Look-back on 5 years of SCAN 2D seismic acquisition and (re)processing

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Dag van de Warmtetransitie

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EBN B.V.

Ministerie van Economische Zaken en Klimaat

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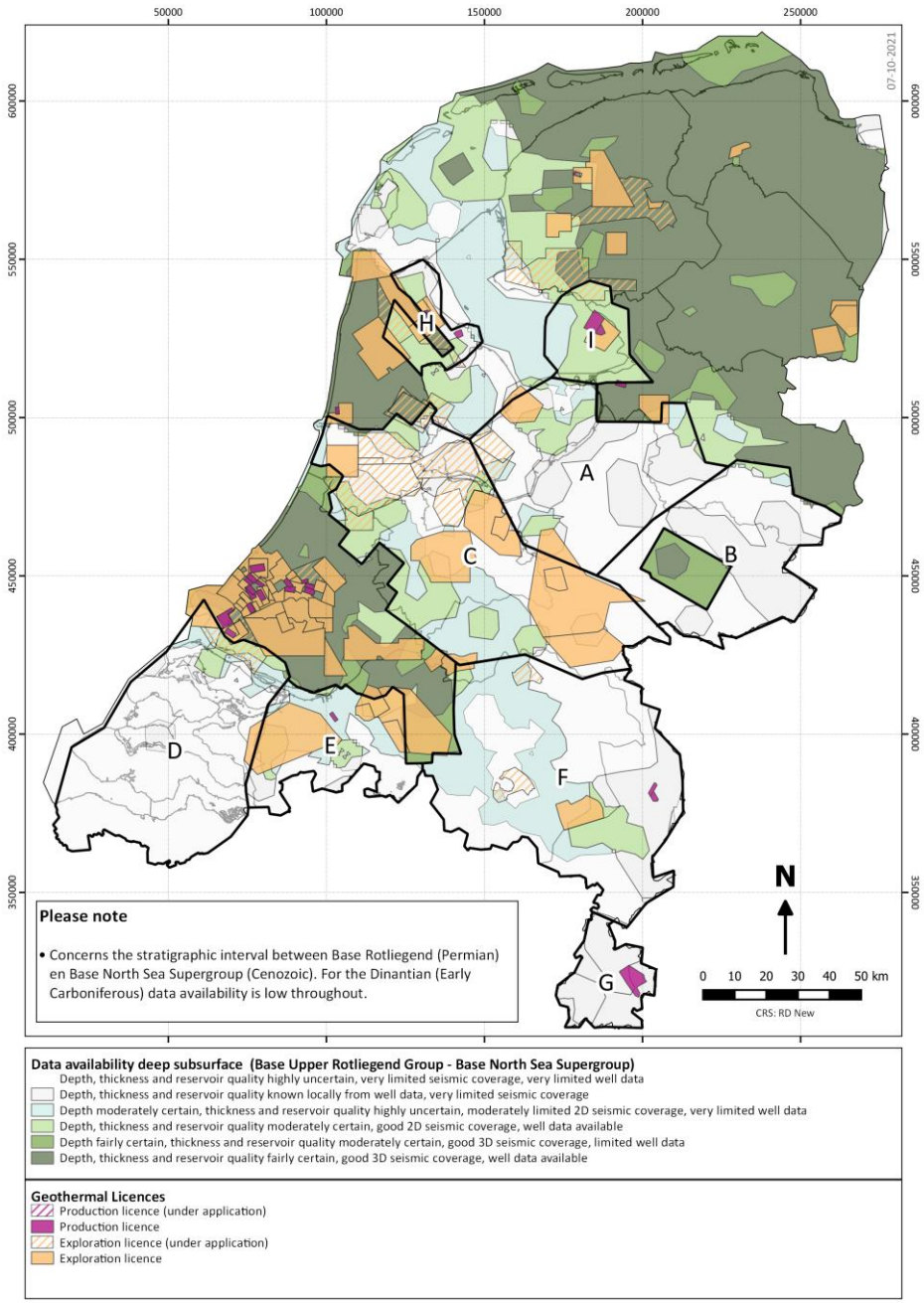
TNO

Agenda

- Introduction to the SCAN program
- SCAN 2D seismic acquisition & data availability
- 2D PreSTM processing examples
- 3D cross-spread acquisition example
- Lessons learned from the SCAN 2D seismic acquisition
- 2D reprocessing summary & examples
- Data selection for a 2D seismic reprocessing project
- How to make your (re)processing project a success?
- Summary

The SCAN program

- The SCAN program is implemented by EBN in collaboration with TNO and financed by the Dutch ministry of economic affairs and climate policy
- The aim of SCAN is to collect data in areas of the Dutch subsurface that have historically been left underexplored to accelerate the development of geothermal projects in the energy transition
- The SCAN data collection comprises:
  - Acquisition of new 2D seismic data (1950 km)
  - Reprocessing existing 2D seismic data (7500 km)
  - Drilling of several research wells
- All data SCAN collects is public and can be used by municipalities and project developers to better evaluate where opportunities lie for geothermal projects
- SCAN is a research program to collect subsurface data and will not develop geothermal projects



SCAN 2D seismic acquisition & data availability

- Acquired 1.837 line km of new regional 2D (46 lines) and 20 local lines (106 km) to support the SCAN well locations with zero LTIs
- Recorded 30.196 shots and 383.467 receivers planted
- SCAN acquisition was combined with local 2D seismic acquisition programs for UDG and MRA
- Visited 164 municipalities, distributed 135.000 letters into the neighbourhoods prior to acquisition
- Land access permissions from some 6.200 land users
- All 46 regional lines & 11 local lines are available on the NLOG website (https://www.nlog.nl/scan-2d-seismische-data)

MRA = Metropoolregio Amsterdam

SCAN 2D seismic acquisition

Key acquisition parameter:

- Shot spacing: 60 m
- Shot depth: Nominally 20 m
- Shot type: Seismic explosives
- Receiver spacing: 5 m
- Receiver type: Wireless nodes
- Spread type: Split-spread
- Maximum offset: 7 km
- Recording length: 10 seconds

Key SCAN HSE numbers (30.11.2023):

- Zero LTIs
- Manhours worked: 1.090.750
- KMs driven: 2.668.779

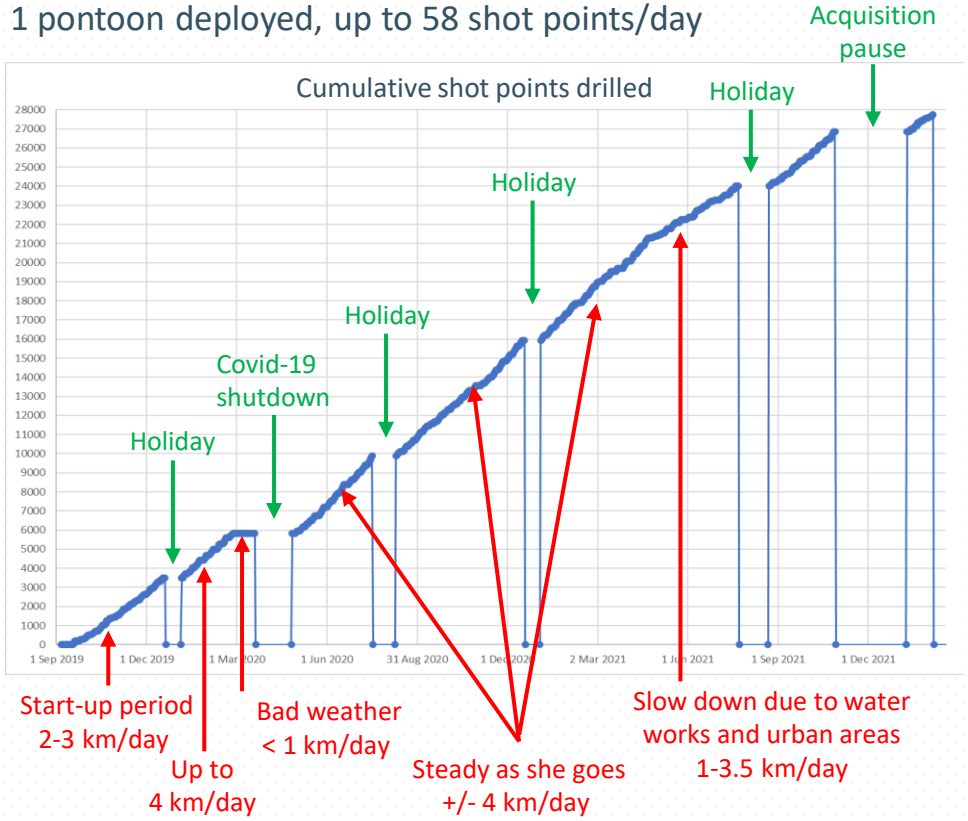
(Numbers include the EBN test line (SCAN001), and all local 2D seismic acquisition).

Land drill tractor,
usually 5 tractors deployed,
up to 100 shot points/day

Shooting crew,
up to 160 shot points/day,
usually 1 crew deployed

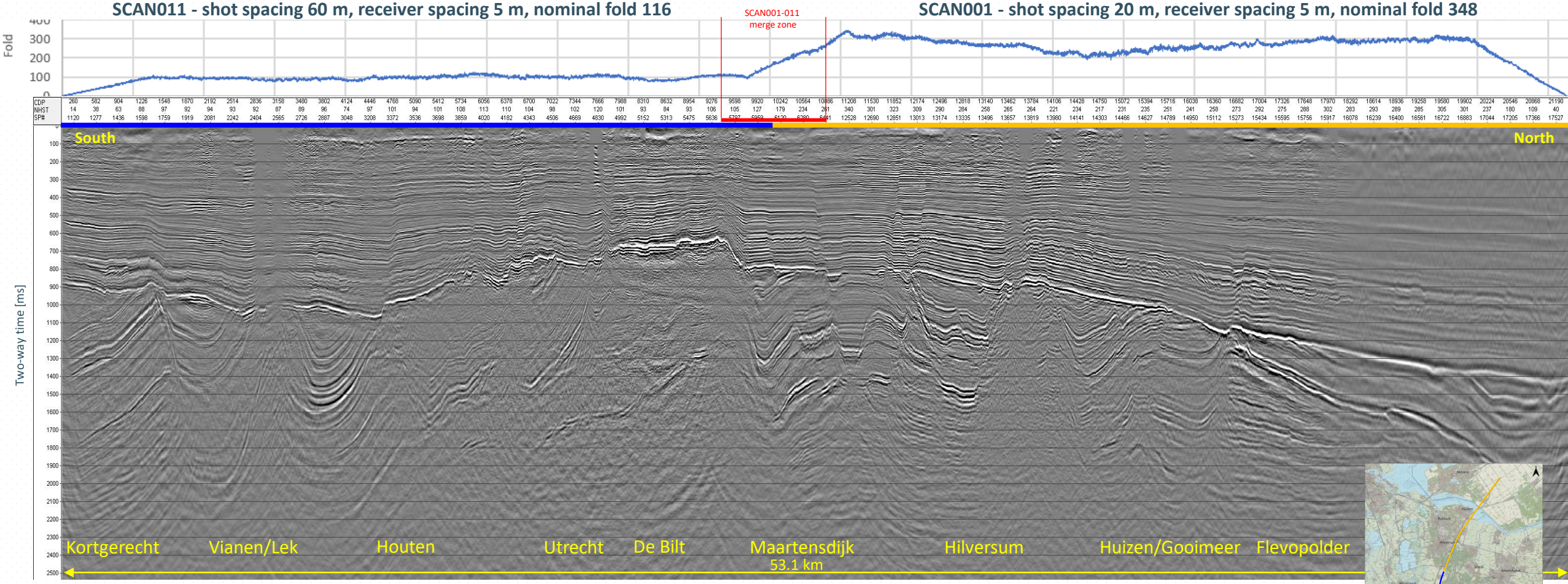
Geophones

Barge/pontoon mounted drill tractor, usually 3 barges and 1 pontoon deployed, up to 58 shot points/day



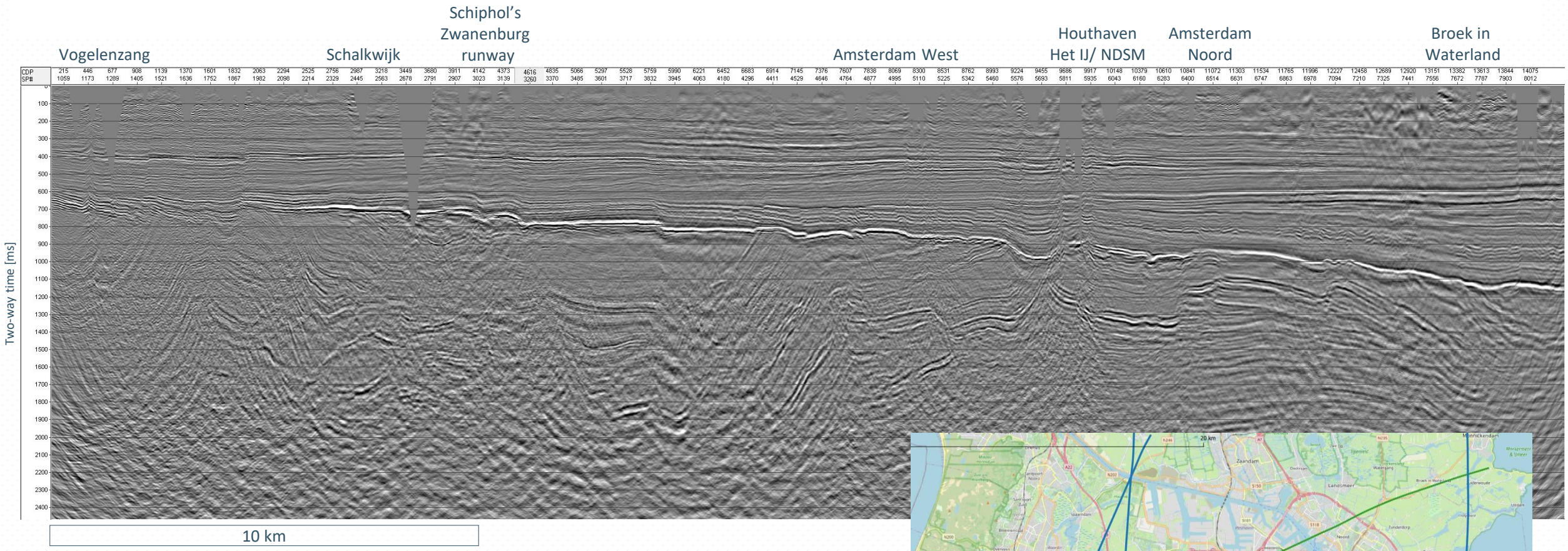
Average shot point drilling since acquisition start (477 days of shot point drilling) is 3.7 km/day.

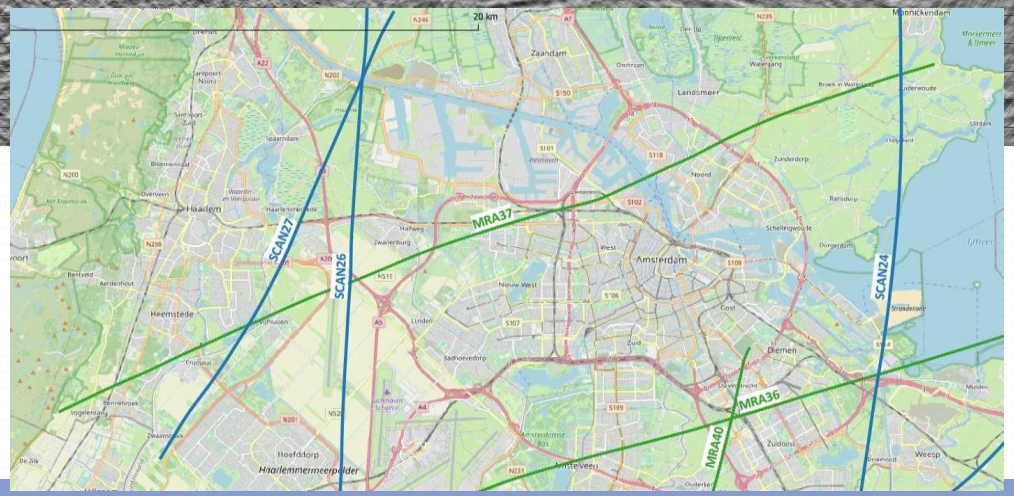
SCAN 2D PreSTM processing – SCAN011 & SCAN001



- Shot spacing of 60 m shot & 5 m receiver spacing provide adequate data quality for 2D regional seismic interpretation
- No significant data quality reduction compared to 2019 test line that would compromise seismic interpretability

SCAN 2D PreSTM processing – MRA037





- With careful planning it was possible to acquired several 2D seismic lines in close proximity to Amsterdam.

SCAN 2D regional/ local seismic on NLOG

NLOG
Nederlandse Olie- en Gasportaal

NLOG website:
https://www.nlog.nl/scan-2d-seismische-data

- Boringen
- **Seismische data**
  - NAM 2D seismische data
  - **SCAN 2D seismische data**
- Productie en injectie data
- Gasvelden
- Modellen, kaarten en datasets
- Dashboards
- Kernhuis van de Geologische Dienst
- Data aanleveren op het Innameportaal

Nummer	Lijn	Toponiem	Eindresultaat: -Seismische secties -Snelheden -Processingrapport	Opmerking
1	L2EBN2019ASCAN001	Testlijn Utrecht – Almere	Seismische data & Processingrapport	Zie Lijn 11 voor een nieuwe versie van Lijn 1.
2	L2EBN2019ASCAN002	Roer Valley Graben – Nijmegen – Bronckhorst	Seismische data, Processingrapport	Extra resultaat, en als test naast de reguliere aanpak, PreSDM-processing: data, rapport.
3	L2EBN2019ASCAN003	Buurmalsen – Renkum	Seismische data, Processingrapport	

Up to line L2EBN2022ASCAN057

For each SCAN line
16 files are available
for downloading
from NLOG

and

a processing report

8 seismic files for each line:

- One full stack in relative true amplitude and one scaled version.
- One near stack in relative true amplitude and one scaled version.
- One mid stack in relative true amplitude and one scaled version.
- One far stack in relative true amplitude and one scaled version.

6 velocity files for each line:

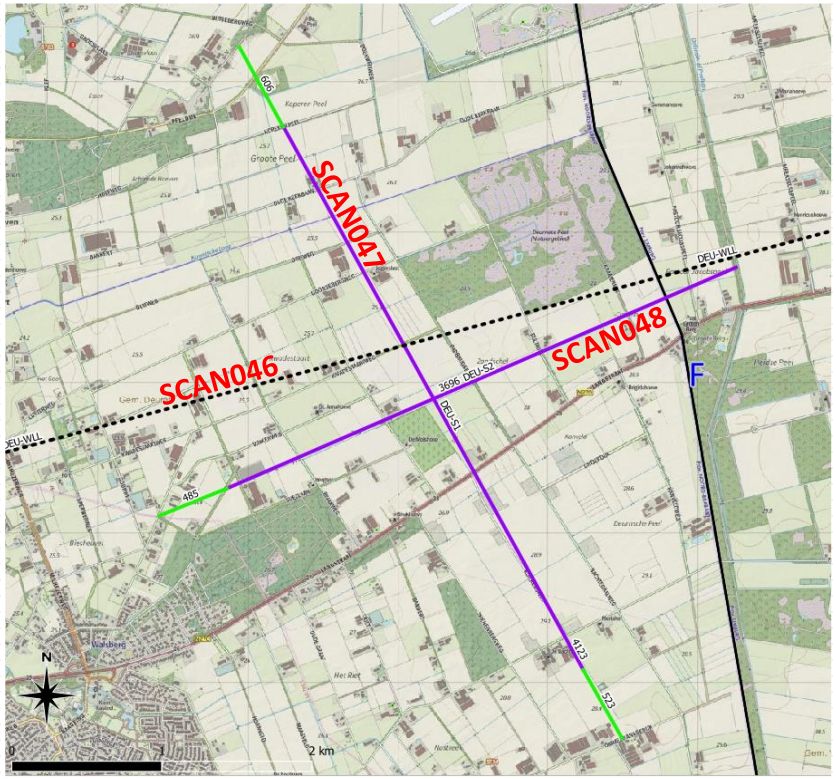
Stacking and migration velocities and an anisotropy volume in two different formats.

2 trace mute files:

These files describe how much data was summed up into the final image.

SCAN 3D cross-spread acquisition – Deurne area

- To de-risk the subsurface at the SCAN well locations as much as possible, often additional short 2D lines have been acquired since the completion of the regional SCAN 2D seismic acquisition
- Whenever possible, the design was chosen such that 3D cross-spread data could be acquired simultaneously



Regional line SCAN046
Two local lines SCAN047 & 048

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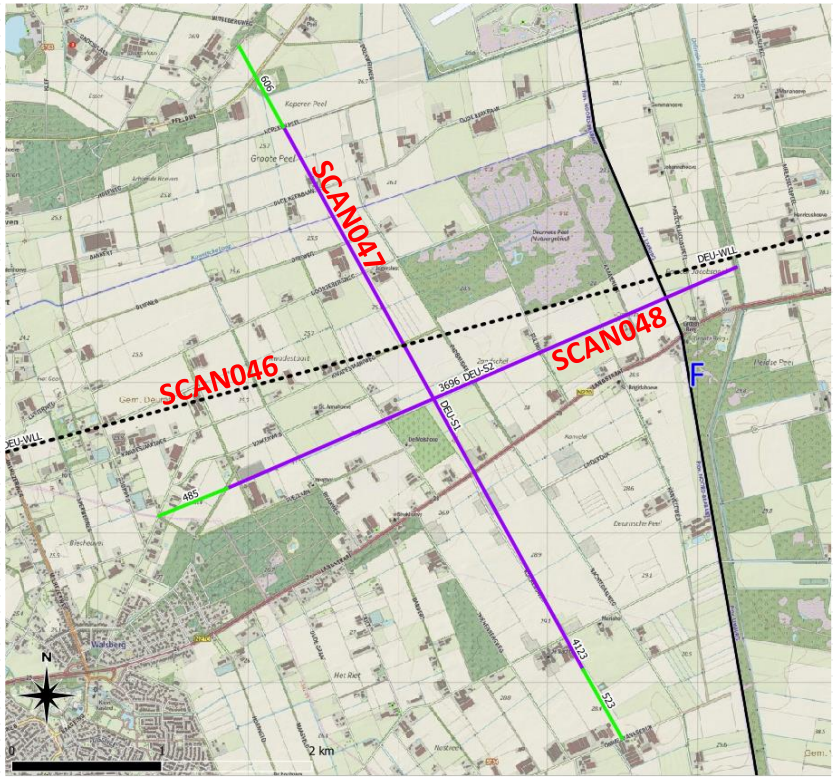

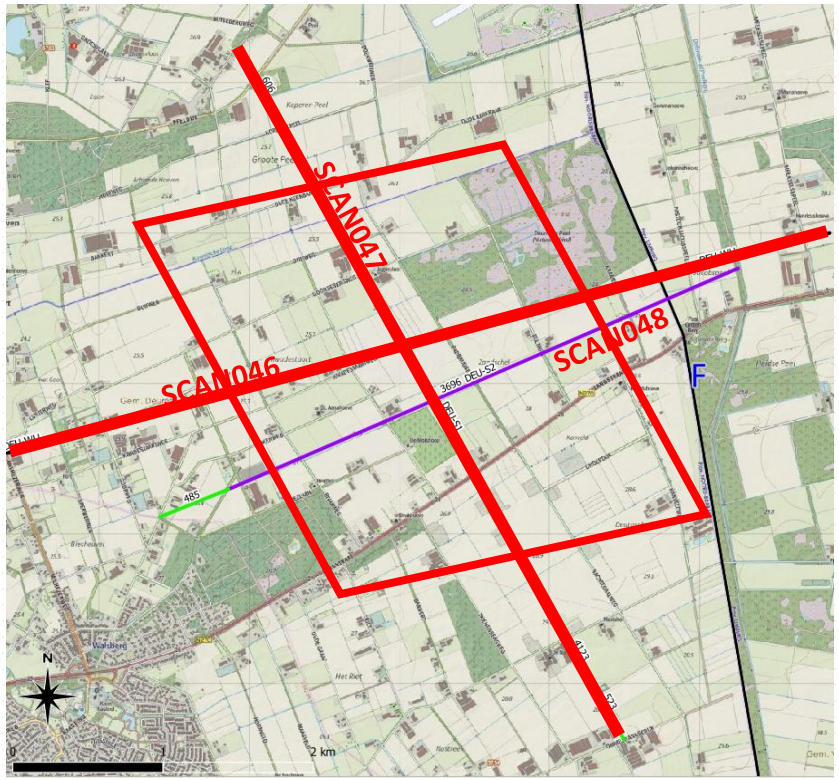

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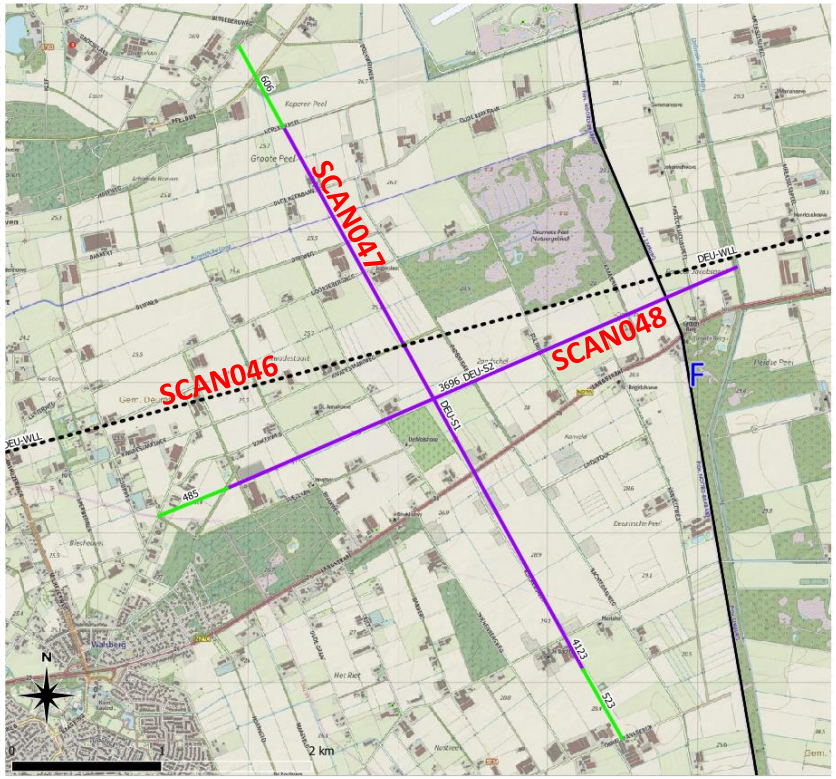

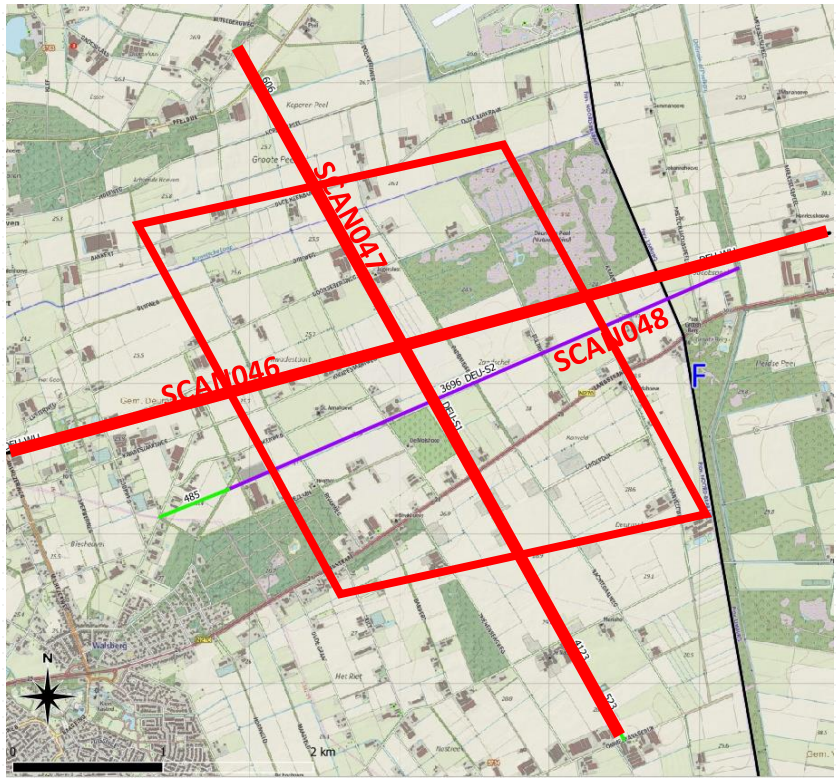

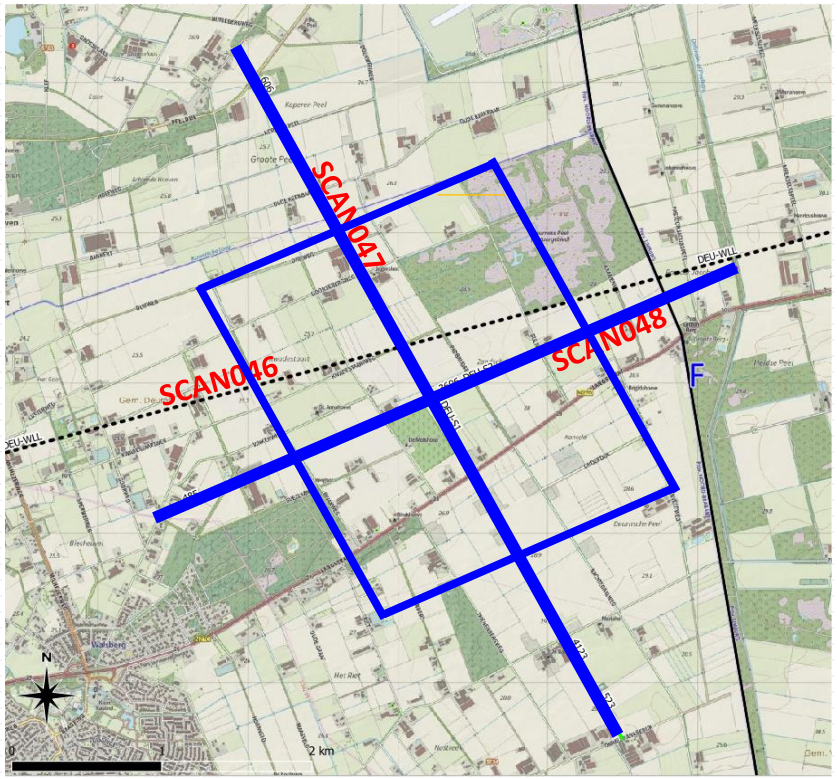

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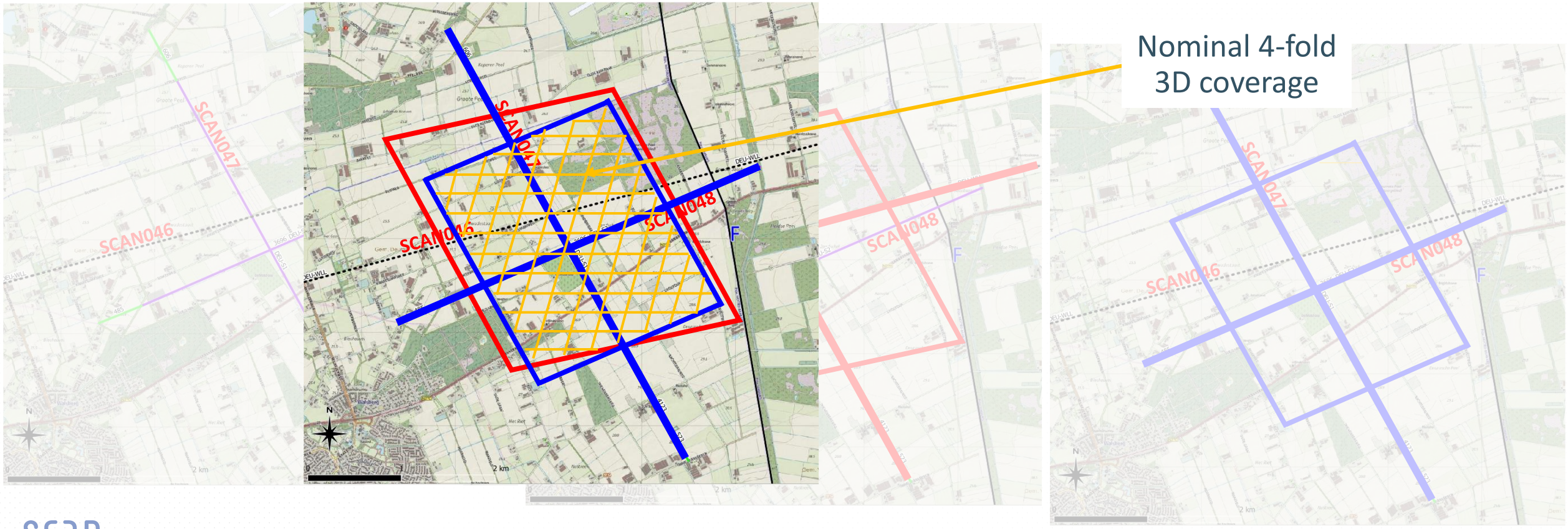

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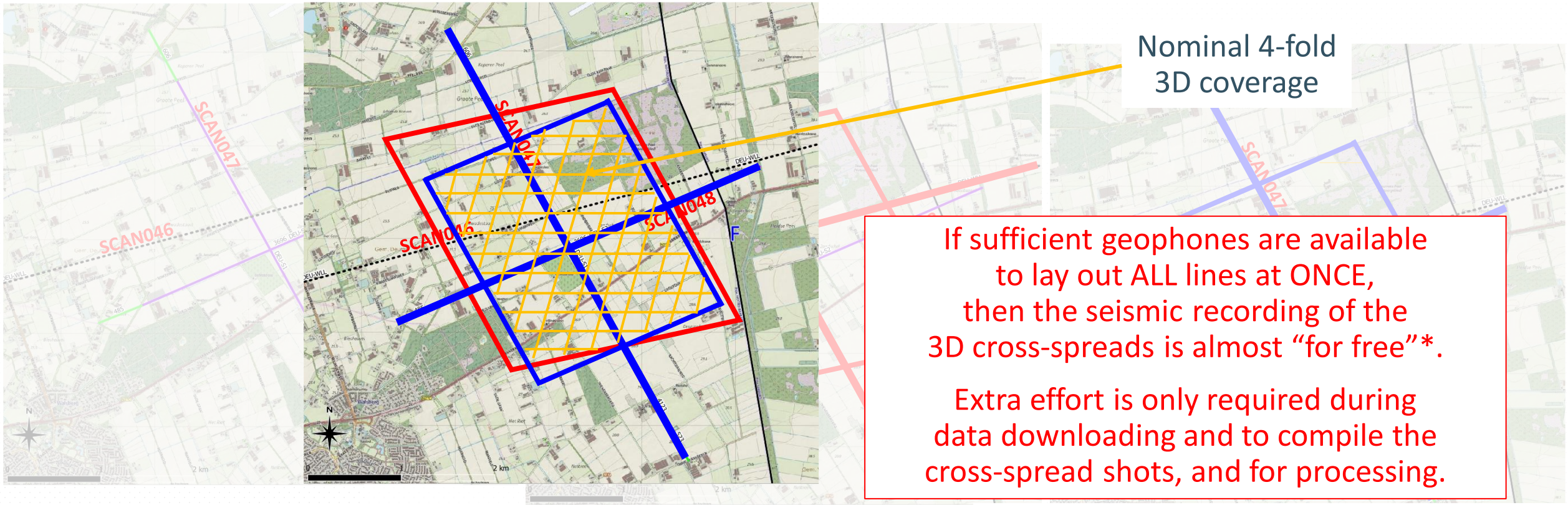

*: This requires a seismic source strong enough to record the wide crossline offsets.

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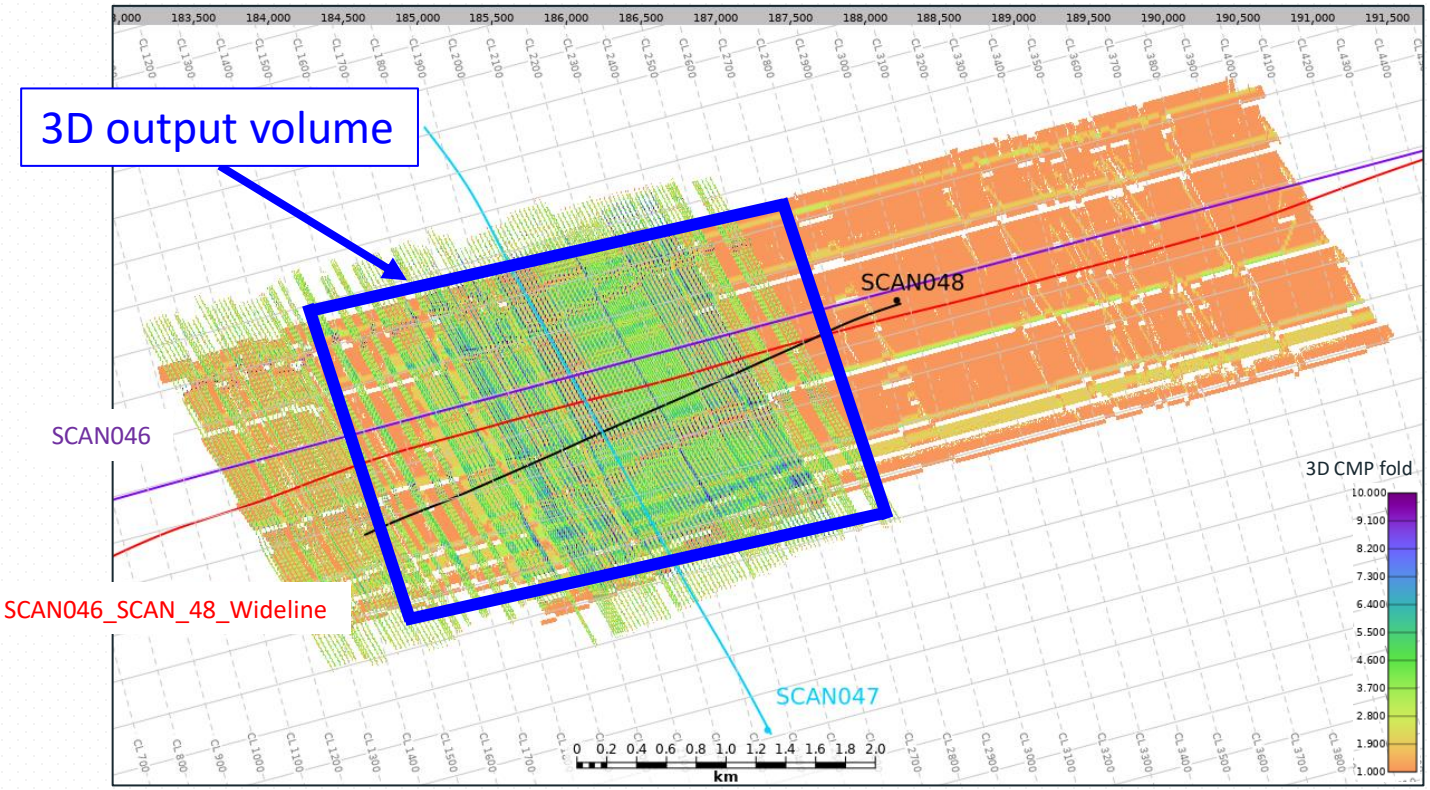
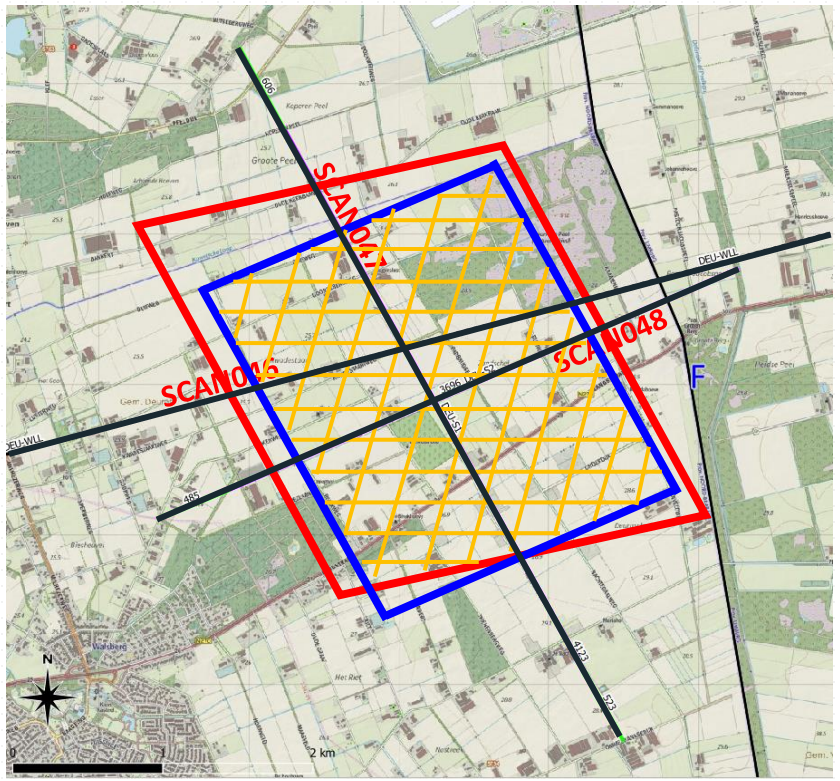
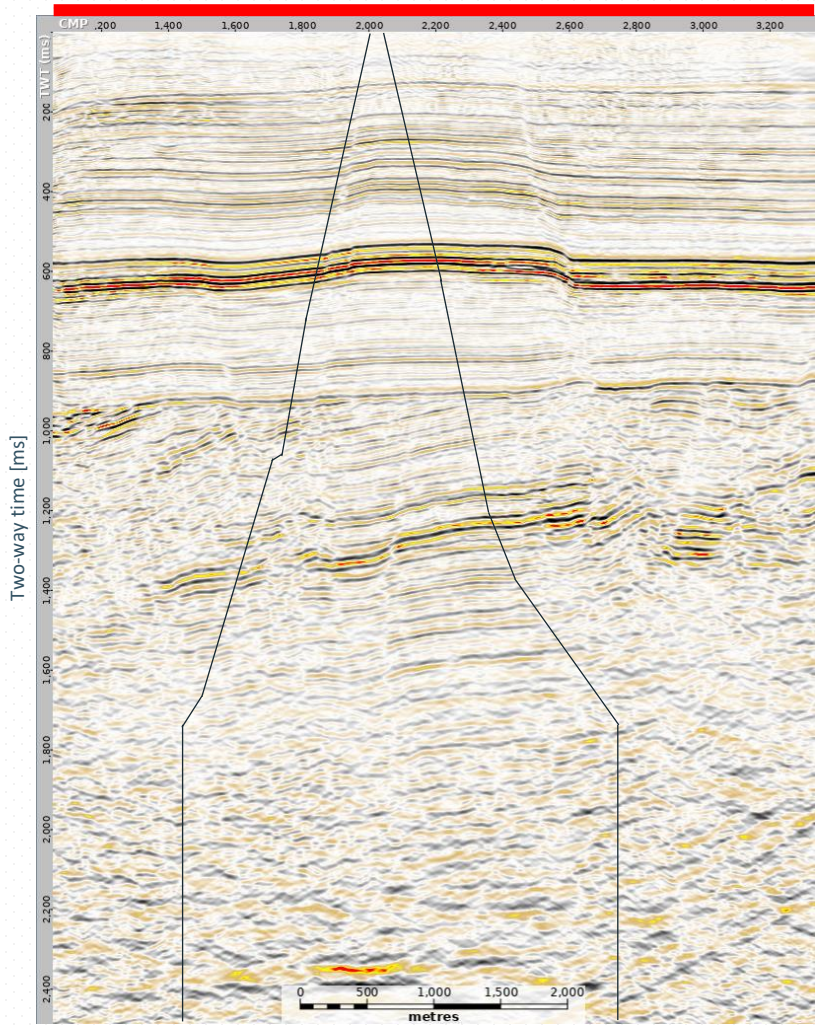




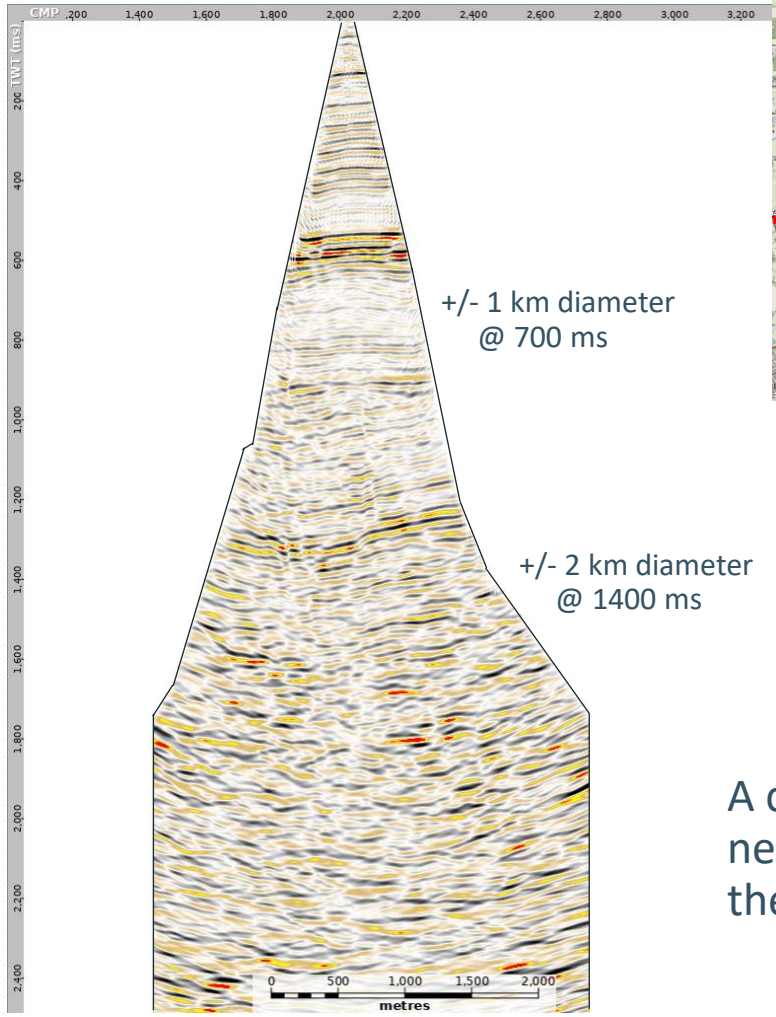
SCAN acquisition, Deurne area

SCAN 3D cross-spread acquisition – Deurne area

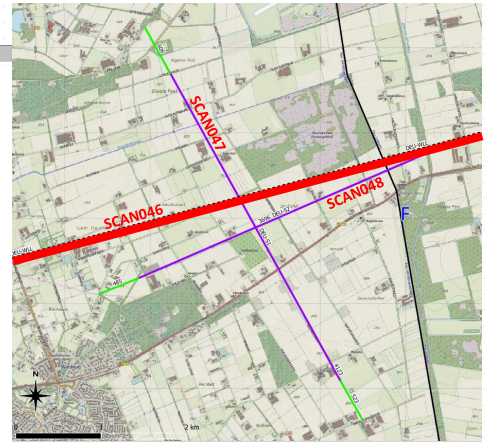
3D cross-spread comparison with SCAN046 (AGC version), 3D cross-spread data extracted from 3D volume along SCAN046



SCAN046



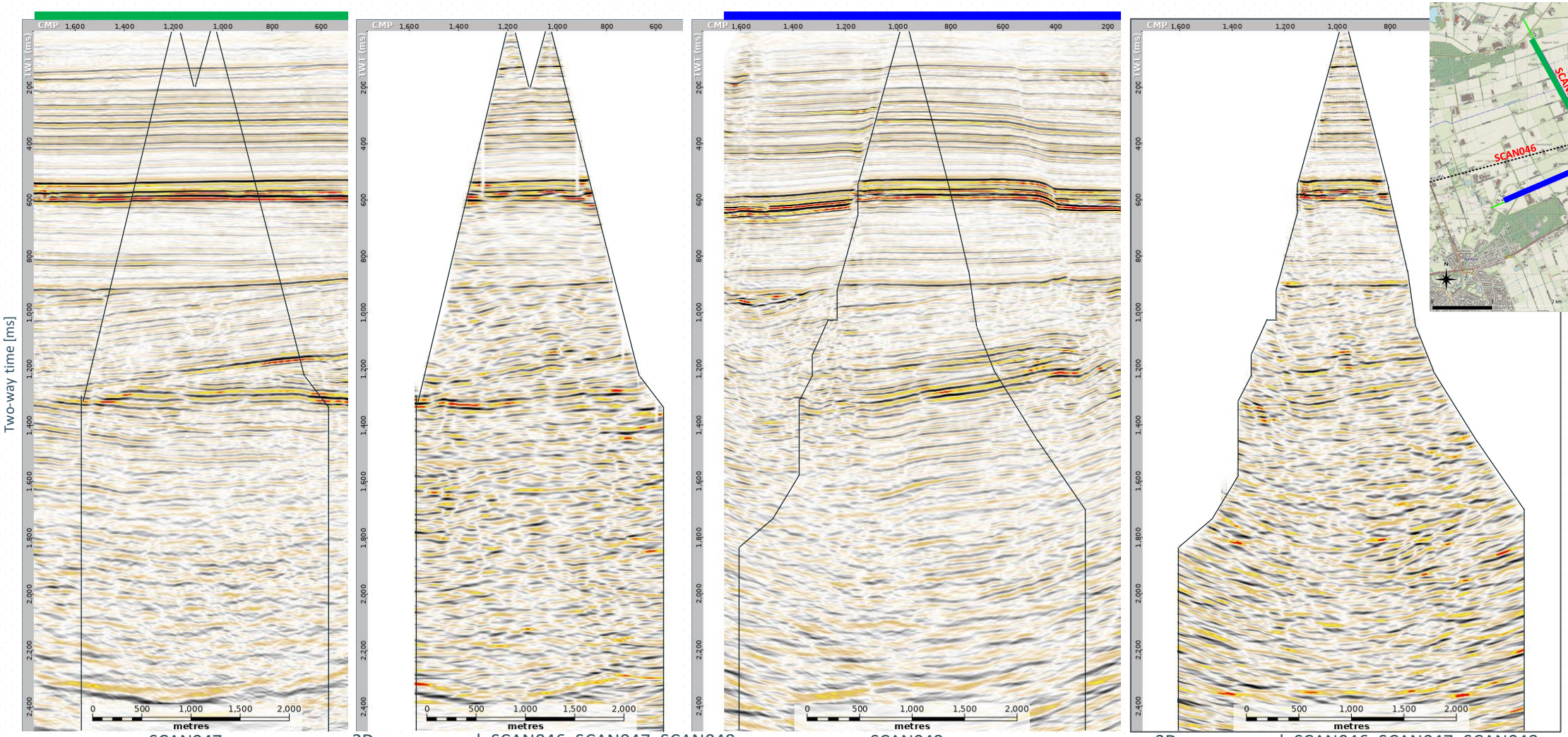
3D cross-spread_SCAN046_SCAN047_SCAN048



A cross-spread is lacking near offset data, hence the cone appearance.

SCAN 3D cross-spread acquisition – Deurne area

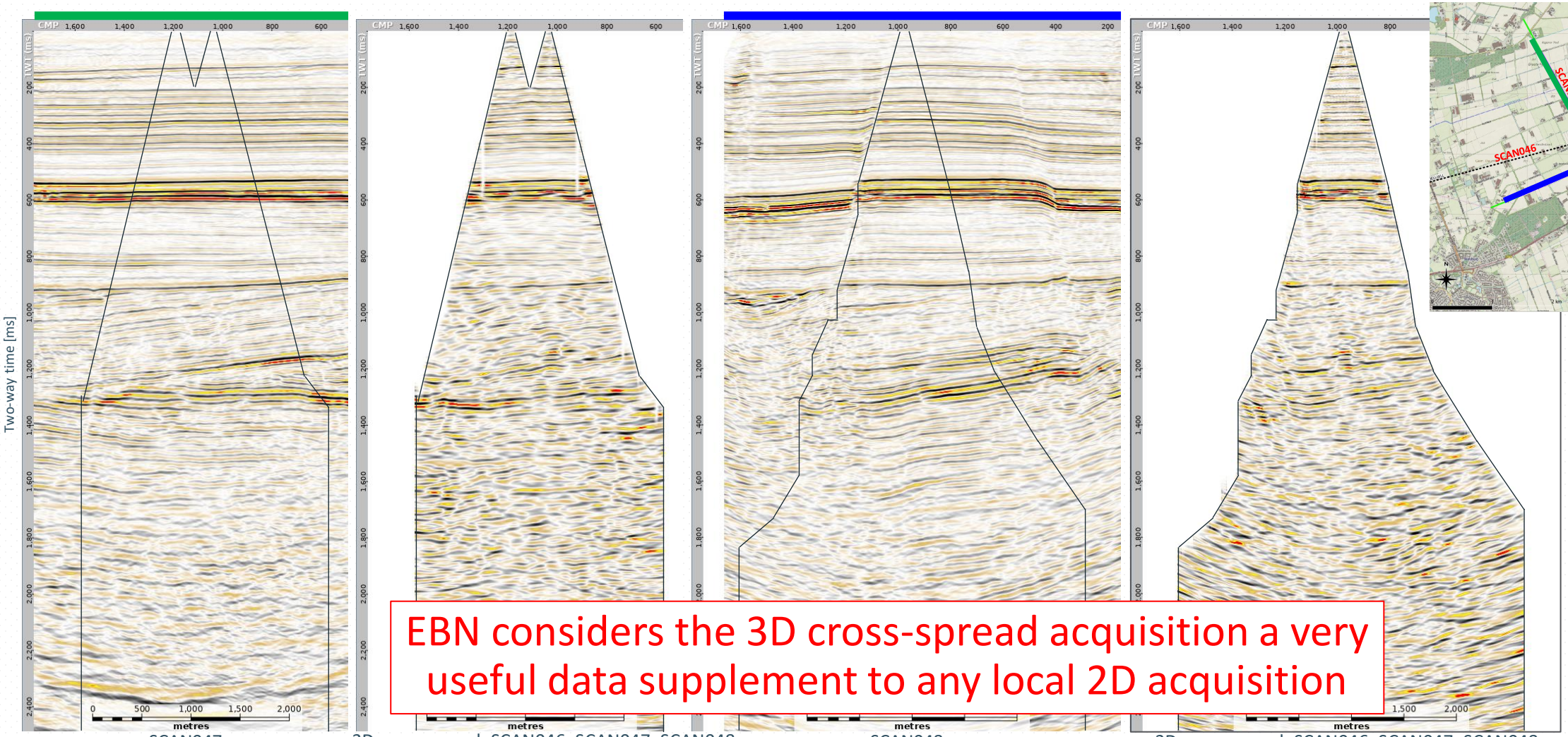
3D cross-spread comparison with SCAN047 & 048 (AGC version), 3D cross-spread data extracted from 3D volume along SCAN047 & SCAN048



SCAN047 | 3D cross-spread_SCAN046_SCAN047_SCAN048 | SCAN048 | 3D cross-spread_SCAN046_SCAN047_SCAN048

SCAN 3D cross-spread acquisition – Deurne area

3D cross-spread comparison with SCAN047 & 048 (AGC version), 3D cross-spread data extracted from 3D volume along SCAN047 & SCAN048



SCAN047 | 3D cross-spread_SCAN046_SCAN047_SCAN048 | SCAN048 | 3D cross-spread_SCAN046_SCAN047_SCAN048

Lessons learned from the SCAN 2D seismic acquisition

- Acquisition of 2019 EBN test line (SCAN001) was fundamental to survey design
  - Through seismic processing 7 different 2D acquisition designs could be tested, allowing for a balanced decision between data quality, survey costs and survey duration
- Wireless node technology allowed for very high receiver density & long offsets, which resulted in very dense subsurface sampling of 2.5m and a nominal high fold of 116
  - Little visibility of nodes resulted in low numbers of theft and vandalism
- Sonic drilling & explosive sources ensured powerful seismic energy source and limited source generated noises, e.g., ground roll
  - Vibroseis sources often suffer from weak near surface conditions, resulting in poor coupling and relatively little seismic energy being delivered into the subsurface

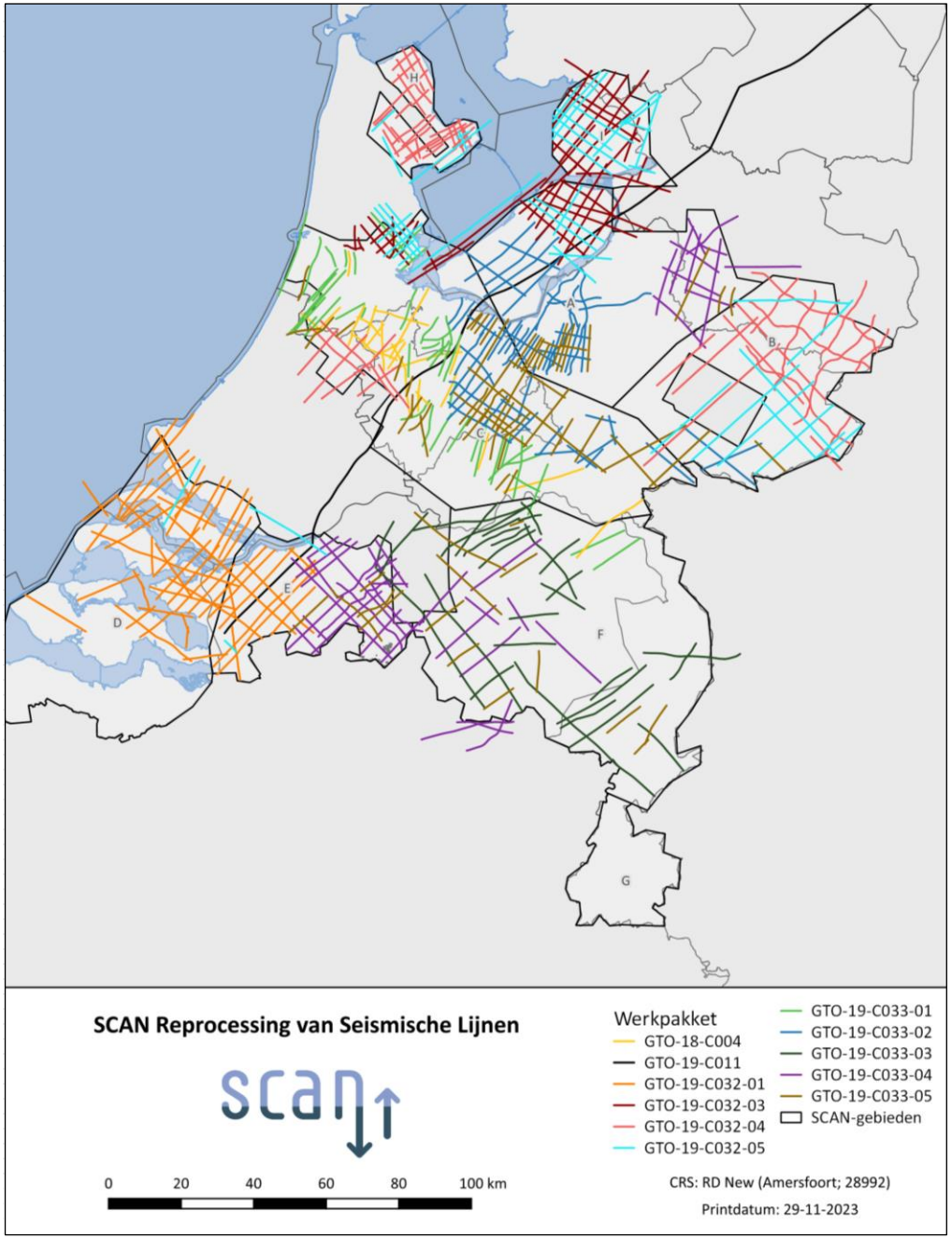
Lessons learned from the SCAN 2D seismic acquisition

- Careful survey planning, using improved GPS & GIS systems allowed for placing of more than 92,8% of all theoretical shot points, ensuring the “desired energy” got into the subsurface
- The SCAN lines were kept as straight as possible in survey planning, so the seismic data is “perfectly” projected onto the 2D line with as little cross-line offsets as possible, resulting in better seismic quality
  - Vibroseis trucks usually must stay on roads which results in “crooked” 2D seismic lines, while drill tractors can go almost anywhere as long as the required safety distance to building is maintained
- With a combination of deep shot holes of 34 m and a small charge size of 120 g, SodM granted an exemption to the mining law allowing for the reduction of safety distance to houses from 50 m to 30 m within the city limits of Amsterdam, resulting in an average seismic fold of 85* (line MRA037)

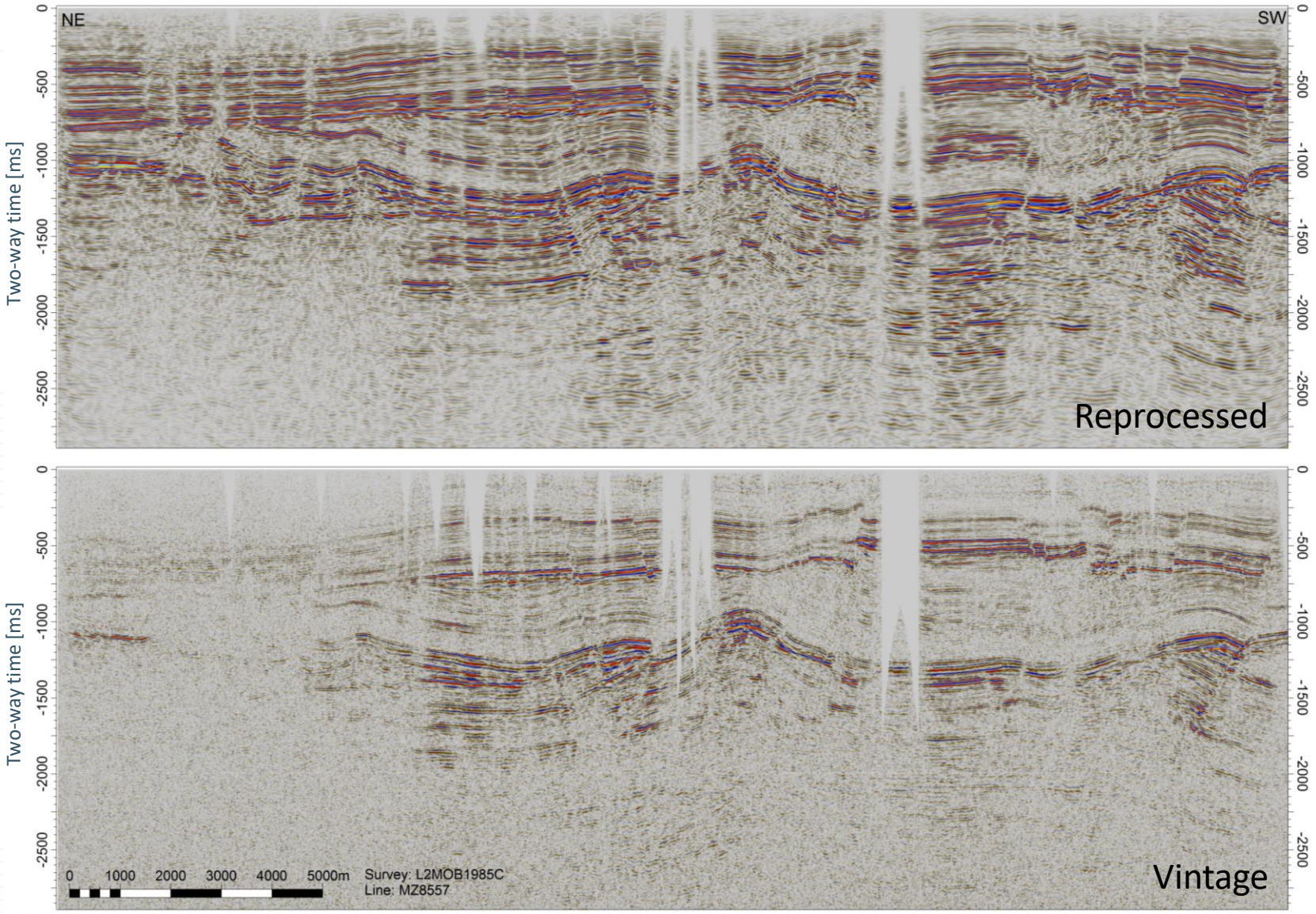
*Excluding 2.5km run-in & run-out

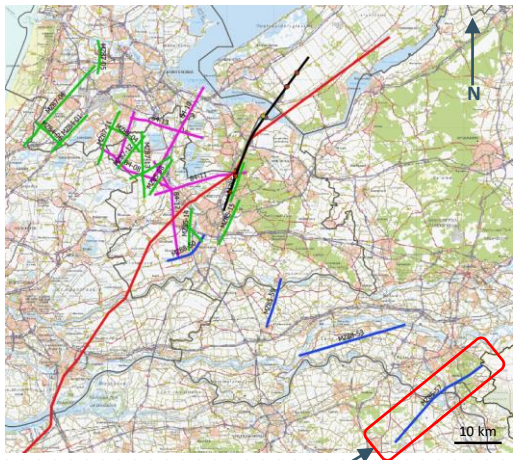
SCAN 2D reprocessing summary

- 2D seismic data, acquired mainly from the early 70s to early 90s, is reprocessed through a broad-band Pre-Stack Time Migration sequence
- Retrieval and QC of vintage data performed by TNO and EBN took more than 6.500 hrs (> 3.5 FTE years)
  - Completeness check of raw field shots, observer logs and navigation data
  - Readability check of raw field shots (SEGY format)
  - If need be, reconstruction of navigation data
  - If need be, reconstruction of elevation data
- A total of 11 reprocessing projects have been released to NLOG, which amounts to 7.504 line km (451 lines)
- Time spend by EBN on QA/QC of seismic processing contractors was more than 5.100 hrs



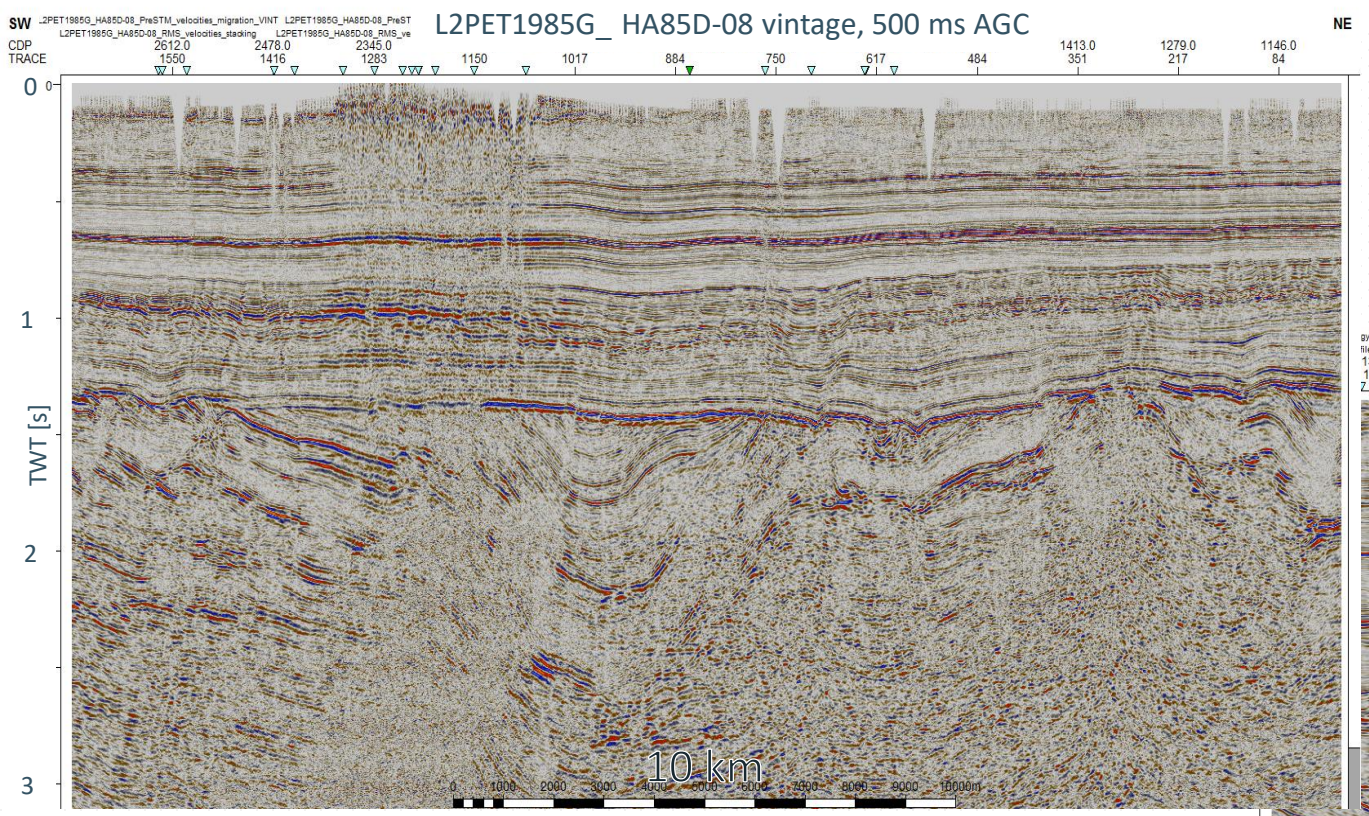
SCAN 2D reprocessing – Old digital vs. new digital



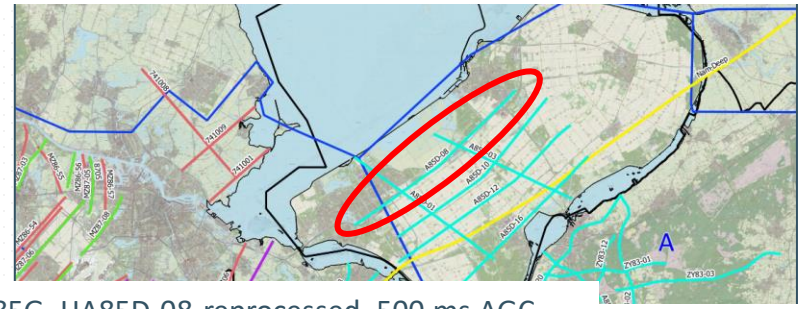


- Reprocessing usually improves Signal-to-Noise, event continuity as well as fault imaging

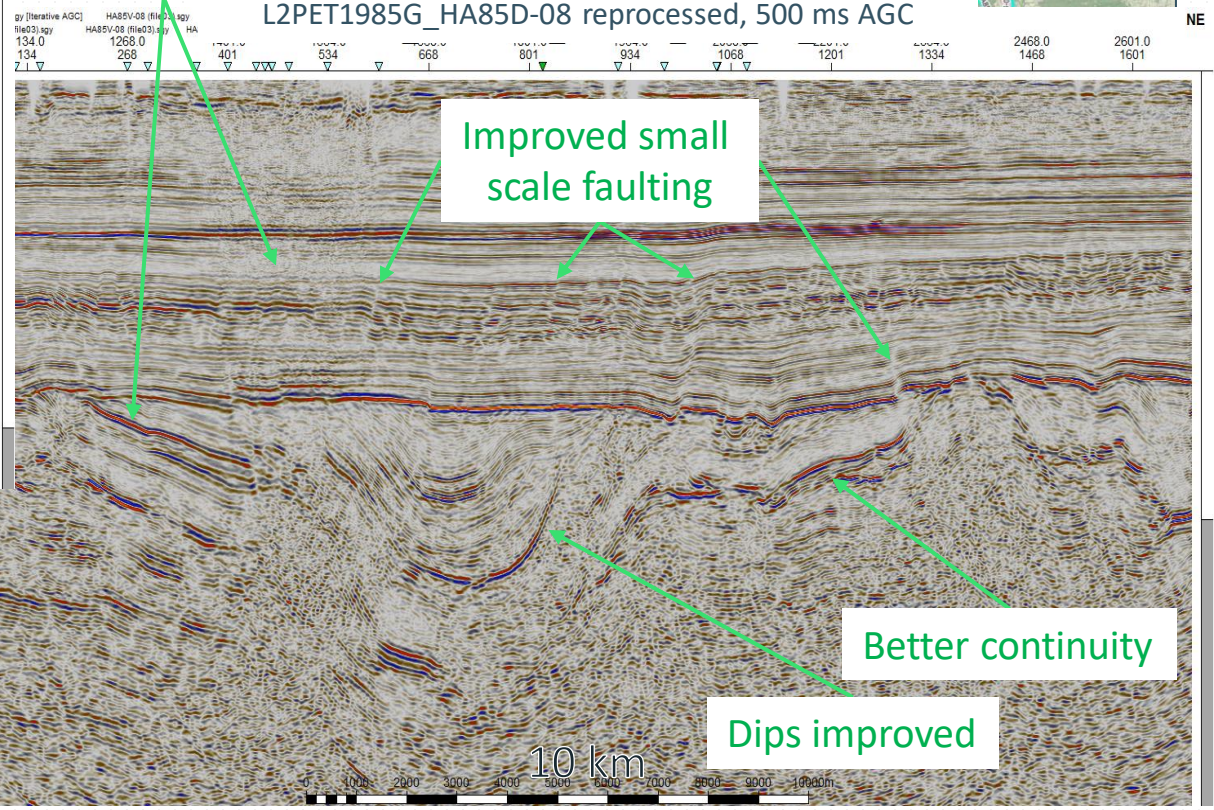
SCAN 2D reprocessing – Old digital vs. new digital line



Flevopolder
Almere-Lelystad

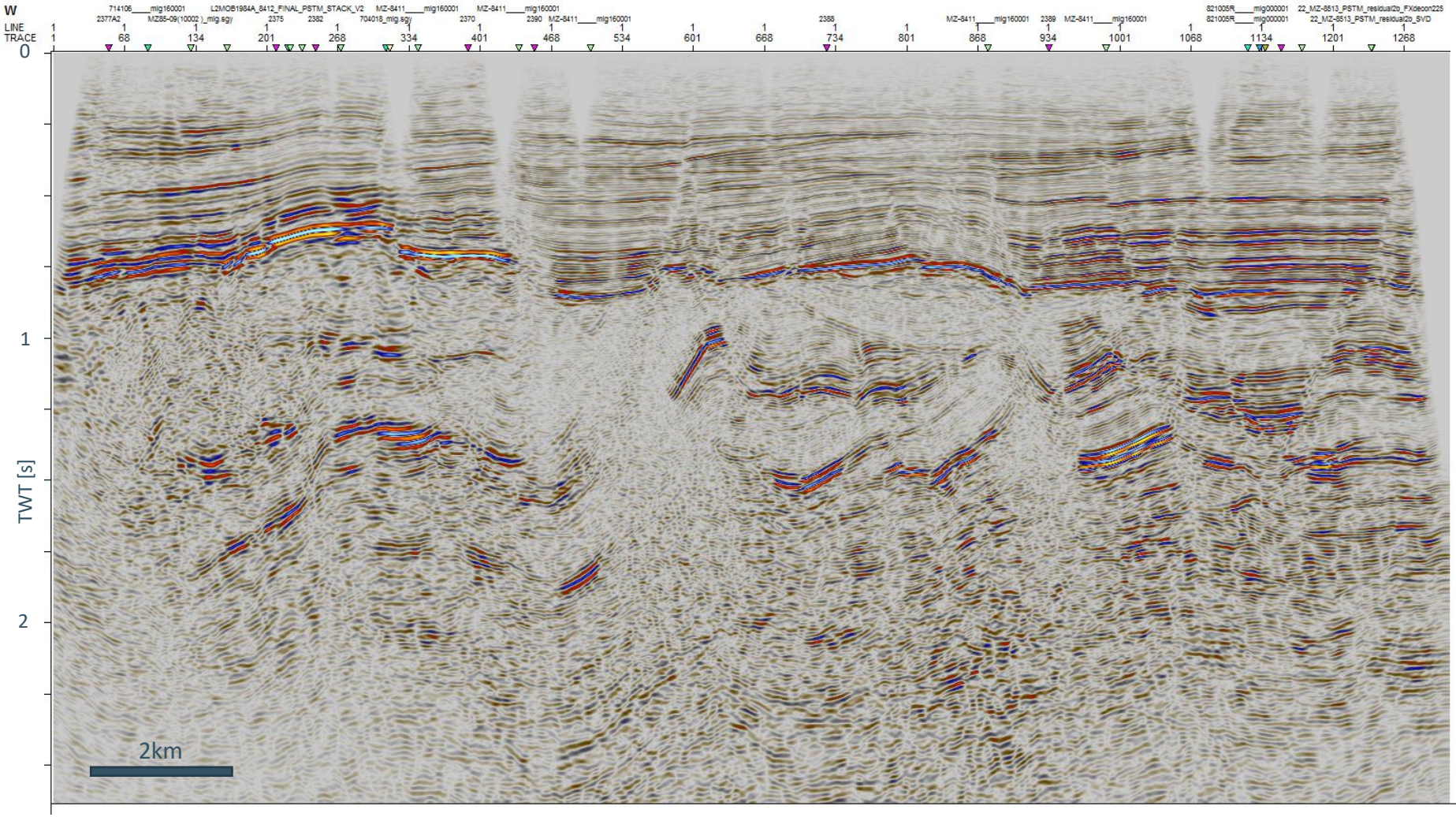


Better S/N



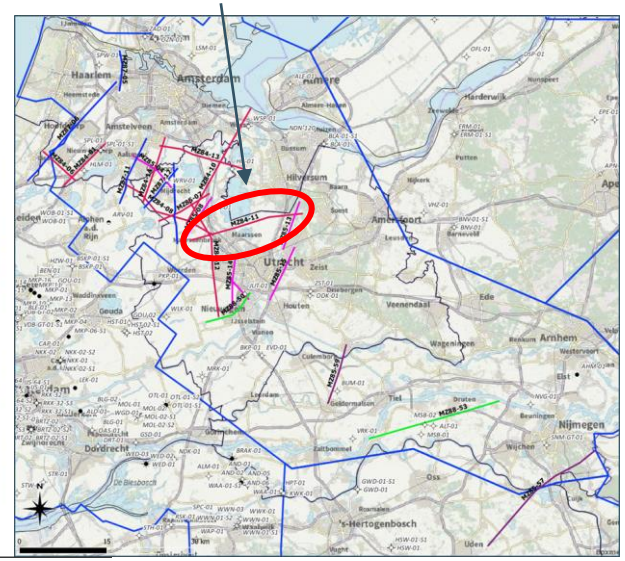
- Reprocessing usually improves Signal-to-Noise, event continuity as well as fault & dip imaging

SCAN 2D reprocessing – “New” digital vintage line



- No digital or paper section present in TNO archive for this line.
- Used vintage field data to create a “new” line

Line MZ84-11 north of Utrecht



Data selection for a 2D seismic reprocessing project

- Basic geophysical & geological selection criteria should be:
  - Select (relative modern) data with the highest possible maximum fold*
    - In the 1970s the fold was usually 6 to 24, in the 1980s the fold was usually 40 to 96**
  - Depending on geological target depth and structural complexity, select data with the appropriate maximum offsets**
    - In the 1970s max. offsets were usually 1175 m to 2450 m, in the 1980s max. offsets were usually 1200 m to 3600 m
  - There are 2 common choices of seismic sources, Vibroseis or Explosives.
    - Based on experience, usually in NL explosive sources have deeper penetration***
- If the choice of 2D vintage seismic data is plentiful:
  - Select the longest lines available
  - Include lines that intersect well locations for seismic well-tie calibration
  - Dip lines are more favourable than strike lines

*Fold means how many times a subsurface point has been measured
** Technically limited due to the acquisition systems at the time
*** If charges were placed sufficiently deep

How to make your (re)processing project a success?

A. Make sure the vintage raw field data is complete for reprocessing.	a) If you received the data from TNO, request TNO to apply the same QA/QC workflow as developed with EBN. If not, consider to have the data reviewed by an expert upfront for completeness.
B. Clearly define the scope of the reprocessing upfront.	b) Define what you want to get out of the reprocessing in terms of subsurface seismic imaging improvements. If you don't know what you want, you surely won't get the best possible reprocessing result.
C. Clearly define, in writing, a minimum base processing flow, intermediate and final processing products.	c) Defining a base processing flow upfront in writing avoids potential price negotiations with the seismic processing contractor at a later stage when he feels you request more than was agreed/budgeted for. Consider requesting a relative true amplitude version and an AGC scaled version of the final reprocessing result.

How to make your (re)processing project a success?

D. Have a face to face (at least online) processing kick-off meeting with contractor.	d) This amplified the importance of the project to the seismic processing contractor, and it allows an initial technical discussion and setting of expectations.
E. If you don't have geophysical expertise inhouse, get help to ensure proper QA/QC of the processing contractor.	e) A seismic processing contractor is only as good as the QA/QC you are willing to "enforce". You want the processing contractor to do his "best", not just run the data through "a" processing flow as quickly as possible. Parameter testing needs to be challenged technically to get the best reprocessing result.
F. EBN's reprocessing reports are available on NLOG and a reprocessing close-out report on the EBN Kennisbank.	f) These documents can help you to define the scope of the reprocessing project, a base processing flow and your project deliverables. … and if in doubt, you can always contact EBN for advice.

EBN reprocessing close-out report:
https://www.ebn.nl/feiten-en-cijfers/kennisbank/scan-2d-herbewerking-eindrapport/

Summary

- The SCAN program is providing a wealth of new and improved subsurface data:
  - A little over 1.950* line km of new high quality broad-band 2D seismic in areas with low seismic coverage
  - A total of 7.504 line km of reprocessed vintage 2D seismic
  - A data well campaign commenced in October 2023 to focus on data acquisition of all potentially attractive geothermal reservoirs, expected completion by mid 2025

- All data is released for free at completion and ready for use for further geothermal exploration and development

*: 2D regional lines, local lines and widelines.

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