Automatiseer de Geo-Engineer

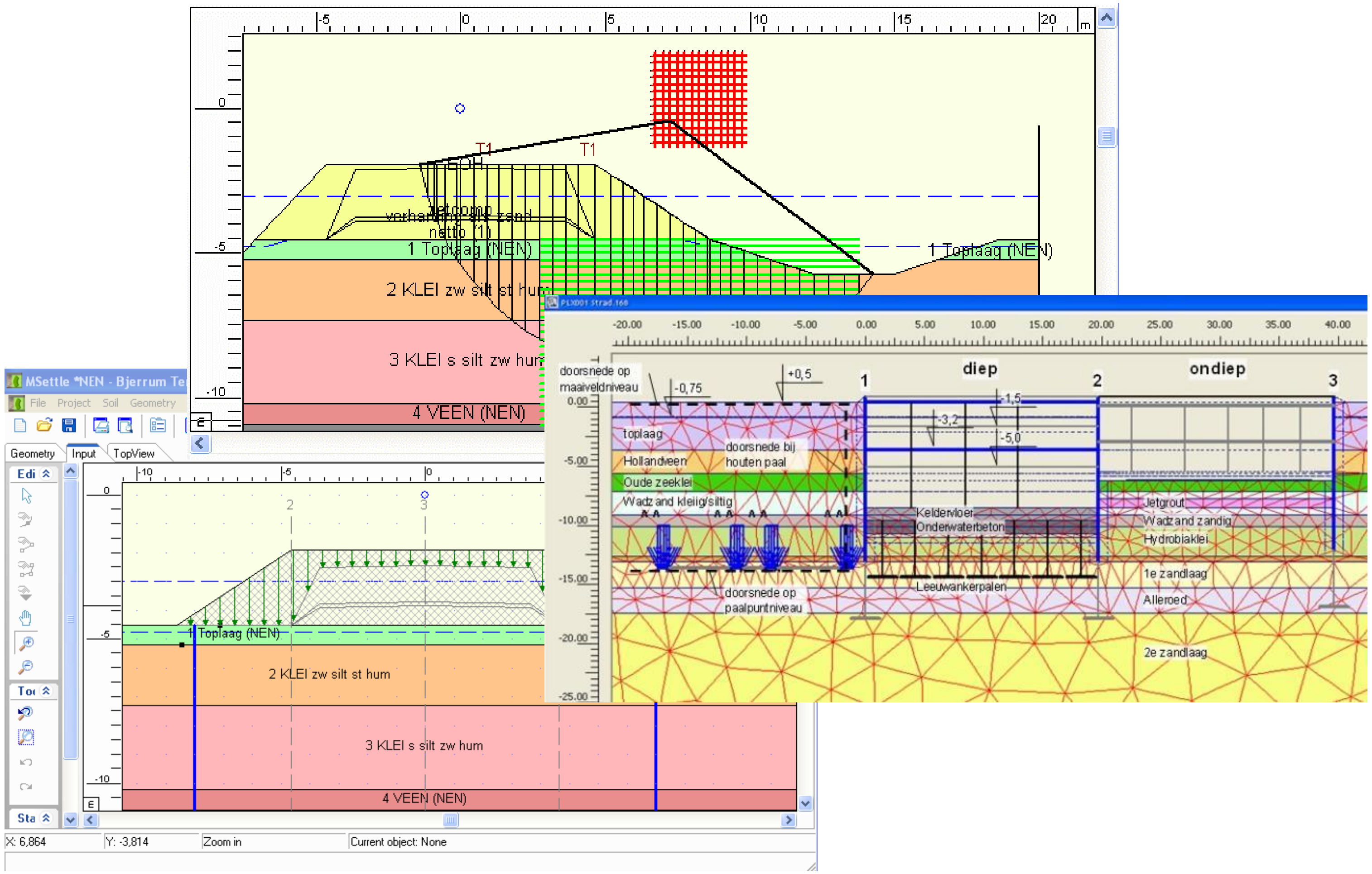
Jacco Haasnoot en Martina Pippi
CRUX Engineering BV

- Hoe zijn we gestart ?
- Waar gaan we naartoe ?
- Waar staan we nu ?

CRUX

25 jaar klikken

GEOTECHNIEKDAG 2019



Ontwikkelingen

- Toenemende rekenkracht en opslagcapaciteit in de cloud
- In de bouwsector veel aandacht voor automatisering d.m.v. BIM, maar ook parametrisch ontwerpen.
- Nieuwe Technologie: Artificial Intelligence, Machine Learning, Big Data

CRUX

GEOTECHNIEKDAG 2019

Hoe te starten ?

zelf software schrijven
versus
ontwerpprocessen automatiseren

WAT ALS CRUX …

…. in BIM een compleet Palenplan kan aanleveren
…. automatisch varianten kan doorrekenen
…. automatisch dijkberekeningen kan uitvoeren
…. eenvoudige ontwerpberekening zeer efficiënt uitvoert
…. pre-processing, software en post-processing integreert
…. de optimale bouwkuip automatisch ontwerpt in Plaxis
…. leert van monitoringsdata
…. de zetting voor iedere grondopbouw al heeft uitgerekend.

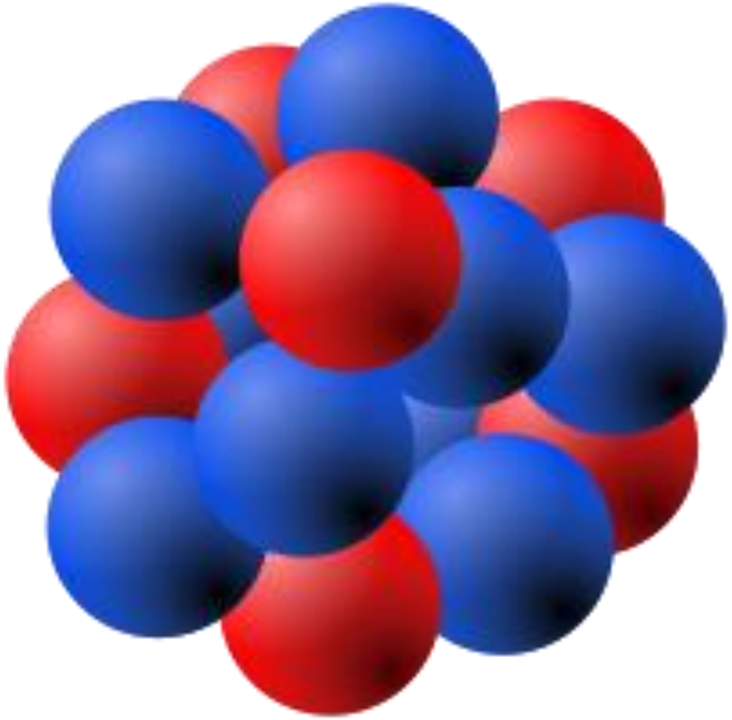
CRUX

Waar gaat CRUX naartoe ?

GEOTECHNIEKDAG 2019

Geo Engineers met digitale tools

- CONTAINERS
- PIPELINES
- API



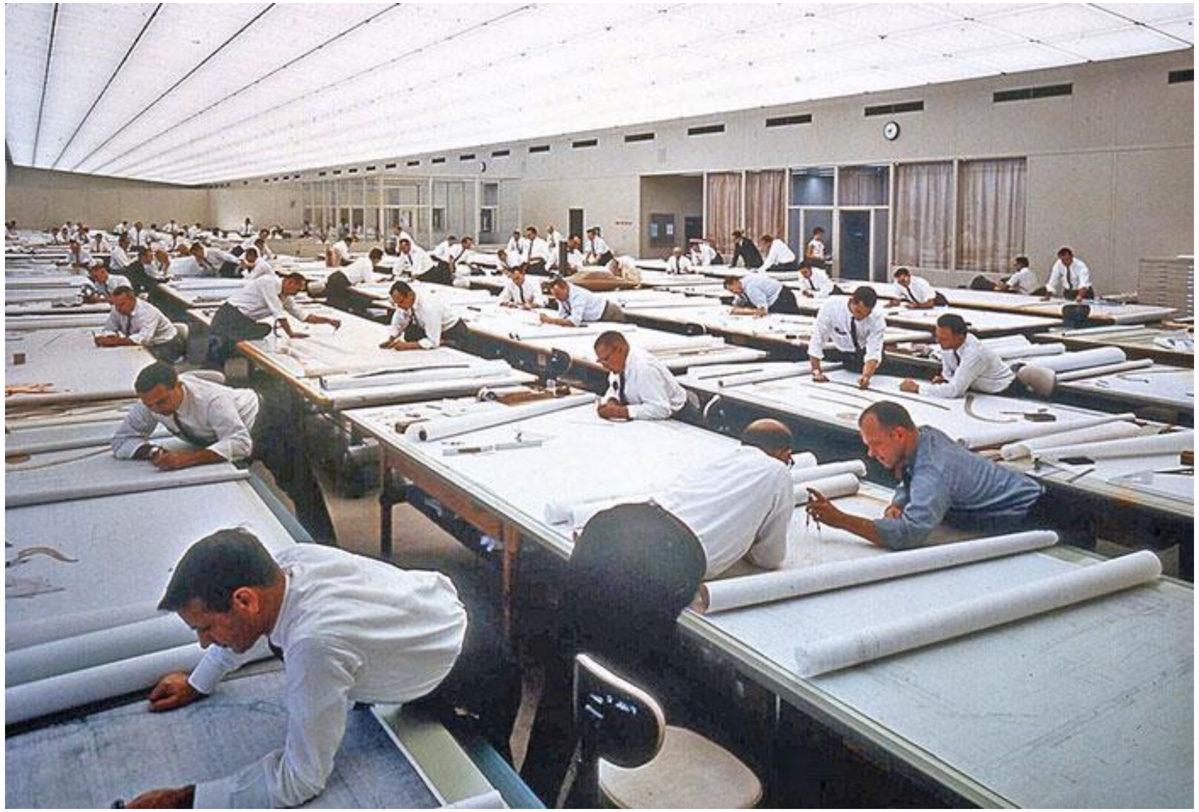
CRUX

Waar gaat CRUX naartoe ?

GEOTECHNIEKDAG 2019

Geo Engineers met digitale tools

- URENFABRIEK
- VAARDIGHEDEN
- VERDIEPING



CRUX

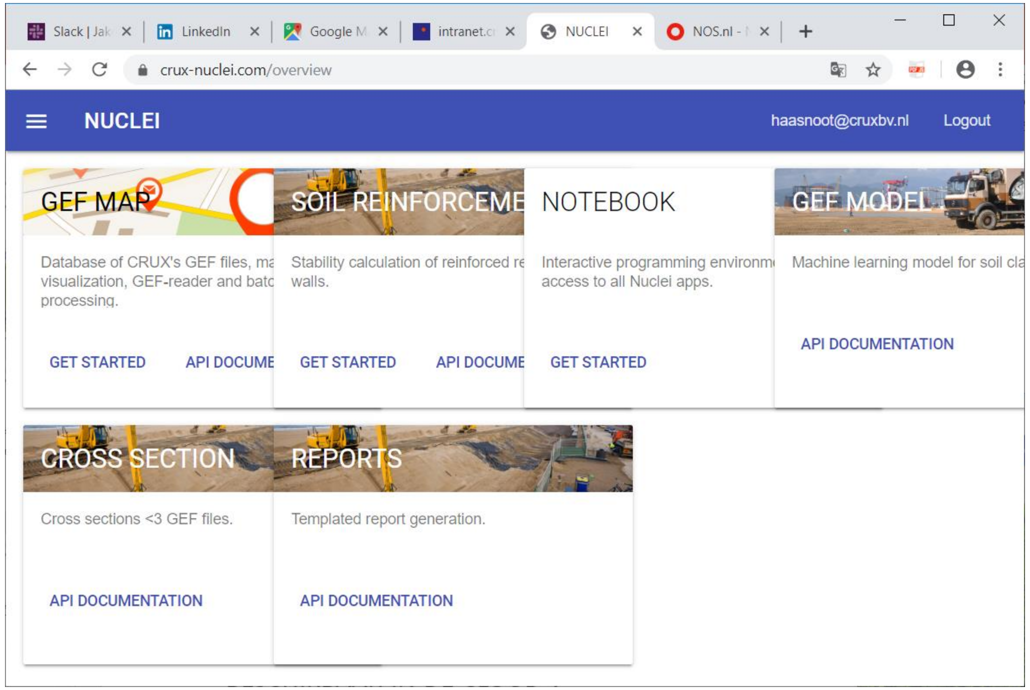
GEOTECHNIEKDAG 2019

Waar staat CRUX?

NUCLEI Omgeving – Jupyter Notebooks

- Sonderingen (interpretatie en GIS)
- Paal draagvermogen
- Gewapende grond
- Dijk stabiliteitsberekeningen

- Zettingsberekeningen - rekenkernel API in de cloud !

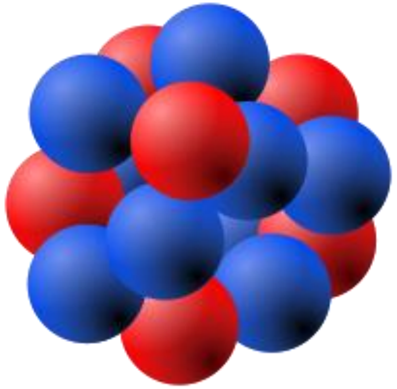


CRUX

Automatiseer de Geo-Engineer

GEOTECHNIEKDAG 2019

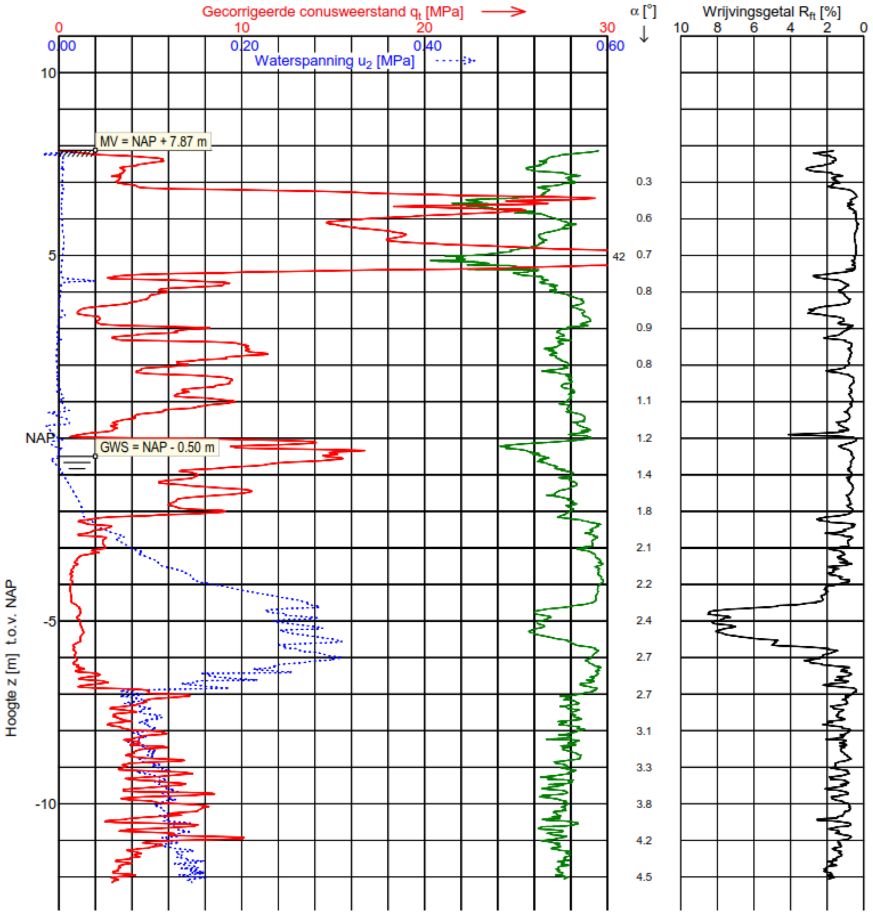
tussen resultaten



- Enorme potentie
- 80/20

  "onderschat de inspanning niet"
- Urgentie
  - Leuk !
  - Business model

Traditional geotechnical process

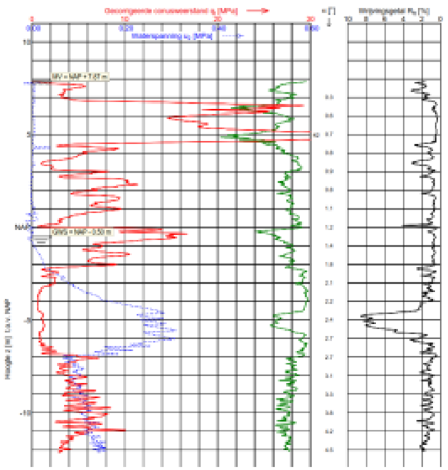


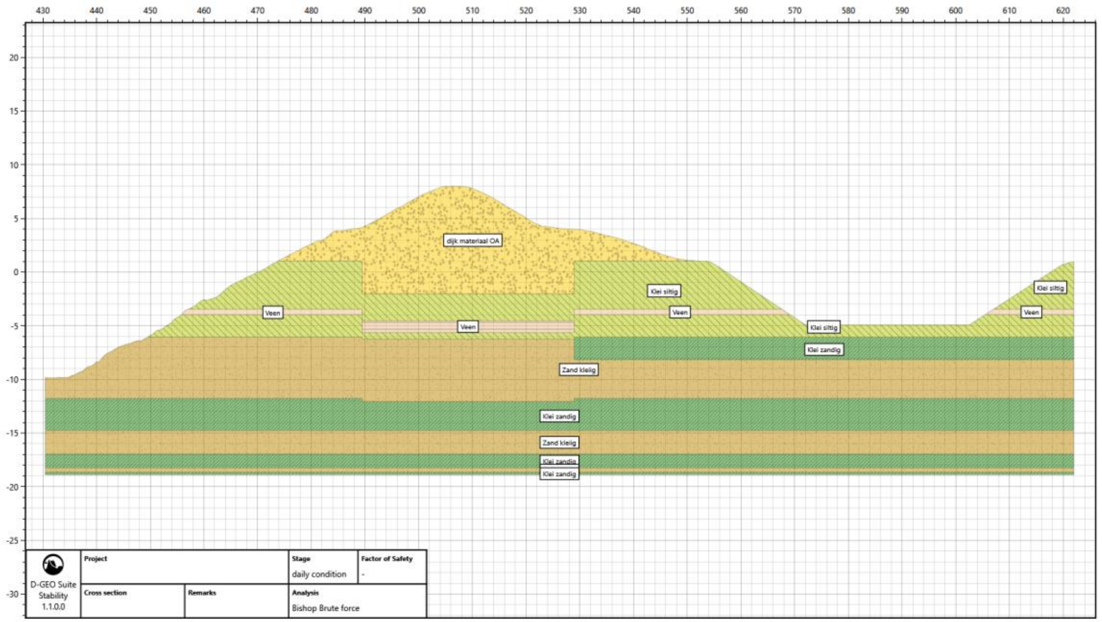
Cpt interpretation:

- layer boundaries based on changing points
- layer type based on (qc, Fr, u2) values

CRUX Traditional geotechnical process

GEOTECHNIEKDAG 2019





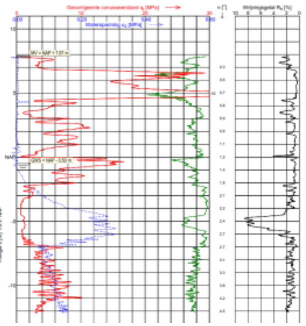
Creation of the model:

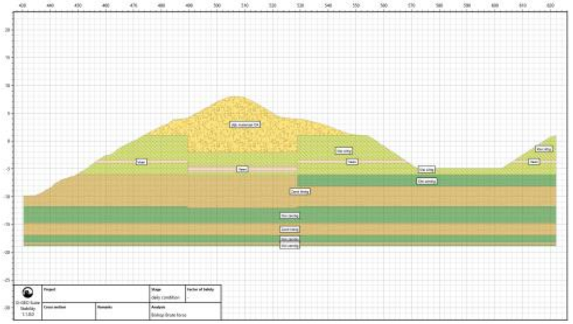
- Import surface line
- Draw soil layers
- Assign soil materials
- Draw water lines
- Assign state parameter

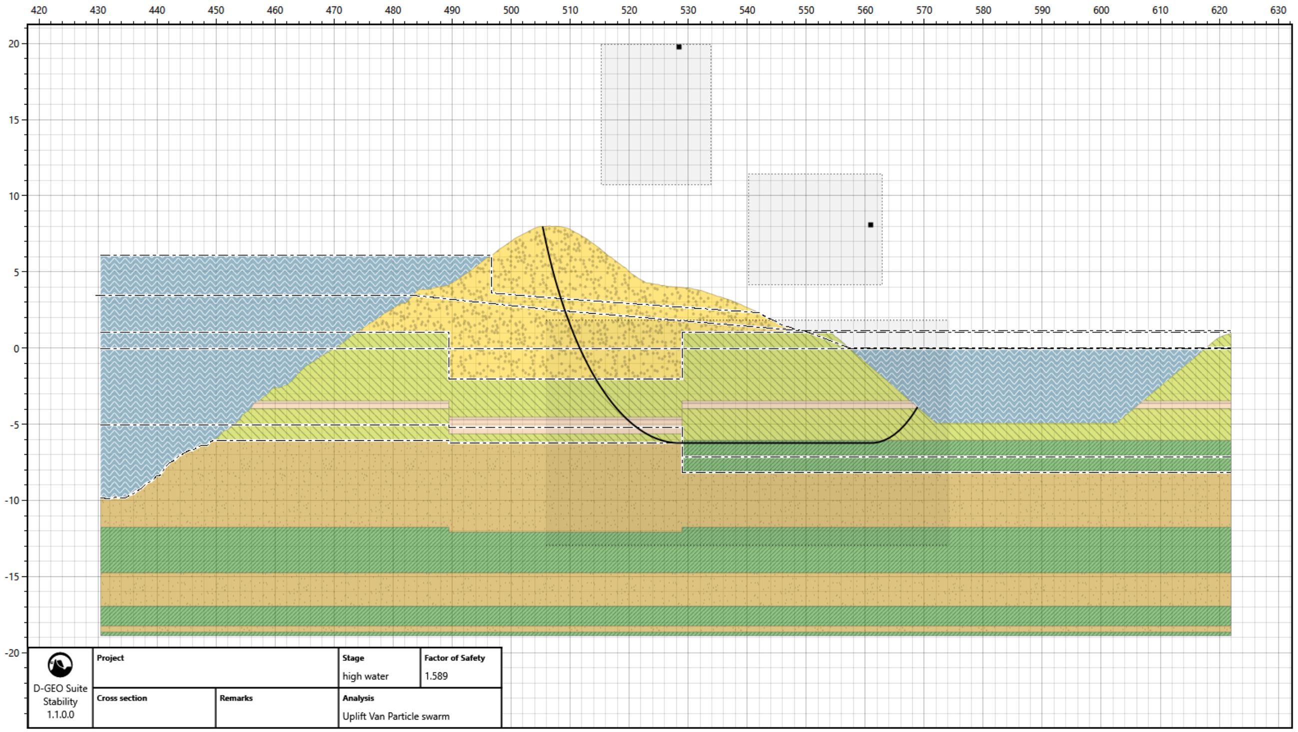
CRUX

Traditional geotechnical process

GEOTECHNIEKDAG 2019





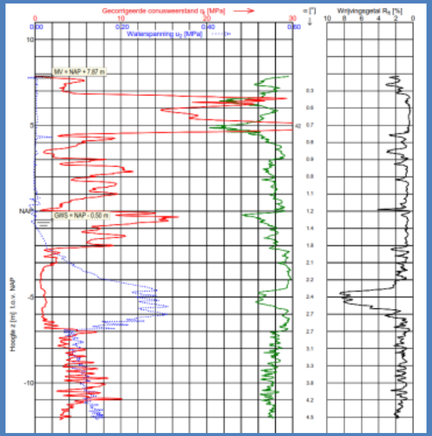


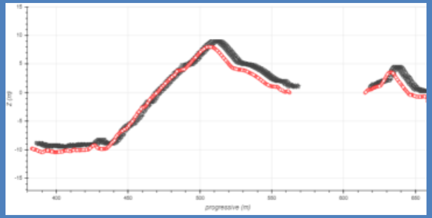
Calculation and check of the results

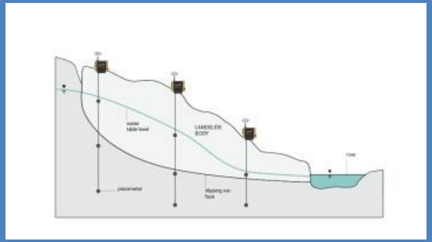
CRUX

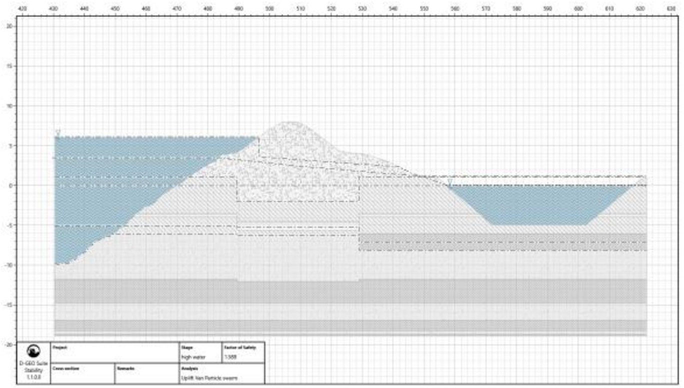
Objective

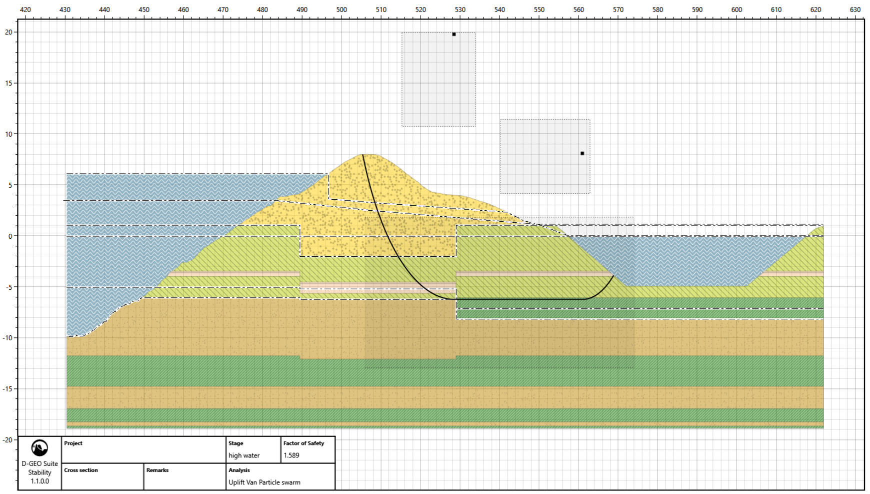
GEOTECHNIEKDAG 2019











Automated Soil Interpretation

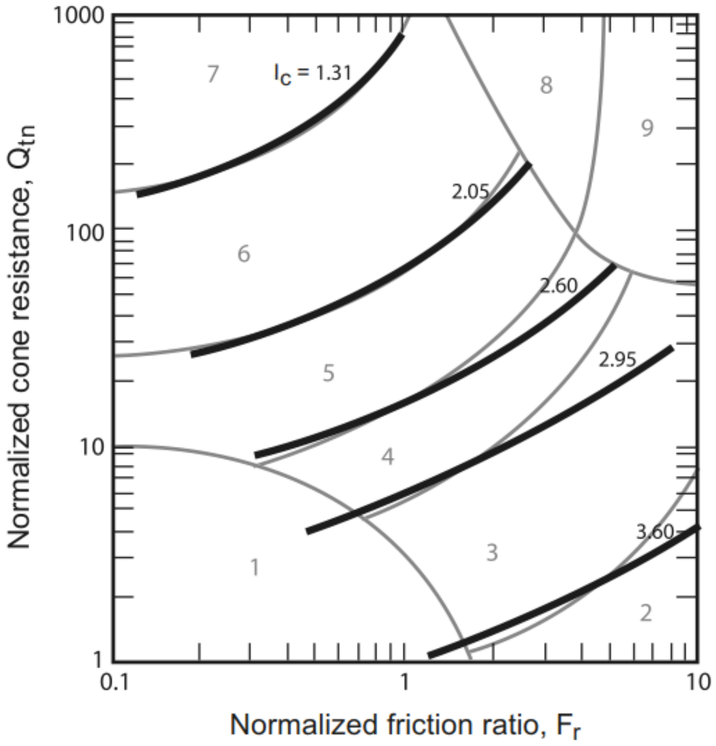
CRUX

GEOTECHNIEKDAG 2019

Empirical formulations:

- Robertson, P. K. "Interpretation of cone penetration tests—a unified approach." *Canadian geotechnical journal* 46.11 (2009): 1337-1355.

$$[5] \qquad I_c = \left[(3.47 - \log Q_{tl})^2 + (\log F_r + 1.22)^2\right]^{0.5}$$



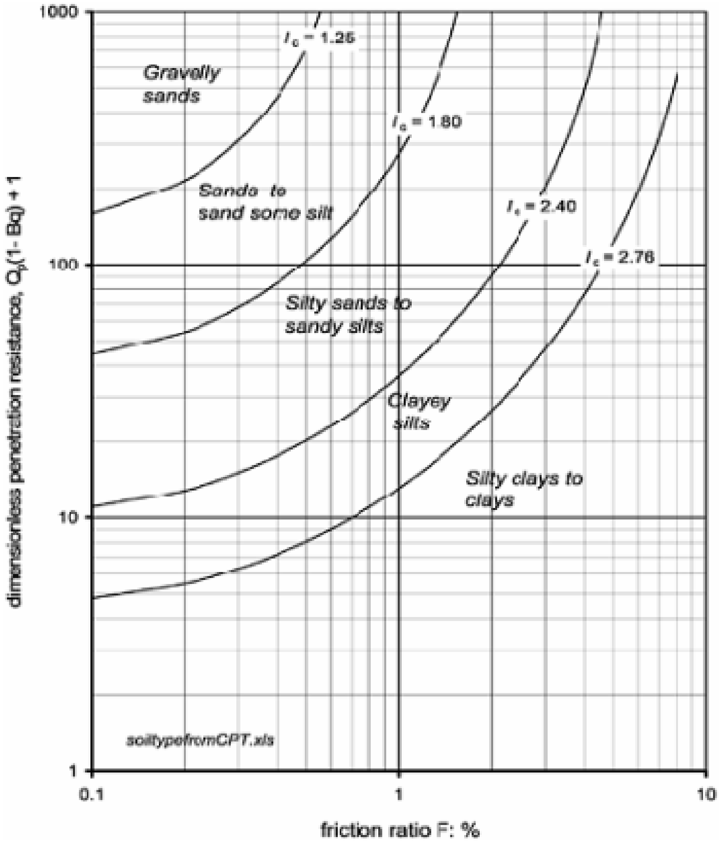
Automated Soil Interpretation

Empirical formulations:

- Robertson, P. K. "Interpretation of cone penetration tests—a unified approach." Canadian geotechnical journal 46.11 (2009): 1337-1355.

- Jefferies & Been (1998)

$$I_c = \sqrt{(3 - \log(Q\,(1 - B_q) + 1)^2 + (1.5 + 1.3\log(F))^2} \qquad [4.16a]$$



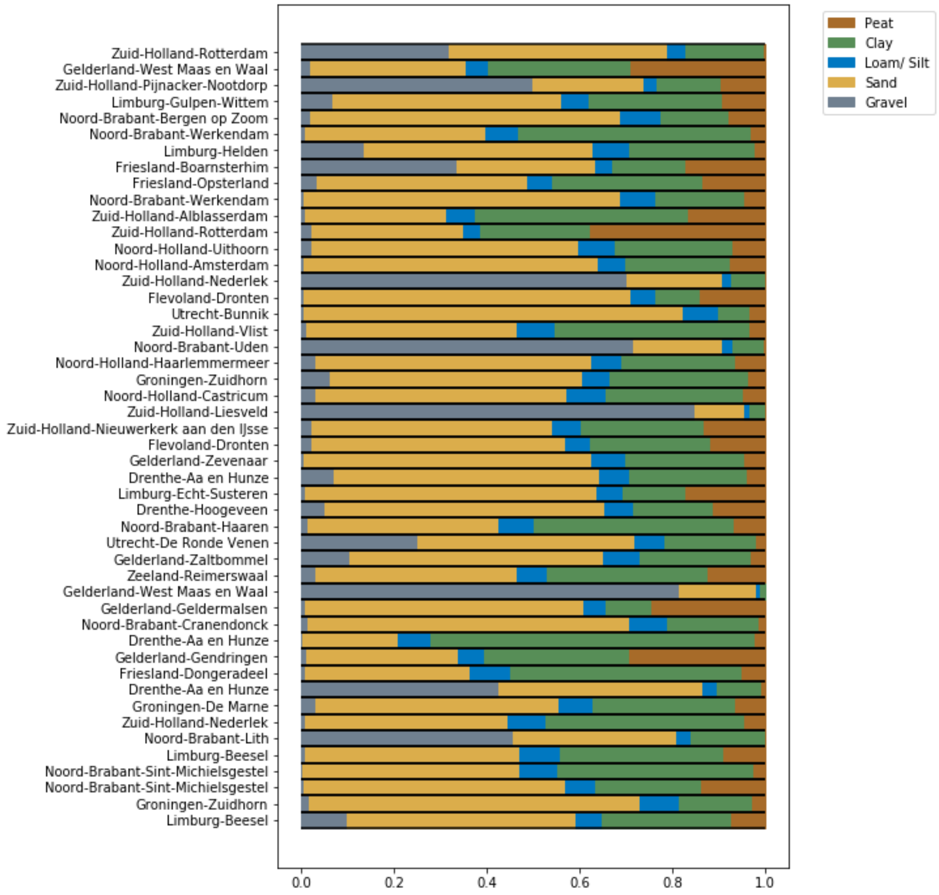
Fully automated soil classification with a ***Convolutional Neural Network*** and ***Location embedding***

- 49.000 CPTs and 40.000 boreholes have been checked
- **1.800 pairs** met the condition of being less than 6 meters apart.
- These have been used as the labeled data of the model

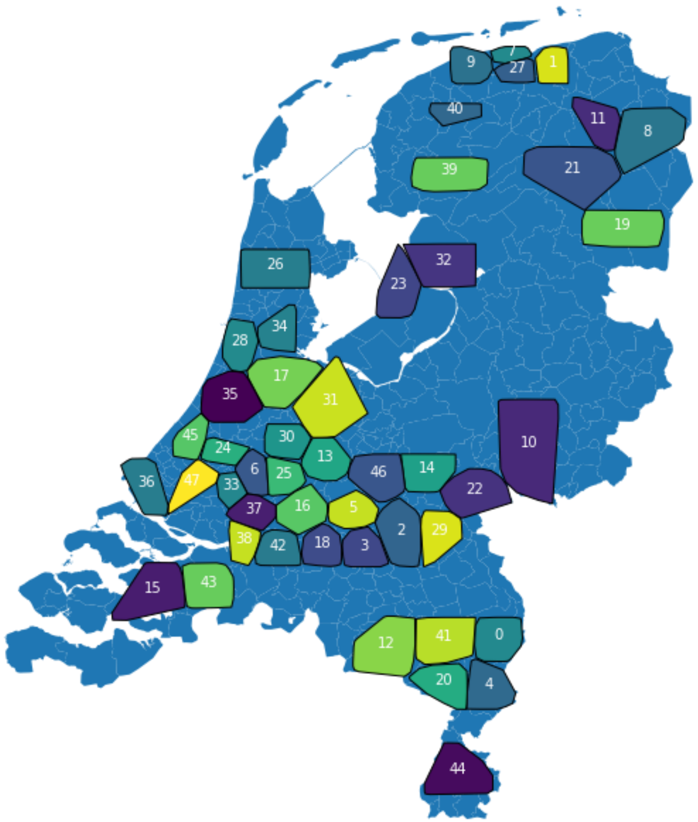
https://cruxbv.nl/artikel/crux-automatiseert-ontwerpprocessen

https://www.ritchievink.com/

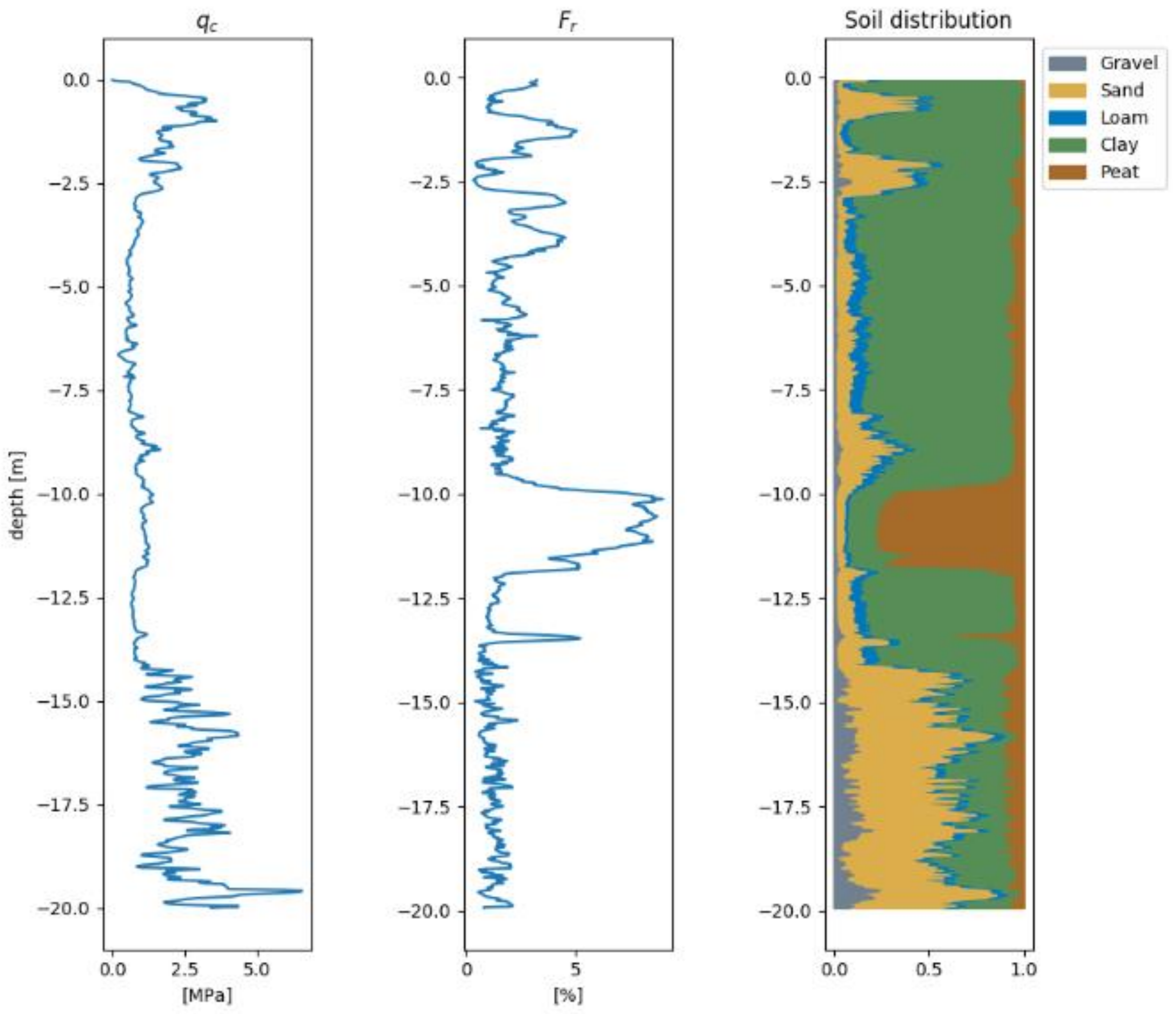
Location embedding



From the 1800 pairs, 48 location clusters were created.



First Result

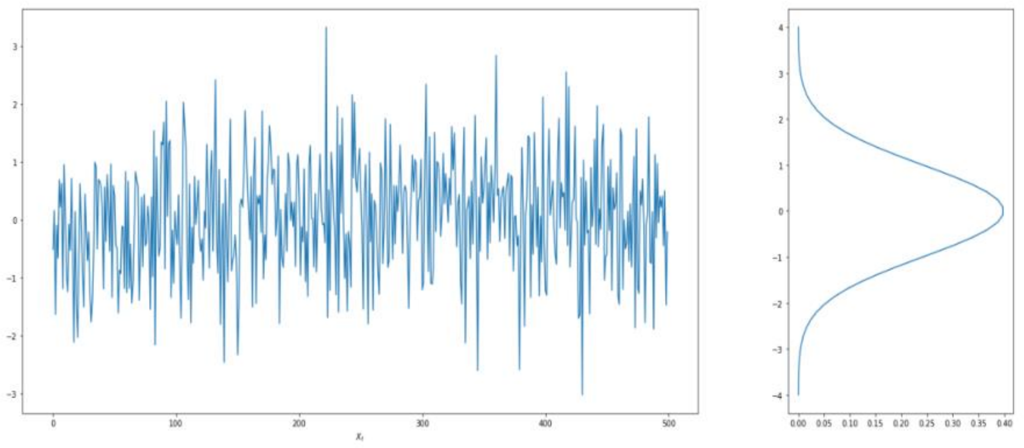


CRUX

Grouping: aggregation of layers

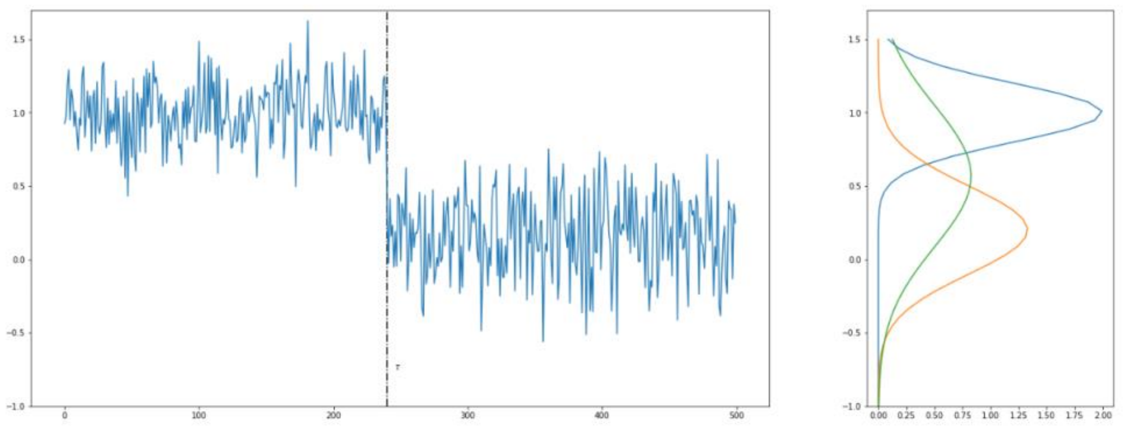
GEOTECHNIEKDAG 2019

$$X_t|\mu,\sigma \sim N(\mu,\sigma)$$



$$\mathcal{L}(X_t,\mu,\sigma) = \prod_{t=1}^{n} P(x_t|\mu,\sigma)$$

$$[\mathcal{L}(x_{1:\tau}) + \mathcal{L}(x_{\tau:n})] > \mathcal{L}(x_{1:n})$$



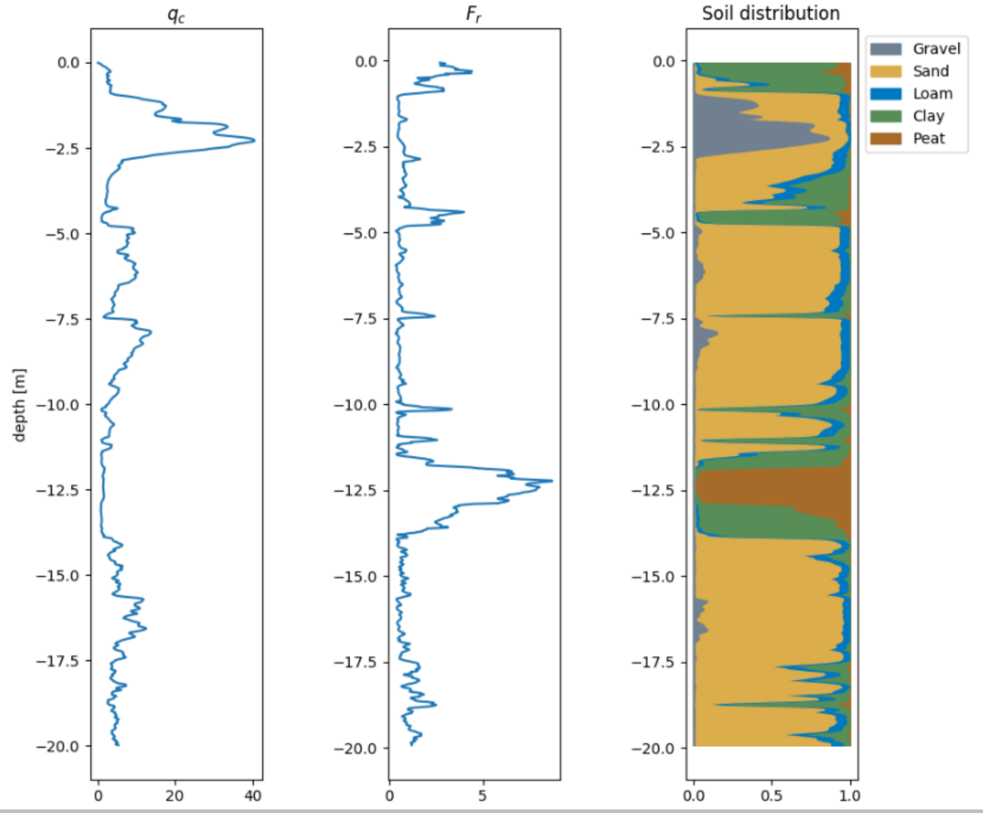
Optimization problem:

$$\min_{k,\tau} \sum_{i=1}^{k+1} [-\mathcal{L}(x_{\tau_{i-1}:\tau_i})] + \lambda$$

Grouping: aggregation of layers

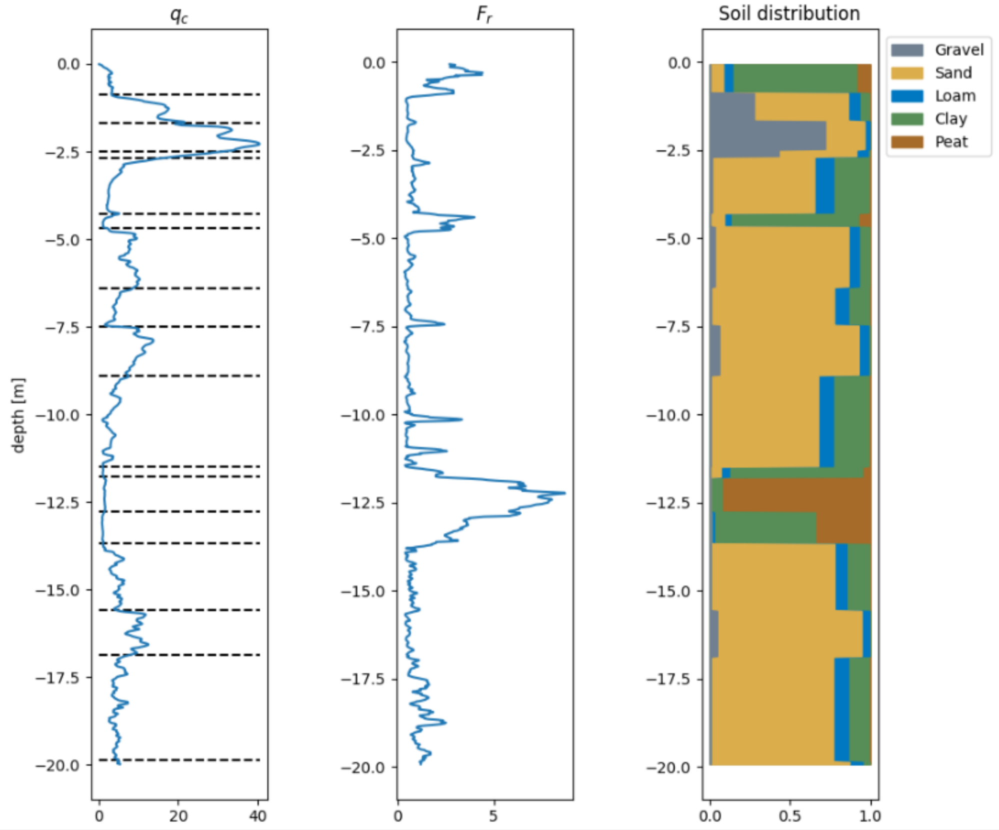
[13]:
```
schema = {
  "aggregate_layers_penalty":0,
  "aggregation_loss": "l1",
  "cpt_content": content,
  "include_features": True,
  "include_location": True,
  "n_clusters": 3
}

call_endpoint(APP, '/plot', schema)
```

[13]:



[14]:
```
schema = {
  "aggregate_layers_penalty":2,
  "aggregation_loss": "l1",
  "cpt_content": content,
  "include_features": True,
  "include_location": True,
  "n_clusters": 3
}

call_endpoint(APP, '/plot', schema)
```

[14]:



Model API

crux-nuclei.com/swagger/gef-model

NUCLEI

Servers

/api/gef-model

default

POST `/classify` Predict soil classification

POST `/plot` Plot soil classification

Parameters

No parameters

Request body required

Example Value | Schema


```
{
  "aggregate_layers_penalty": 3,
  "aggregation_loss": "l1",
  "cpt_content": "string",
  "img_encoding": null,
  "include_features": true,
  "include_location": true,
  "interpolate_nen_table_values": false,
  "merge_nen_table": false,
  "n_clusters": 3,
  "overwrite_groundwaterlevel": -4.5,
  "with_respect_to_nap": true
}
```

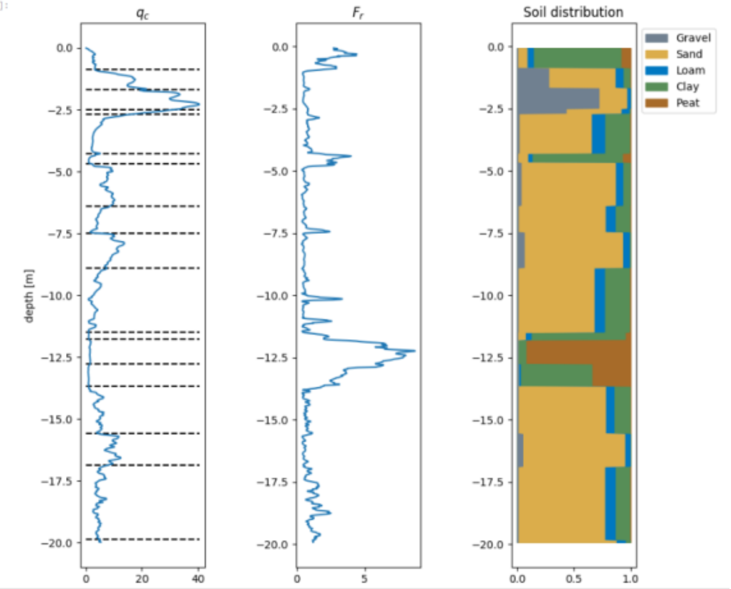

[14]:

```
schema = {
    "aggregate_layers_penalty":2,
    "aggregation_loss": "l1",
    "cpt_content": content,
    "include_features": True,
    "include_location": True,
    "n_clusters": 3
}

call_endpoint(APP, '/plot', schema)
```


[14]:

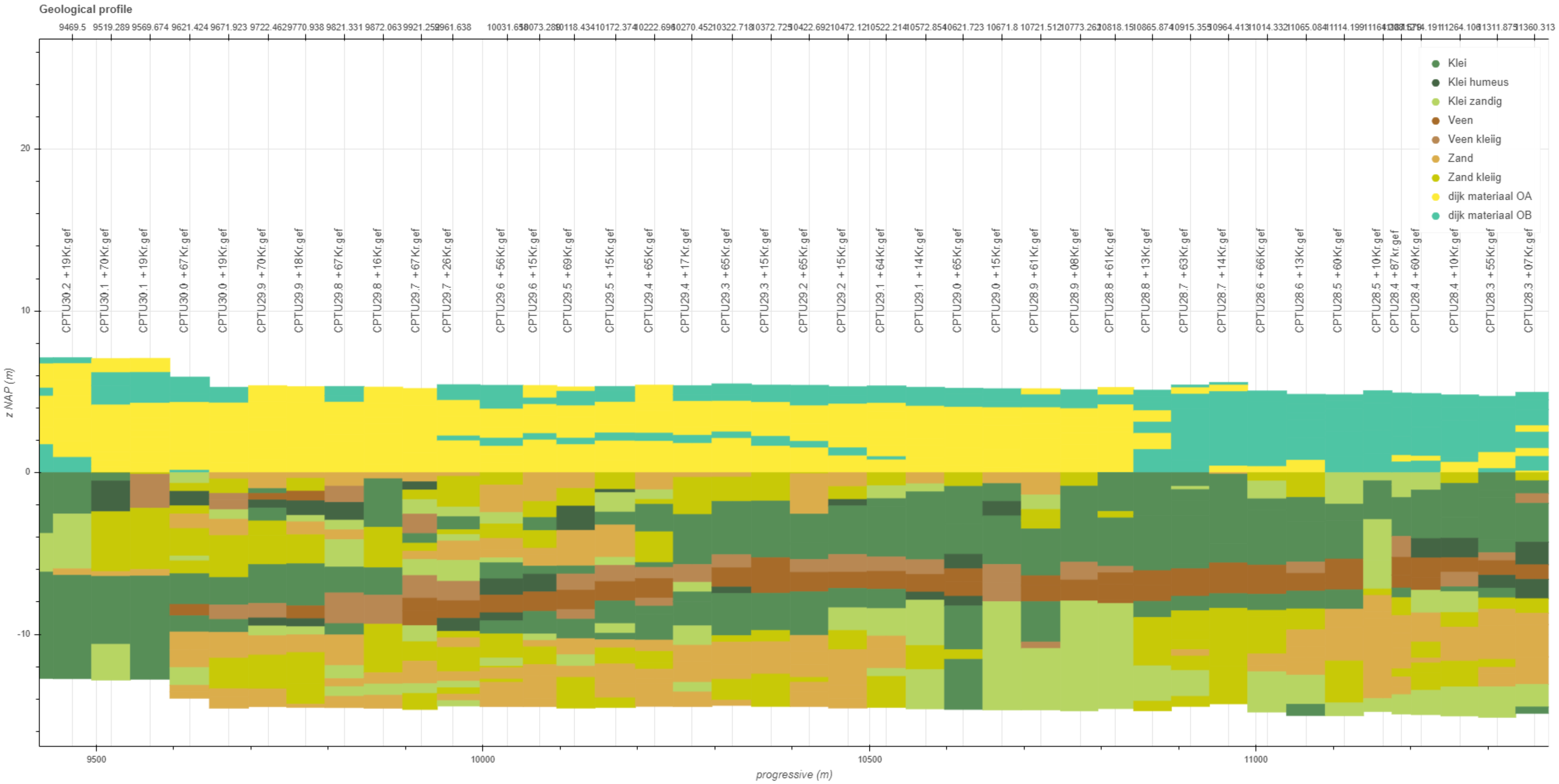
```
schema = {
    "aggregate_layers_penalty":2,
    "aggregation_loss": "l1",
    "cpt_content": content,
    "include_features": True,
    "include_location": True,
    "n_clusters": 3
}

call_endpoint(APP, '/plot', schema)
```


[14]:



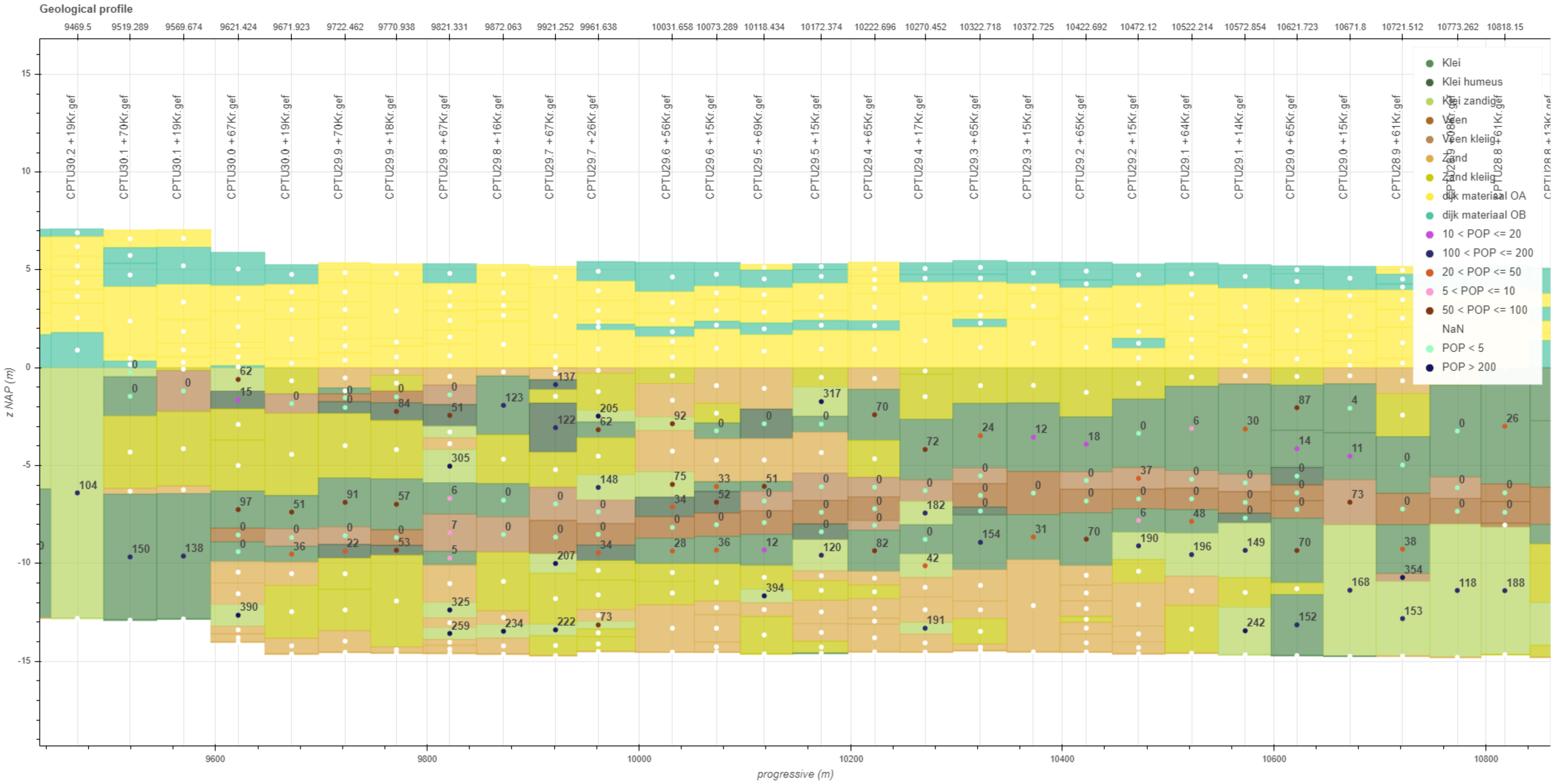
Applications

- Lithological profiles



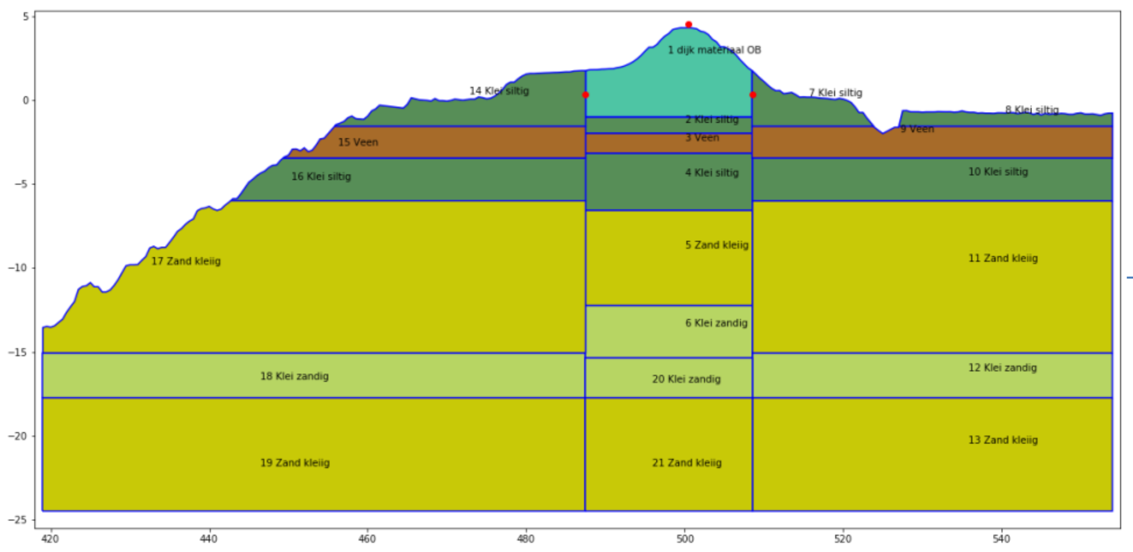
Applications

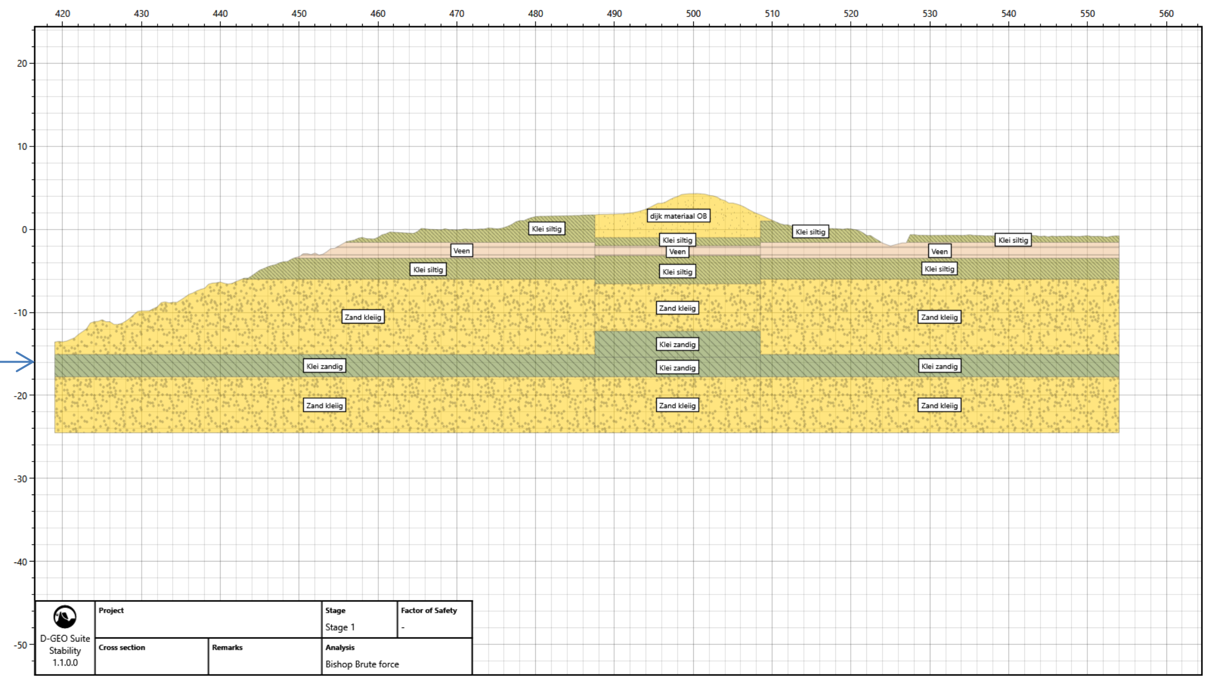
- Lithological profiles
- Spatial variation of state parameters



Applications

- Lithological profiles
- Spatial variation of state parameters
- Cross section → Stability calculation





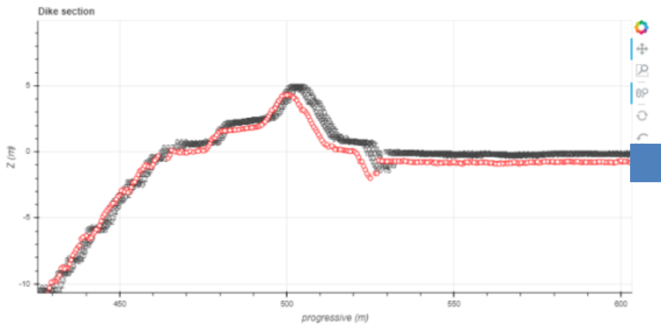
CRUX

Automated cross sections

GEOTECHNIEKDAG 2019

```
[3]: # INPUT #####
location= 1350
#################

from bokeh.io import output_notebook, show
from dike_profile.dike_profile import DikeProfile


# Insert location and Plot AHN
read = DikeProfile(ahn_string, location=location, sep=",")
fig = read.plot_ahn_bokeh(fig_size=(900, 450), reverse_ahn=False)
output_notebook()
show(fig)
```

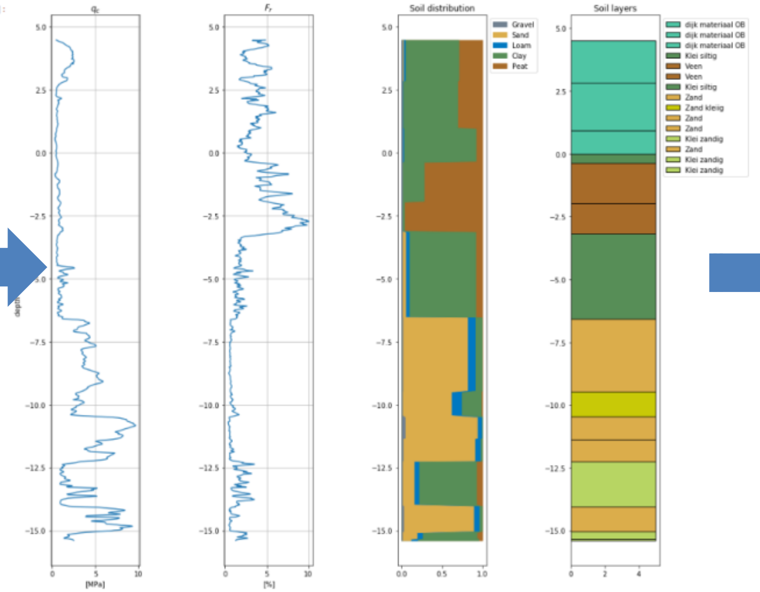
BokehJS 1.3.4 successfully loaded.




```
[4]: # Insert significant points
left_limit = 813
right_limit = 1071
toe_bt = 994 # toe binnenteen
toe_vl = 916 # toe voorland
crest_vl = 962
crest_bt = 969
#####
```

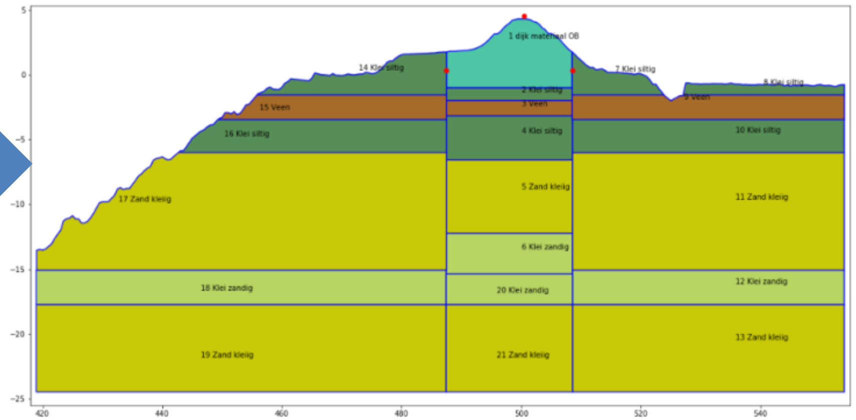
```
    schema = {"aggregate_layers_penalty": 3,
              "aggregation_loss": "l1",
              "cpt_content": content,
              "include_features": True,
              "include_location": True,
              "n_clusters": 3
              }
    result = call_endpoint('gef-model', '/classify', schema)
    df_layers_crest = util_ML.create_classification_table(result["layer_table"], cpt, thresholds=thresholds,  filter_classification=filter_classification)
    df = result['prediction'].sort_index().merge(cpt.df, how='inner', on='depth')
    fig_crest = plot_ML.create_plot(df, df_layers_crest)
fig_crest
```

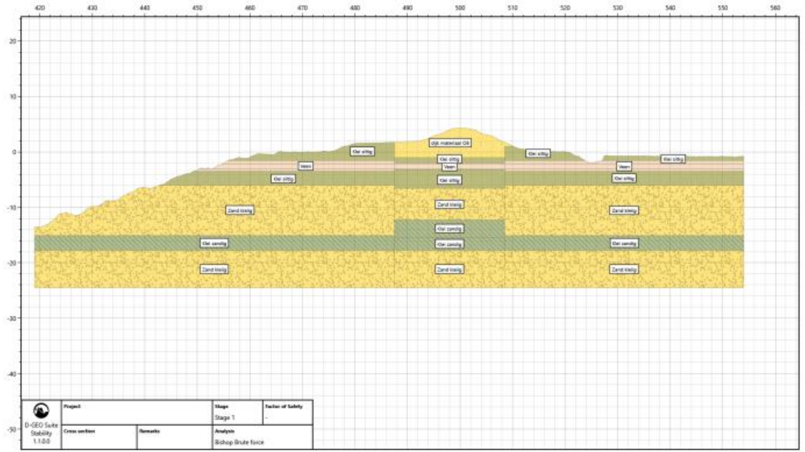
[9]:



Plot dike layering

```
[17]: from dike_layering.plot_layering import PlotLayering
plot = PlotLayering(ahn_string, distance_csv, path_GEF_folder, water_level_NAP, toe_vl=toe_vl, toe_bt=toe_bt, crest_bt=crest_bt, crest_vl=crest_vl,
                    left_limit=left_limit, right_limit=right_limit,
                    location=location,df_layers_crest=df_layers_crest, df_layers_toe=df_layers_toe, accept_cpt=False, sep=",", reverse_ahn=False, reverse_limits=False)
plot.plot_polygons(True, classification, filter_classification=filter_classification)
```





```
[58]: from input_dstab import input_file

      input_file(plot.polygons, str(location), soil_properties_dict)
```

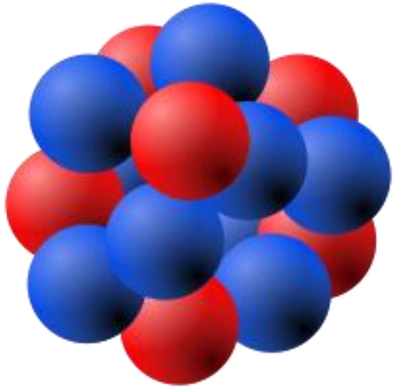
CRUX

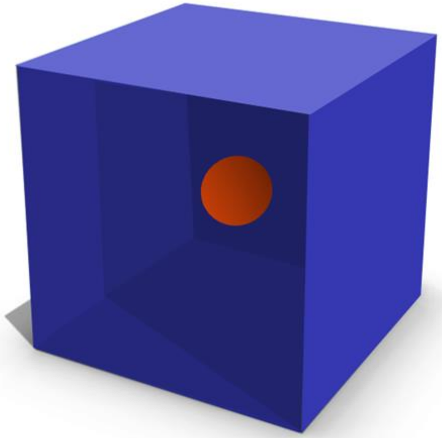
Automatiseer de Geo-Engineer

GEOTECHNIEKDAG 2019

Summary:

- CPT interpretation: Machine learning model
  - 1800 pairs cpt-boreholes
  - Location embedding
  - Grouping algorithm
- Lithological profile
- Tool for automated cross section





Heeft u nog vragen?

pippi@cruxbv.nl

haasnoot@cruxbv.nl

CRUX

Validation metrics

GEOTECHNIEKDAG 2019

Considering the mode:

$\{G, S, L, C, P\}$. $\operatorname{argmax}\{P(x)\}$

F1 scores (higher is better)

Soil Type	Support	Robertson F1	KL-divergence F1	Wasserstein F1
Gravel	3731	0.15	0.15	0.10
Sand	137998	0.86	0.83	0.85
Loam	0	0	0	0
Clay	91523	0.64	0.70	0.67
Peat	21398	0.37	0.57	0.74

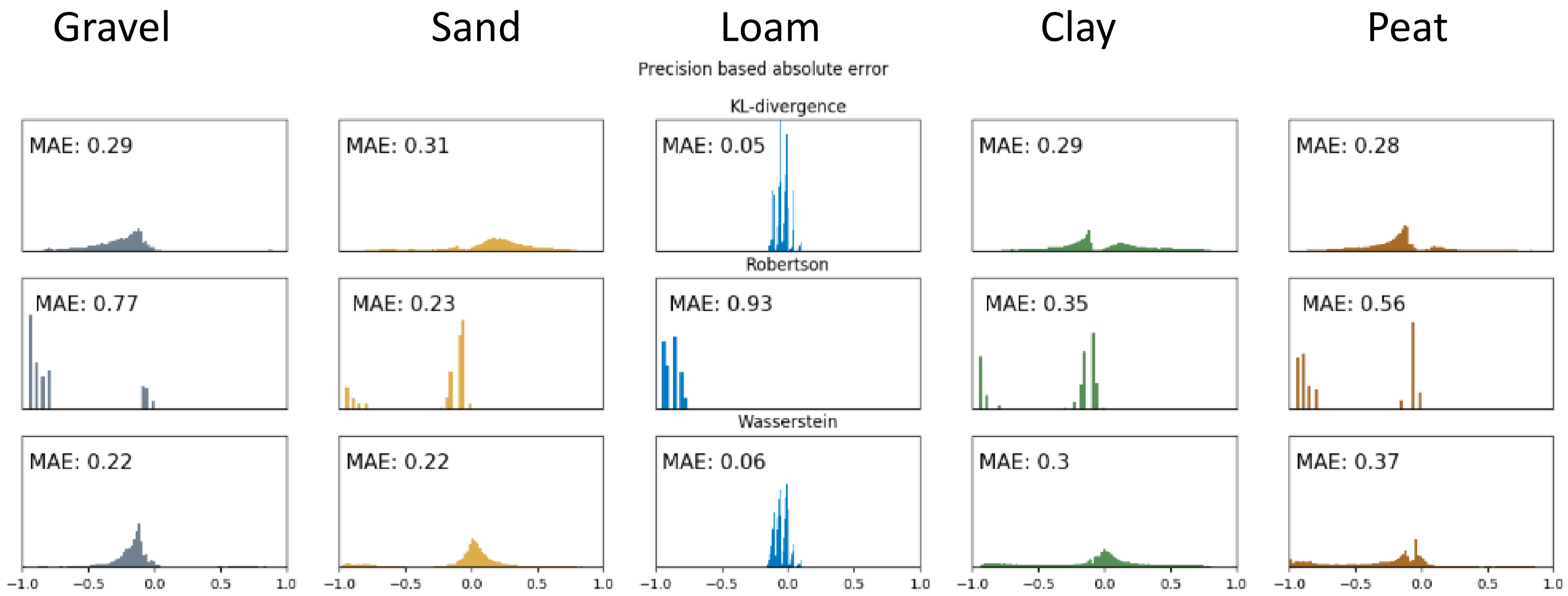
CRUX

Validation metrics

GEOTECHNIEKDAG 2019

Error distribution: $\mathrm{MAE} = \frac{\sum_{i=1}^{n} |y_i - x_i|}{n}$

- Precision based absolute errors (lower is better)



Precision $= \frac{N}{M}$

N = number of times in which the model said it was clay and in reality it was indeed clay

M = total number of times in which the model said it was clay

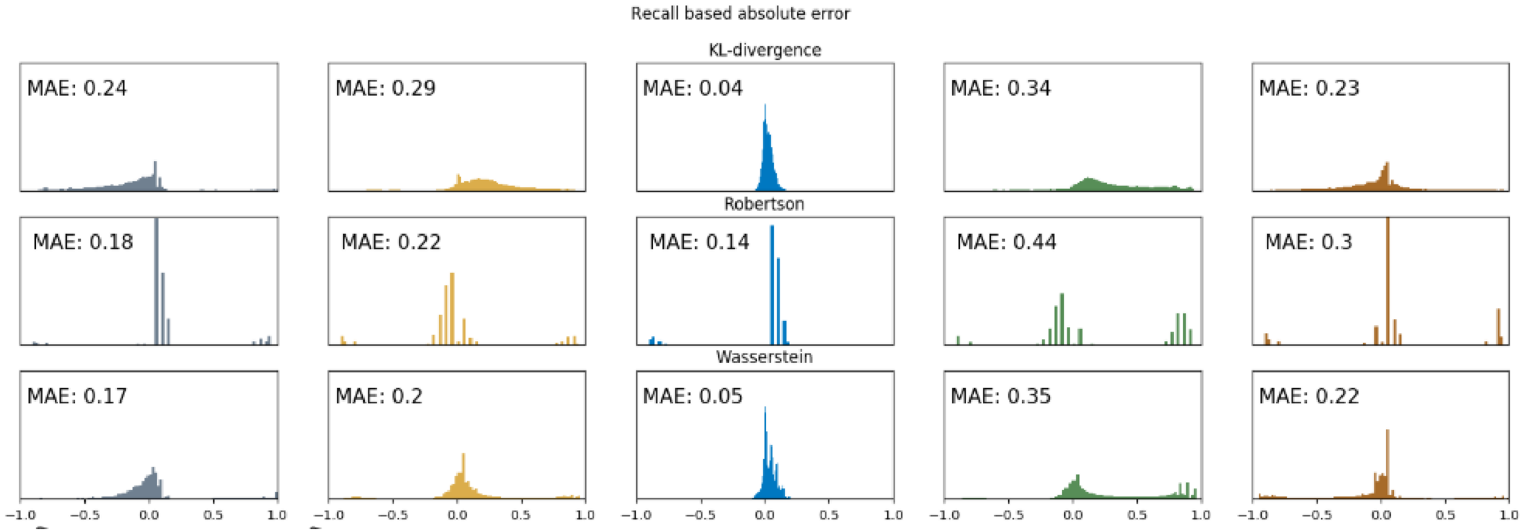
Validation metrics

Error distribution:

$$\text{MAE} = \frac{\sum_{i=1}^{n} |y_i - x_i|}{n}$$

- Recall based absolute errors (lower is better)

Gravel Sand Loam Clay Peat



Recall$= \frac{N}{M}$

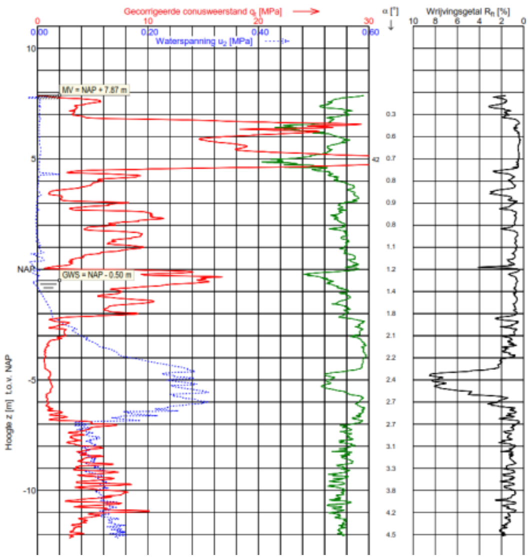
N = number of times in which the model said it was clay and it was indeed clay

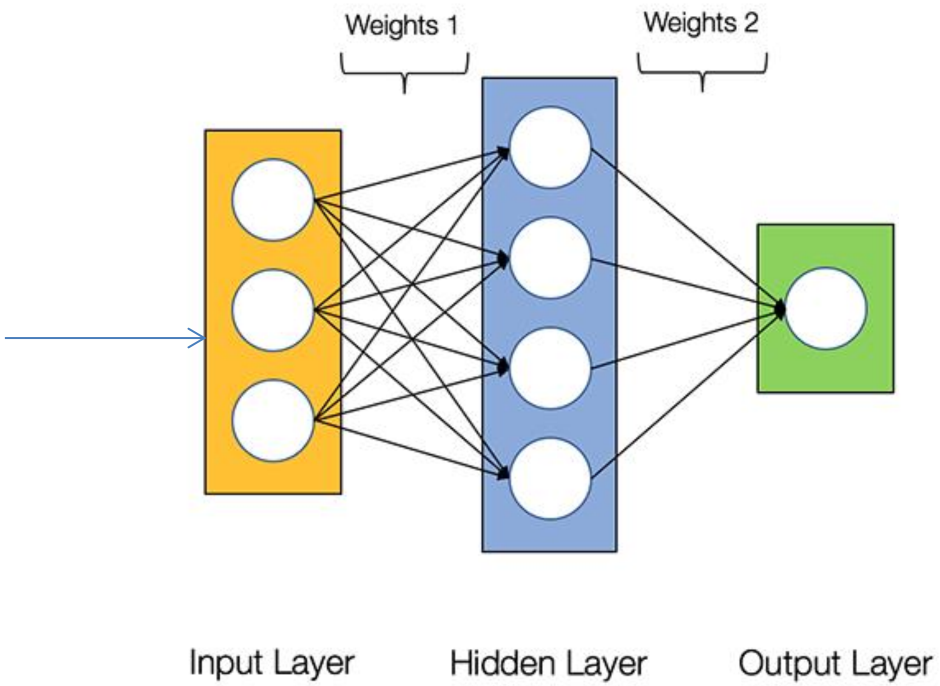
M = number of times in which the model said it was clay and it was clay + number of times in which the model said it was not clay but in reality it was clay

CRUX

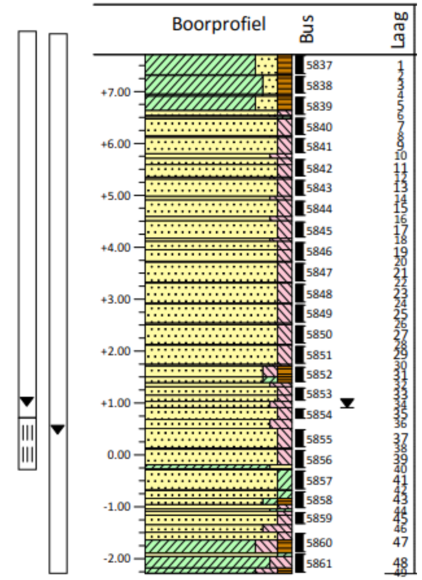
GEOTECHNIEKDAG 2019

Neural Network: training process

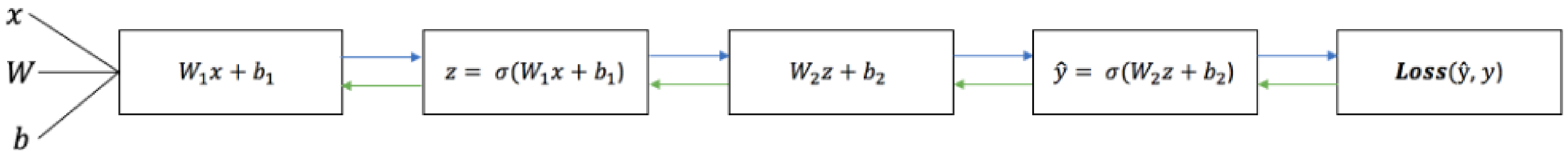




$$\hat{y} = \sigma(W_2\sigma(W_1x + b_1) + b_2)$$



$$Sum-of-Squares\ Error = \sum_{i=1}^{n}(y - \hat{y})^2$$



Feedforward

Backprogation