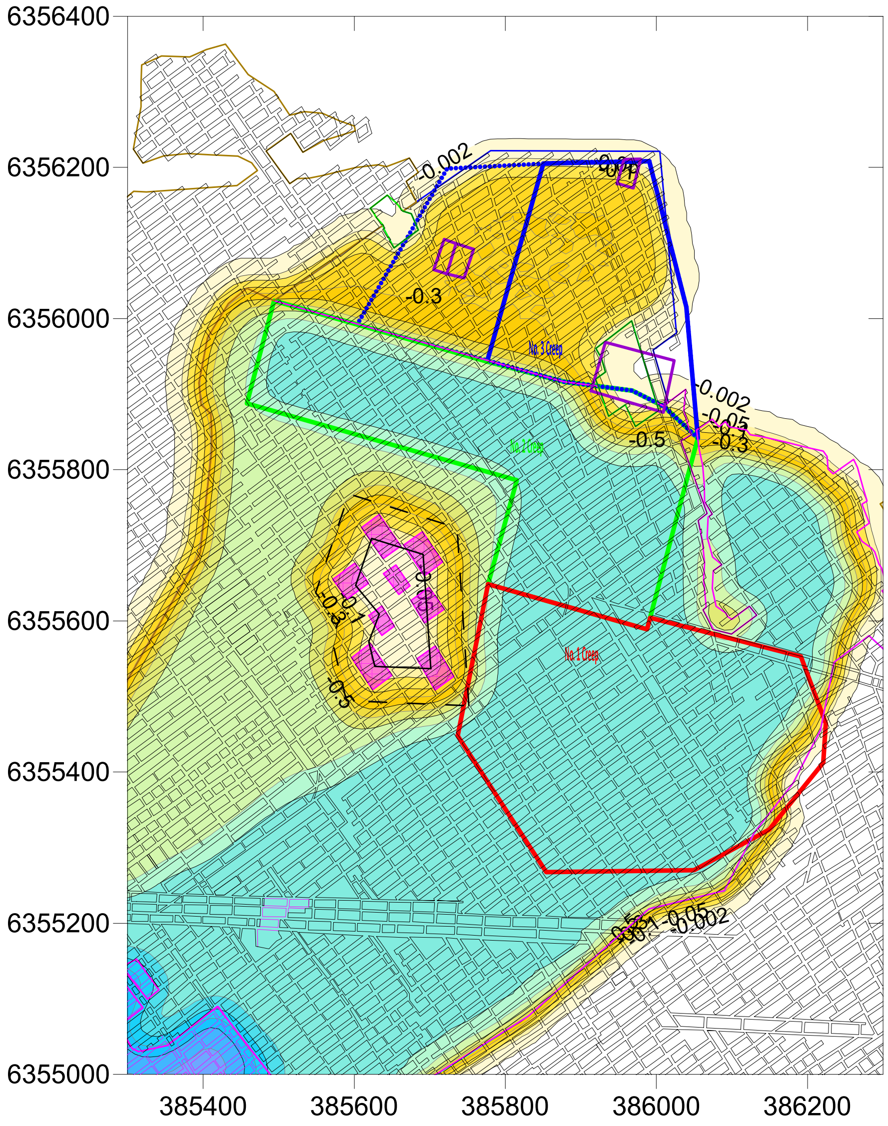
DgS	Engineer:	S.Ditton	Client:	Coffey COF-009/1		
	Drawn:	S.Ditton				
	Date:	12.03.19	Title:	Stress Strain Curves for Ungrouted and Grout-Confined Pillars (fully encapsulated by 5 MPa UCS Grout) below the Northern End of the Mosbri Site		
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS	Figure No:	9d



DgS	Engineer:	S.Ditton	Client:	Coffey COF-009/1			
	Drawn:	S.Ditton					
	Date:	12.03.19	Title:	Stress Strain Curves for Ungrouted and Grout-Confined Pillars (fully encapsulated by 5 MPa UCS Grout) below the Southern End of the Mosbri Site			
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS	Figure No:	9e	

Subsidence (m):

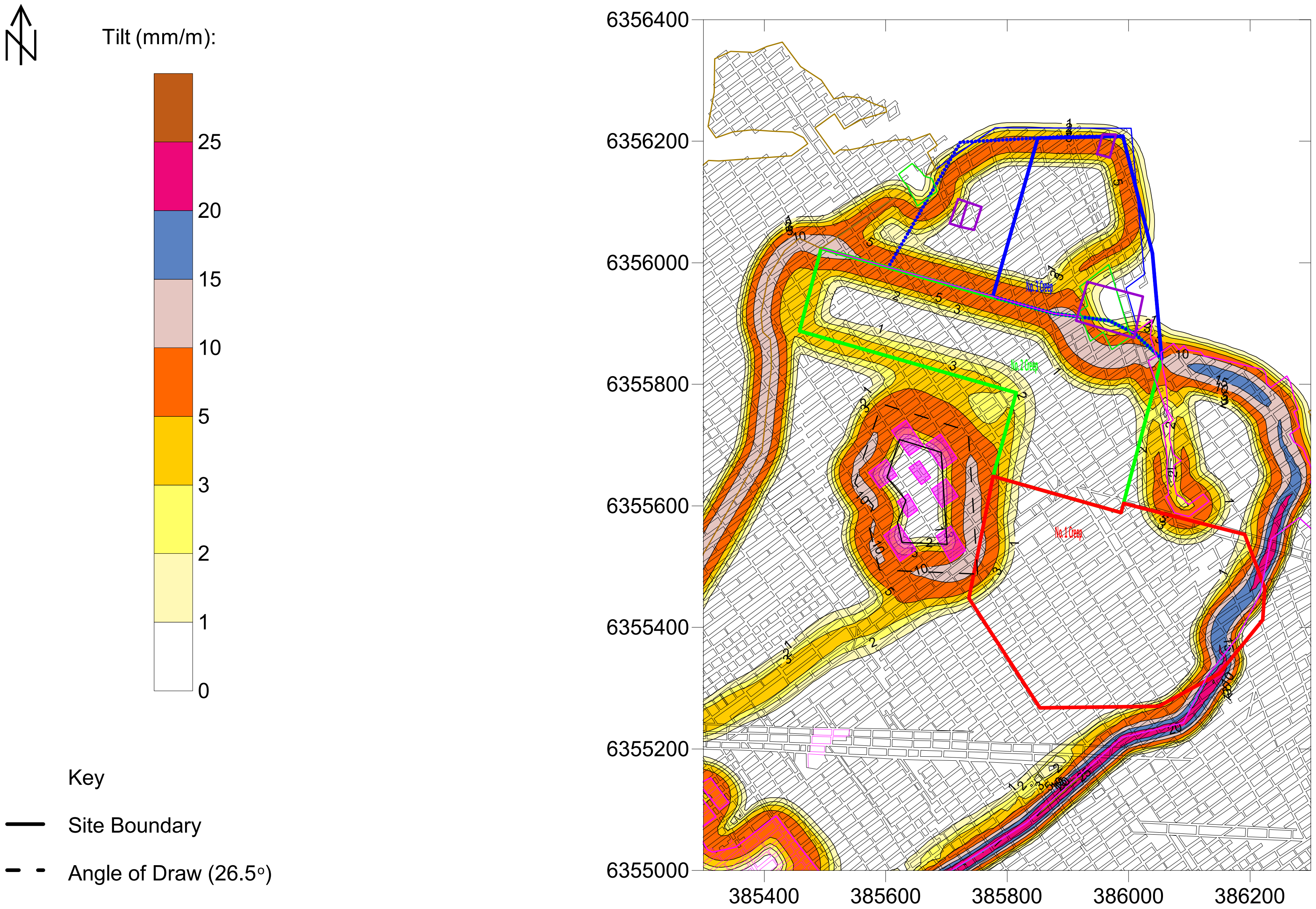
-0.002
-0.05
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1
-1.1
-1.2
-1.3
-1.4
-1.5



Key

- Site Boundary
- Angle of Draw (26.5°)
- Interpreted Panel Creep Boundaries
- Buildings damaged by Creeps 2-3
- AAC Mine Workings Pillars in Borehole Seam
- Grout Modified Pillars

DgS	Engineer:	S.Ditton	Client: Coffey COF-009/1
	Drawn:	S.Ditton	
	Date:	08.03.19	Title: Predicted Final Subsidence Contours (Credible Worst Case) with 5 MPa Strategic Grout in the Borehole Seam
Ditton Geotechnical Services Pty Ltd			Scale: 1:10,000 (A4) — Figure No: 10a

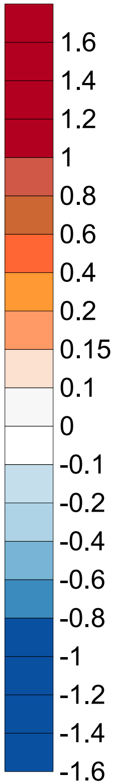


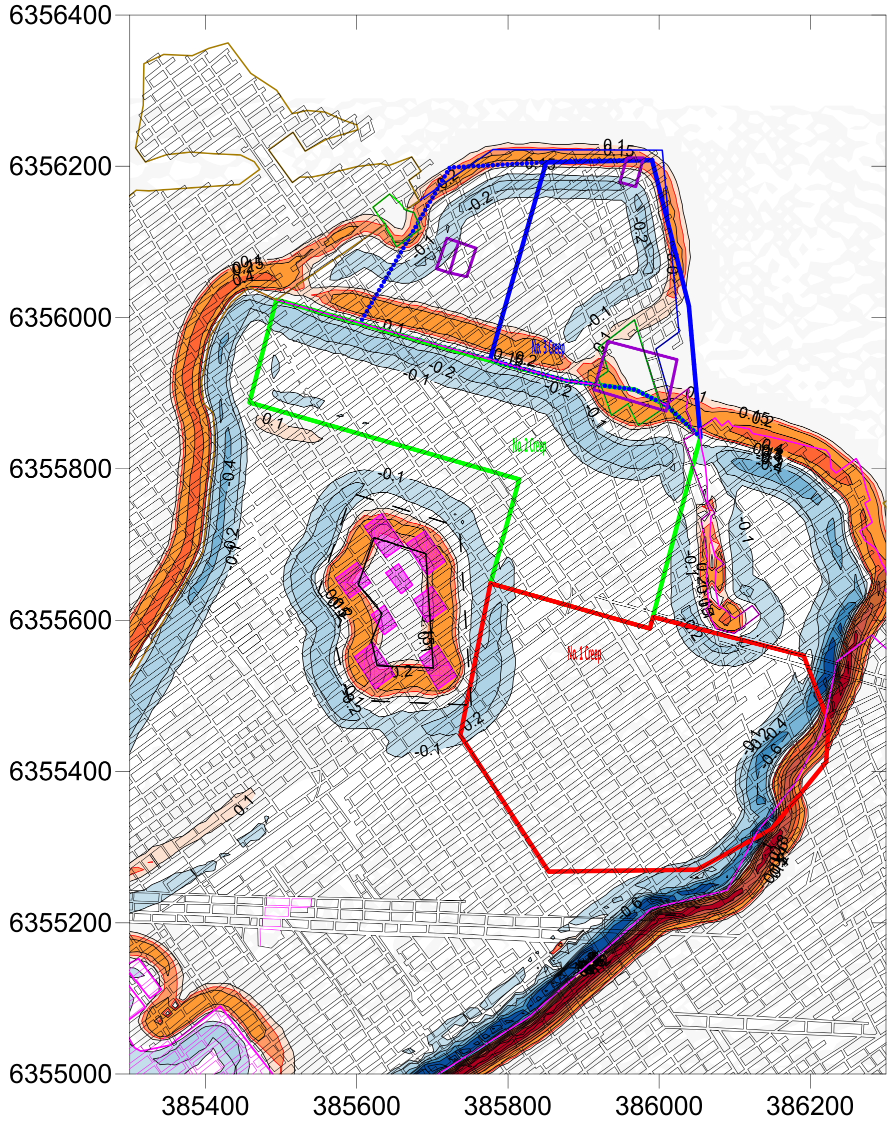
Key

- Site Boundary
- Angle of Draw (26.5°)
- Interpreted Panel Creep Boundaries
- Buildings damaged by Creeps 2-3
- AAC Mine Workings Pillars in Borehole Seam
- Grout Modified Pillars

DgS	Engineer:	S.Ditton	Client:	Coffey COF-009/1		
	Drawn:	S.Ditton	Title:	Predicted Final Tilt Contours (Credible Worst Case) with 5 MPa Strategic Grout in the Borehole Seam		
	Date:	20.02.19				
Ditton Geotechnical Services Pty Ltd			Scale:	1:10,000 (A4)	Figure No:	10b

Curvature (km-1):

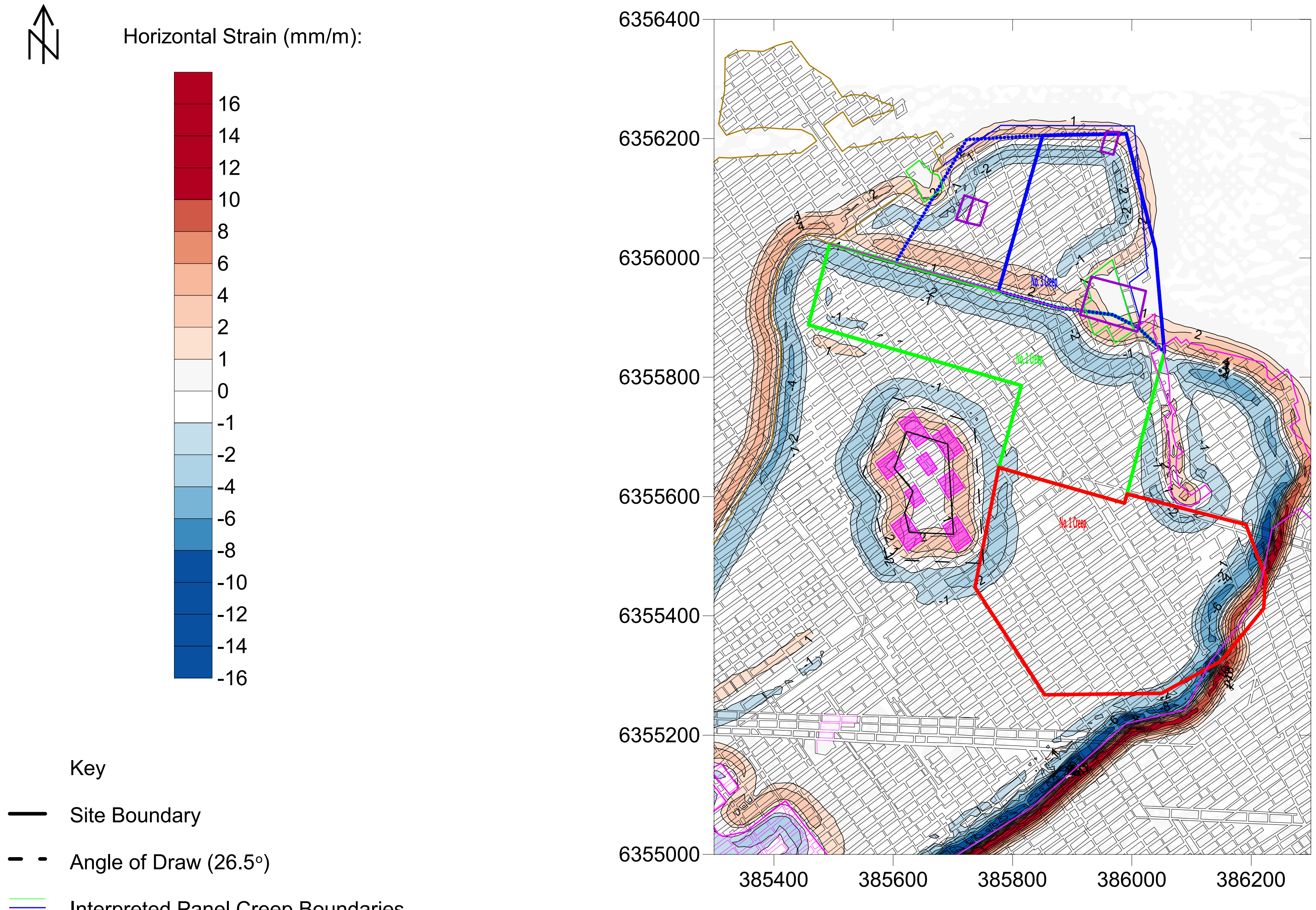




Key

- Site Boundary
- Angle of Draw (26.5°)
- Interpreted Panel Creep Boundaries
- Buildings damaged by Creeps 2-3
- AAC Mine Workings Pillars in Borehole Seam
- Grout Modified Pillars

DgS	Engineer:	S.Ditton	Client:	Coffey COF-009/1	
	Drawn:	S.Ditton			
	Date:	20.02.19	Title:	Predicted Final Curvature Contours (Credible Worst Case) with 5 MPa Strategic Grout in the Borehole Seam	
Ditton Geotechnical Services Pty Ltd			Scale:	1:10,000 (A4)	Figure No: 10c



Key

- Site Boundary
- Angle of Draw (26.5°)
- Interpreted Panel Creep Boundaries
- Buildings damaged by Creeps 2-3
- AAC Mine Workings Pillars in Borehole Seam
- Grout Modified Pillars

DgS	Engineer:	S.Ditton	Client:	Coffey COF-009/1		
	Drawn:	S.Ditton				
	Date:	20.02.19	Title:	Predicted Final Horizontal Strain Contours (Credible Worst Case) with 5 MPa Strategic Grout in the Borehole Seam		
	Ditton Geotechnical Services Pty Ltd					
			Scale:	1:10,000 (A4)	Figure No:	10d

Hannah Stephenson

From: [redacted] <[redacted]@coffey.com>
Sent: Monday, 1 April 2019 3:25 PM
To: Kieran Black
Subject: NBN - Crescent Newcastle Geotechnical Report - 11-17 Mosbri Crescent The Hill - TBA1904135 & TSUB19-00543

Kieran

Have you had a chance to look at the info for NBN?

Regards

[redacted]
Senior Geotechnical Engineer

19 Warabrook Boulevard
Warabrook NSW 2304

t: [redacted]
m: [redacted]

coffey
A TETRA TECH COMPANY

Ingenuity@coffey - it's the ideas that count

Hannah Stephenson

From: Melanie Fityus
Sent: Thursday, 13 June 2019 3:24 PM
To: [redacted]@coffey.com
Cc: SA Risk
Subject: RE: NBN Site

Hi [redacted],

The report is currently undergoing our internal approval process.

Regards

Melanie

Melanie Fityus | Senior Risk Engineer
Subsidence Advisory NSW
Better Regulation Division | Department of Customer Service
P: 4908 4329
E: melanie.fityus@finance.nsw.gov.au | www.subsidenceadvisory.nsw.gov.au

Please consider the environment before printing this email

From: Shane McDonald
Sent: Thursday, 13 June 2019 2:29 PM
To: Melanie Fityus <Melanie.Fityus@finance.nsw.gov.au>
Subject: FW: NBN Site

FYI

Shane McDonald | Senior Risk Engineer
Subsidence Advisory NSW
Better Regulation Division | Department of Customer Service
P: 4908 4328
E: shane.mcdonald1@finance.nsw.gov.au | www.subsidenceadvisory.nsw.gov.au

Please consider the environment before printing this email

From: [redacted] [mailto:[redacted]@coffey.com]
Sent: Thursday, 13 June 2019 1:53 PM
To: Shane McDonald <shane.mcdonald1@finance.nsw.gov.au>
Subject: NBN Site

Hi Shane,

I trust you are well. As you might already know [redacted]. One of our clients is asking about MSB's response to Coffey report for NBN site. [redacted] said it has been sorted out a long time ago. Could you please provide the approval number for that site? Many thanks.

Regards

Dr [redacted]
Geotechnical Engineer

16 Callistemon Close
Warabrook NSW 2304

t: [redacted]
m: [redacted]

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A TETRA TECH COMPANY

Ingenuity@coffey - it's the ideas that count

Hannah Stephenson

From: sa-riskeng
Sent: Wednesday, 3 July 2019 3:24 PM
To: mail@ncc.nsw.gov.au
Cc: llindsay@ncc.nsw.gov.au; [redacted]@coffey.com; [redacted]; Kieran Black
Subject: ATTN: Leah Lindsay & William Toose - 11-17 Mosbri Cres The Hill - TBA1-04135 & TSUB19-00543

Dear Leah & William

SA NSW is currently assessing the above applications for surface development and subdivision at Mosbri Cres The Hill.

Due to the geotechnical complexity of the site and the scale of the proposed development, SA NSW advises that we intend to obtain further independent advice regarding the suitability of the geotechnical treatments proposed for the site (grouting of abandoned workings) and the ability of the structures to remain safe, serviceable and readily repairable under the proposed residual parameters.

We apologise that this will extend the time taken to complete this assessment.

Regards

Melanie Fityus | Senior Risk Engineer
Subsidence Advisory NSW
Better Regulation Division | Department of Customer Service
P: 4908 4300
E: melanie.fityus@finance.nsw.gov.au | www.subsidenceadvisory.nsw.gov.au

NSW GOVERNMENT | Subsidence Advisory NSW

Hannah Stephenson

From: sa-riskeng
Sent: Monday, 8 July 2019 4:21 PM
To: [redacted]
Cc: SA Risk
Subject: RE: 11-17 Mosbry Crescent The Hill

Categories: Need to Save

Hi [redacted]

Available now if you like. 4908 4300

Melanie

From: [redacted]@coffey.com>
Sent: Monday, 8 July 2019 4:17 PM
To: Melanie Fityus <Melanie.Fityus@finance.nsw.gov.au>
Subject: 11-17 Mosbry Crescent The Hill

Hi Melanie

I would like to talk with you about whether you require any additional information from Coffey for the NBN site at 11-17 Mosbri Crescent, The Hill. I understand that SANSW has requested additional independent advice regarding geotechnical treatment for the site.

Please let me know when is a good time to call.

Regards,

[redacted]
Principal Engineering Geologist - Warabrook

16 Callistemon Close
Warabrook NSW 2304

t: [redacted]
m: [redacted]

coffey
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Ingenuity@coffey - it's the ideas that count

Hannah Stephenson

From: sa-riskeng
Sent: Thursday, 18 July 2019 11:26 AM
To: [redacted]
Cc: SA Risk
Subject: RE: Geotechnical Report - 11-17 Mosbri Crescent The Hill - TBA1904135 & TSUB19-00543

Hi [redacted],

Peer review has commenced. We anticipate it will take at least a few weeks to undertake and for us to consider.

What happens after that will depend on the comments in the peer review.

Regards

Melanie Fityus | Senior Risk Engineer
Subsidence Advisory NSW
Better Regulation Division | Department of Customer Service
P: 4908 4300
E: sa-riskeng@finance.nsw.gov.au | www.subsidenceadvisory.nsw.gov.au

NSW GOVERNMENT | Subsidence Advisory NSW

From: [redacted]@stronach.com.au>
Sent: Thursday, 18 July 2019 10:08 AM
To: Melanie Fityus <Melanie.Fityus@finance.nsw.gov.au>
Subject: FW: Geotechnical Report - 11-17 Mosbri Crescent The Hill - TBA1904135 & TSUB19-00543

Hi Melanie

I just thought I would touch base to see if you have been able to confirm with your staff when the second peer review is likely to commence/complete?

Kind Regards

[redacted]
Assistant Development Manager

STRONACH PROPERTY

PO Box 292, Wickham NSW 2293
p [redacted] | m [redacted] | e [redacted]@stronach.com.au |
a Suite C502, Lee Harbour, 19 Honeysuckle Drive, Newcastle NSW 2300
www.stronach.com.au

From: [redacted] [mailto[redacted]@coffey.com]
Sent: Tuesday, 19 March 2019 2:46 PM
To: Melanie.Fityus@finance.nsw.gov.au

Cc: Kieran Black <Kieran.Black@finance.nsw.gov.au>
Subject: Geotechnical Report - 11-17 Mosbri Crescent The Hill - TBA1904135 & TSUB19-00543

Melanie

Please find attached DGS review for NBN

Note There is an updated modelling report with a new layout which will come via we transfer

Regards

[redacted]
Senior Geotechnical Engineer

16 Callistemon Close
Warabrook NSW 2304

t: [redacted]
m: [redacted]

We've moved!

Our new address is
16 Callistemon Close
Warabrook, NSW 2304

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A TETRA TECH COMPANY

Hannah Stephenson

From: J.Galvin@bigpond.net.au
Sent: Thursday, 4 July 2019 8:57 AM
To: Kieran Black
Subject: RE: Expert Review - Mosbri Crescent

Hi Kieran

I have downloaded the files and first impression is that it is likely to be a few days before I can complete a first pass read of this material. However, I will be surprised if I can answer all of your questions, since subsidence engineering is not such a precise science. I will give you a ring once I have a better idea of the what the matter is about.

Can you please advise a purchase order number or invoicing details.

Regards

Jim

Emeritus Professor J Galvin
FTSE, FIEAust CPEng, FAusIMM CPMin

Mobile: +61 417 710 476

Galvin & Associates Pty Ltd
A.B.N. 27 086 258 871

Postal Address **Courier Address**
PO Box 1228 28/2 Cerretti Crescent
Manly NSW 1655 Manly NSW 2095

From: Kieran Black <Kieran.Black@finance.nsw.gov.au>
Sent: Wednesday, 3 July 2019 1:49 PM
To: j.galvin@bigpond.net.au
Subject: Expert Review - Mosbri Crescent

Hi Jim,

Thanks so much for agreeing to have a look at this particular application.

I initially sent through the reports and they were just too large. So I have shared a drop box account.

If you have time, would you be able to review the initial report and DGS's peer review?

SA NSW would like to know

1) Whether the proposed grouting strategy for the Borehole Seam will result in the following maximum residual conventional ground movements (assuming bulk grouting of the Yard Seam workings);
    - Maximum horizontal strains (+/-): 2 mm/m
    - Maximum tilt: 4 mm/m
    - Maximum radius of curvature: 7 km

2) What is the likelihood of these conventional subsidence impact parameters being exceeded?

3) What is the estimated likelihood of non-conventional subsidence and what would the magnitude be? (note: site is located on steep slope)

4) In your opinion, would a bulk grouting solution eliminate the risk?

Kind Regards

Kieran Black
Technical Manager

Subsidence Advisory NSW | An Agency of the Department of Finance, Services and Innovation
p (02) 4908 4391
e Kieran.Black@finance.nsw.gov.au | www.subsidenceadvisory.nsw.gov.au
Ground Floor, Government Offices, 117 Bull Street Newcastle West NSW 2302

Hannah Stephenson

From: Melanie Fityus
Sent: Friday, 19 July 2019 12:47 PM
To: J.Galvin@bigpond.net.au
Cc: Kieran Black
Subject: FW: Expert Review - Mosbri Crescent

Hi Jim

Kieran has asked me to provide the reports below. They are obviously large and can't be e-mailed.

I have checked the Newcastle City Council DA Tracker and the first two reports listed in your e-mail are publicly available as part of the DA submission. You can download directly from the Council's website.

The direct link to the DA is here:

https://property.ncc.nsw.gov.au/T1PRPROD/WebApps/eProperty/P1/eTrack/eTrackApplicationDetails.aspx?r=TCON.LG.WEBGUEST&f=%24P1.ETR.APPDET.VIW&ApplicationId=DA2019%2f00061

Scrolling down you can see a list of all of the relevant documents. The extract below highlights the reports for 14 Jan 2019 and 18 Jan 2019.

Section AA - 11-17 Mosbri Crescent The Hill.pdf	PDF
Shadow Analysis Diagram - 11-17 Mosbri Crescent The Hill.pdf	PDF
Site Analysis - 11-17 Mosbri Crescent The Hill.pdf	PDF
Site Plan - 11-17 Mosbri Crescent The Hill.pdf	PDF
Stormwater Management Plan - 11-17 Mosbri Crescent The Hill.PDF	PDF
Civil Engineering Plans - 11-17 Mosbri Crescent The Hill.PDF	PDF
Voluntary Planning Agreement Letter of Offer - 11-17 Mosbri Crescent The Hill.pdf	PDF
Development Control Plan Compliance Table - 11-17 Mosbri Crescent The Hill.pdf	PDF
LEP Clause 4.6 Variation Request - 11-17 Mosbri Crescent The Hill.pdf	PDF
Statement of Environmental Effects - 11-17 Mosbri Crescent The Hill.pdf	PDF
Mines Subsidence Assessment Report - 11-17 Mosbri Crescent The Hill.pdf	PDF
Site Contamination Assessment - 11-17 Mosbri Crescent The Hill.pdf	PDF
Survey Plan - 11-17 Mosbri Crescent The Hill.pdf	PDF
Traffic & Parking Report - 11-17 Mosbri Crescent The Hill.pdf	PDF
Waste Mangement Report - 11-17 Mosbri Crescent The Hill.pdf	PDF
Arborist Report - 11-17 Mosbri Crescent The Hill.pdf	PDF
BASIX Certificate & Plans - 11-17 Mosbri Crescent The Hill.pdf	PDF
BCA Assessment Report - 11-17 Mosbri Crescent The Hill.pdf	PDF
Superseded Bushfire Report - 11-17 Mosbri Crescent The Hill.pdf	PDF
Crime & Safety Report - 11-17 Mosbri Crescent The Hill.pdf	PDF
Design Verification Statement (SEPP65) - 11-17 Mosbri Crescent The Hill.pdf	PDF
Disability Access Report - 11-17 Mosbri Crescent The Hill.pdf	PDF
Geotechnical Report - 11-17 Mosbri Crescent The Hill.pdf	PDF
Heritage Impact Statement - 11-17 Mosbri Crescent The Hill.pdf	PDF
Hunter Water Stamped Plans - 11-17 Mosbri Crescent The Hill.pdf	PDF
Mines Subsidence Assessment Report Numerical - 11-17 Mosbri Crescent The Hill.pdf	PDF
Public Application Form - 11-17 Mosbri Crescent The Hill.pdf	PDF
Referral - Ausgrid - DA2019-00061 - 11-17 Mosbri Crescent The Hill.pdf	PDF
Referral - Subsidence Advisory NSW - DA2019-00061 - 11-17 Mosbri Crescent The Hill.pdf	PDF
Referral - NSW Rural Fire Service - DA2019-00061 - 11-17 Mosbri Crescent The Hill.pdf	PDF
Plans - 11-17 Mosbri Crescent The Hill.pdf	PDF

I will have to send the 12 March 2019 report separately.

Regards

Melanie Fityus | Senior Risk Engineer
Subsidence Advisory NSW
Better Regulation Division | Department of Customer Service
P: 4908 4300
E: sa-riskeng@finance.nsw.gov.au | www.subsidenceadvisory.nsw.gov.au

Subsidence Advisory NSW

Please consider the environment before printing this email

From: Kieran Black <Kieran.Black@finance.nsw.gov.au>
Sent: Friday, 19 July 2019 7:23 AM
To: Melanie Fityus <Melanie.Fityus@finance.nsw.gov.au>
Subject: FW: Expert Review - Mosbri Crescent

Hi Mel,

Would you be able to dropbox these coffey reports to Jim Galvin?

His email is listed below.

Cheers

Kieran

From: J.Galvin@bigpond.net.au [mailto:J.Galvin@bigpond.net.au]
Sent: Wednesday, 17 July 2019 12:11 PM
To: John Johnston <John.Johnston@finance.nsw.gov.au>
Cc: Kieran Black <Kieran.Black@finance.nsw.gov.au>; SA Risk <SA-Risk@finance.nsw.gov.au>; SA Procure <sa-procure@finance.nsw.gov.au>
Subject: RE: Expert Review - Mosbri Crescent

Hi Kieran and John

I am trying to prepare the tender document based on the Coffey Report of 14 January 2019 and the Ditton Report of 14 March 2019 that you sent me. I note that the Ditton Report states that *The Coffey reports reviewed include:*

 Report No 754-NTLGE220504-AH (Rev 3) (14 January 2019)
 Report No 754-NTLGE220504-AI (18 January 2019)
 Report No 754-NTLGE220504-AI (12 March 2019)

I presume that you have no need for the latter 2 Coffey reports to be reviewed. If they do need to be reviewed, I would need to see them to gain some idea of the issues and time involved.

Regards

Jim

+61 417 710 476

From: John Johnston <John.Johnston@finance.nsw.gov.au>
Sent: Wednesday, 10 July 2019 10:34 AM
To: J.Galvin@bigpond.net.au
Cc: Kieran Black <Kieran.Black@finance.nsw.gov.au>; SA Risk <SA-Risk@finance.nsw.gov.au>; SA Procure <sa-procure@finance.nsw.gov.au>
Subject: FW: Expert Review - Mosbri Crescent

Hi Jim,

In Kieran's absence, I have been asked to send you the tender form for the review.

Please find attached.

Cheers,

John Johnston | Senior Risk Engineer
Subsidence Advisory NSW
Policy and Regulation Division | Department of Customer Service
P: 4908 4353
E: John.Johnston@finance.nsw.gov.au | www.subsidenceadvisory.nsw.gov.au

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Hannah Stephenson

From: Kieran Black
Sent: Monday, 5 August 2019 10:59 AM
To: Melanie Fityus
Subject: FYI Update re Mosbri Development

From: Kieran Black
Sent: Friday, 2 August 2019 3:30 PM
To: J.Galvin@bigpond.net.au
Subject: RE: Update re Mosbri Development

Hi Jim,

I hope you are feeling better soon. I have had back pain before, and there is nothing worse!

Much appreciated for the update.

Kind Regards

Kieran Black
Technical Manager

Subsidence Advisory NSW | An Agency of the Department of Finance, Services and Innovation
p (02) 4908 4391
e Kieran.Black@finance.nsw.gov.au | www.subsidenceadvisory.nsw.gov.au
Ground Floor, Government Offices, 117 Bull Street Newcastle West NSW 2302

NSW GOVERNMENT | Subsidence Advisory NSW

From: J.Galvin@bigpond.net.au [mailto:J.Galvin@bigpond.net.au]
Sent: Friday, 2 August 2019 1:21 PM
To: Kieran Black <Kieran.Black@customerservice.nsw.gov.au>
Subject: Update re Mosbri Development

Hi Kieran

Just a brief update. I have read the documentation and am in a position to write a report. However, I have one glitch. I received pleasing clean bills of health from internal check ups early last week but it now transpires that the procedures have left me with a hernia at the site of an appendix scar and a partially slipped disc. They must have been a bit rough while I was out to it. Anyway, I have been in a lot of pain and immobilised but now that the problems have finally been diagnosed, I am picking up and hope to get to your report later next week, subject to not having to have corrective surgery before then.

However, I can already tell you that I do not consider that the studies provide an adequate basis for concluding that the limits on the designated subsidence parameters cannot be exceeded. Given all the uncertainties associated with the mine plan, past instabilities and aspects of various assessment processes, it is my opinion that an adequate level of assurance can only be achieved by completely filling the workings in both seams within their area of influence.

Please do not hesitate to contact me if you wish to discuss further.

Regards

Jim

Emeritus Professor J Galvin
FTSE, FIEAust CPEng, FAusIMM CPMin

Mobile: +61 417 710 476

Galvin & Associates Pty Ltd
A.B.N. 27 086 258 871

Postal Address **Courier Address**
PO Box 1228 28/2 Cerretti Crescent
Manly NSW 1655 Manly NSW 2095

Hannah Stephenson

From: Kieran Black
Sent: Monday, 11 February 2019 1:58 PM
To: Melanie Fityus
Subject: RE: Geotech for 11-17 Mosbri Crescent The Hill

Thanks heaps Mel!

From: Melanie Fityus
Sent: Monday, 11 February 2019 1:38 PM
To: Kieran Black <Kieran.Black@finance.nsw.gov.au>
Subject: Geotech for 11-17 Mosbri Crescent The Hill

Kieran,

The two geotech reports for the proposed redevelopment of the NBN Television studios in Newcastle need to be reviewed by you.

The application is for 172 units/townhouses in total spread over 4 separate structures up to 8 storeys. Value is $70M.

Documents are pretty big. They are in this directory G:\Risk Enginering\Geology\03. Geotechnical Report VS Documap\Reports not yet added to S.Sheet

At some point Cassie will clean this up and file them. Note the suburb should be searchable as The Hill, not Newcastle.

Otherwise they are in the documents attached to TBA19-04135.

I will ask Simon the schedule a meeting.

Regards

Melanie Fityus
Senior Risk Engineer
Subsidence Advisory NSW | Department of Finance, Services and Innovation
p 4908 4329 (New Number)
e Melanie.Fityus@finance.nsw.gov.au | **w** www.subsidenceadvisory.nsw.gov.au
Ground Floor, Government Offices, 117 Bull Street, Newcastle West. NSW 2302.

NSW GOVERNMENT

Hannah Stephenson

From: Melanie Fityus
Sent: Friday, 8 February 2019 9:44 AM
To: SA Risk
Subject: RE: Multi Building Residential Development - 11-17 Mosbri Crescent, The Hill - TBA19-04135

All done! Once I downloaded it I had to put it somewhere. I think I managed it.

I saved to the job in CRM and put it in the Risk Engineering/Geology file for it to go on our database.

Thanks

Melanie

From: SA Risk
Sent: Friday, 8 February 2019 9:41 AM
To: Melanie Fityus <Melanie.Fityus@finance.nsw.gov.au>
Subject: RE: Multi Building Residential Development - 11-17 Mosbri Crescent, The Hill - TBA19-04135

Hi Mel

Can you send me any docs you need me to save or where you've put them in G Drive? cheers

---

From: Melanie Fityus
Sent: Friday, 8 February 2019 9:37 AM
To: [redacted]@coffey.com>
Cc: John Johnston <John.Johnston@finance.nsw.gov.au>; Kieran Black <Kieran.Black@finance.nsw.gov.au>; SA Risk <SA-Risk@finance.nsw.gov.au>
Subject: RE: Multi Building Residential Development - 11-17 Mosbri Crescent, The Hill - TBA19-04135

Thanks [redacted].

File came through with no apparent errors.

Regards

Melanie

From: [redacted]@coffey.com>
Sent: Friday, 8 February 2019 9:14 AM
To: Melanie Fityus <Melanie.Fityus@finance.nsw.gov.au>
Cc: John Johnston <John.Johnston@finance.nsw.gov.au>; Kieran Black <Kieran.Black@finance.nsw.gov.au>; SA Risk <SA-Risk@finance.nsw.gov.au>
Subject: RE: Multi Building Residential Development - 11-17 Mosbri Crescent, The Hill - TBA19-04135

Melanie

I'm sending through a WeTransfer link now.

Regards

[redacted]
Senior Geotechnical Engineer

t: [redacted]
m: [redacted]

We're moving
on the 4th of March

Our new address will be
16 Callistemon Close
Warabrook, NSW 2304

From: Melanie Fityus <Melanie.Fityus@finance.nsw.gov.au>
Sent: Friday, 8 February 2019 9:07 AM
To: [redacted]r@coffey.com>
Cc: John Johnston <John.Johnston@finance.nsw.gov.au>; Kieran Black <Kieran.Black@finance.nsw.gov.au>; SA Risk <SA-Risk@finance.nsw.gov.au>
Subject: Multi Building Residential Development - 11-17 Mosbri Crescent, The Hill - TBA19-04135

Hi [redacted],

I am reviewing documents for the above development.

We have your geotech report from18 January 2019 (754-NTLGE220504-AI) and it references Coffey Report 754-NTLGE220504-AH.Rev2 dated 17 December 2018. We don't have this earlier report.

Would you mind e-mailing us a copy?

Many thanks

Melanie Fityus
Senior Risk Engineer
Subsidence Advisory NSW | Department of Finance, Services and Innovation
p 4908 4329 (New Number)
e Melanie.Fityus@finance.nsw.gov.au | **w** www.subsidenceadvisory.nsw.gov.au
Ground Floor, Government Offices, 117 Bull Street, Newcastle West. NSW 2302.

NSW GOVERNMENT

Hannah Stephenson

From: Leah Lindsay <llindsay@ncc.nsw.gov.au>
Sent: Wednesday, 3 July 2019 3:24 PM
To: sa-riskeng
Subject: Automatic reply: ATTN: Leah Lindsay & William Toose - 11-17 Mosbri Cres The Hill - TBA1-04135 & TSUB19-00543

Categories: MEL

Thank you for your email.

I am currently out of the office and returning on Thursday, 4 July 2019.

If you would like to speak to a Business Support Officer in Regulatory, Planning & Assessment before I return please call 4974 2050.

Alternatively, I will respond to your enquiry on my return.

Kind regards

Leah Lindsay
Business Support Officer
Regulatory, Planning & Assessment
City of Newcastle

Hannah Stephenson

From: Jim Galvin <j.galvin@bigpond.net.au>
Sent: Friday, 19 July 2019 12:59 PM
To: Melanie Fityus
Subject: Re: Expert Review - Mosbri Crescent

Follow Up Flag: Follow up
Flag Status: Flagged

Thanks Melanie. I already have the first report. Would it be possible to have the other two sent via Dropbox.

Regards

Jim
0417 710 476

On 19 Jul 2019, at 12:47 pm, Melanie Fityus <Melanie.Fityus@finance.nsw.gov.au> wrote:

Hi Jim
Kieran has asked me to provide the reports below. They are obviously large and can't be e-mailed.
I have checked the Newcastle City Council DA Tracker and the first two reports listed in your e-mail are publicly available as part of the DA submission. You can download directly from the Council's website.
The direct link to the DA is here:
https://property.ncc.nsw.gov.au/T1PRPROD/WebApps/eProperty/P1/eTrack/eTrackApplicationDetails.aspx?r=TCON.LG.WEBGUEST&f=%24P1.ETR.APPDET.VIW&ApplicationId=DA2019%2f00061
Scrolling down you can see a list of all of the relevant documents. The extract below highlights the reports for 14 Jan 2019 and 18 Jan 2019.
<image002.jpg>
I will have to send the 12 March 2019 report separately.
Regards
Melanie Fityus | Senior Risk Engineer
Subsidence Advisory NSW
Better Regulation Division | Department of Customer Service
P: 4908 4300
E: sa-riskeng@finance.nsw.gov.au | www.subsidenceadvisory.nsw.gov.au
<image003.jpg>
Please consider the environment before printing this email

From: Kieran Black <Kieran.Black@finance.nsw.gov.au>
Sent: Friday, 19 July 2019 7:23 AM
To: Melanie Fityus <Melanie.Fityus@finance.nsw.gov.au>
Subject: FW: Expert Review - Mosbri Crescent
Hi Mel,
Would you be able to dropbox these coffey reports to Jim Galvin?
His email is listed below.
Cheers
Kieran

From: J.Galvin@bigpond.net.au [mailto:J.Galvin@bigpond.net.au]
Sent: Wednesday, 17 July 2019 12:11 PM
To: John Johnston <John.Johnston@finance.nsw.gov.au>
Cc: Kieran Black <Kieran.Black@finance.nsw.gov.au>; SA Risk <SA-Risk@finance.nsw.gov.au>; SA Procure <sa-procure@finance.nsw.gov.au>
Subject: RE: Expert Review - Mosbri Crescent
Hi Kieran and John

I am trying to prepare the tender document based on the Coffey Report of 14 January 2019 and the Ditton Report of 14 March 2019 that you sent me. I note that the Ditton Report states that *The Coffey reports reviewed include:*

- *Report No 754-NTLGE220504-AH (Rev 3) (14 January 2019)*
- *Report No 754-NTLGE220504-AI (18 January 2019)*
- *Report No 754-NTLGE220504-AI (12 March 2019)*

I presume that you have no need for the latter 2 Coffey reports to be reviewed. If they do need to be reviewed, I would need to see them to gain some idea of the issues and time involved.
Regards
Jim
+61 417 710 476

From: John Johnston <John.Johnston@finance.nsw.gov.au>
Sent: Wednesday, 10 July 2019 10:34 AM
To: J.Galvin@bigpond.net.au
Cc: Kieran Black <Kieran.Black@finance.nsw.gov.au>; SA Risk <SA-Risk@finance.nsw.gov.au>; SA Procure <sa-procure@finance.nsw.gov.au>
Subject: FW: Expert Review - Mosbri Crescent
Hi Jim,
In Kieran's absence, I have been asked to send you the tender form for the review.
Please find attached.
Cheers,
John Johnston | Senior Risk Engineer
Subsidence Advisory NSW
Policy and Regulation Division | Department of Customer Service
P: 4908 4353
E: John.Johnston@finance.nsw.gov.au | www.subsidenceadvisory.nsw.gov.au
<image001.jpg>

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Hannah Stephenson

From: Mosbri Review for Jim Galvin
Sent: Wednesday, 3 July 2019 1:13 PM
To: Kieran Black
Subject: You've joined the Mosbri Review for Jim Galvin group

Office 365 Work Brilliantly Together

MR

Welcome to the Mosbri Review for Jim Galvin Group

Mosbri Review for Jim Galvin

Public group with 1 member

View group in Outlook

Get started

You're set to receive only replies and events in your inbox. Change this setting below, or anywhere you see the group in Outlook, to see all of this group's conversations.

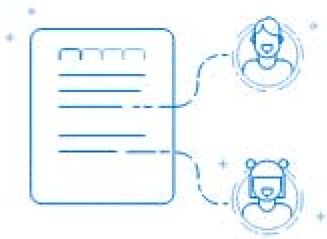
Follow in inbox

Get the conversation rolling

Start your own. Or just catch up. All in the group inbox.

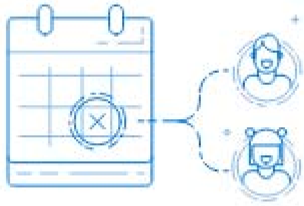
Keep things together

Now, your documents and attachments in one place.



Stay on the same page

Groups that take notes together, stay together. In the group notebook.



Don't miss a thing

Track milestones (and everything in between) in the group calendar.

Collaborate with your group across Office 365

Create content seamlessly

The group's SharePoint team site is the place to share news, work on and organize content, manage rich data within lists, and track all site activities across all members.

Check it out

Organize group work with Planner

Planner makes it easy for your team to create new plans, organize and assign tasks, share files, chat about what you're working on, and get updates on progress.

Check it out

Go further. Do more. Look here.

Follow your Twitter feeds.

Track your Salesforce updates.

All your Trello cards, lists and boards.

Team notifications from Jira.

View all connectors

Microsoft Corporation
One Microsoft Way
Redmond, WA 98052 USA