Deltares

# DAM UI

## Functional Design

# DAM UI

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**Authors**
Irene van der Zwan, John Bokma, Bernard van der Kolk, Tom The

**Partners**
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| **Client** | Deltares - GFS |
| **Contact** | john.bokma@deltares.nl |
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## Author(s)

| | | |
|---|---|---|
| | Bernard van der Kolk<br>Tom The | Deltares |
| | | |

# Summary

This document contains the functional design for DAM UI, a software module that computes the strength of a complete dikering with respect to several failure mechanisms, such as macro stability and piping

**Samenvatting**

Dit document bevat het functioneel ontwerp voor DAM UI, een software module die een gebruiker in staat stelt om voor een dijktraject berekeningen uit te voeren voor verschillende faalmechanismen, waaronder macrostabiliteit en piping.

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# 1 Introduction

## 1.1 Purpose and scope of this document

This document contains the functional design for the DAM UI, a user interface for the DAM Engine. The DAM Engine is designed for the automated calculation of the strength of dikes. DAM was developed by Deltares with and for STOWA for all water authorities. This document describes requirements and functional design of DAM UI. What will actually will be implemented depends on the requirements of the clients using this DAM UI. If some functionality is not (yet) needed, then that part does not need to be implemented.

### 1.1.1 Future options

As mentioned above this document contains some options that will not be implemented in the first release, but are foreseen to be implemented in the near future. Therefore although sometimes a reference will be made to these options, these will not be described in detail yet.

That applies in particular to the following subjects:

- NWO module("Niet Waterkerende Objecten")
- WBI failure mechanisms (Piping, Macrostability)

## 1.2 Other system documents

The full documentation on the program comprises the following documents.

| Title | Content |
|---|---|
| DAM UI- Architecture Overall (The, 2017) | Description of overall architecture of the DAM UI and its components. |
| DAM UI- Functional Design (Zwan and Bokma, 2022) | Description of the requirements and functional design. |
| DAM UI- Technical Design (The and Bokma, 2022a) | Description of the implementation of the technical design of DAM UI. |
| DAM UI- Technical documentation (Doxygen, 2017) | Description of the arguments and usage of different software components, generated from in-line comment with Doxygen. |
| DAM UI- Test Plan (Trompille, 2017a) | Description of the different regression and acceptation tests, including target values. |
| DAM UI- Test Report (Trompille, 2017b) | Description of the test results (benchmarks and test scripts). |
| Architecture Guidelines (Kleijn *et al.*, 2017) | Architecture guidelines that are used by DSC-Deltares. |

Table 1.1 DAM UI system documents.

## 1.3 Document revisions

### 1.3.1 Revision 0.1

First concept of the document.

### 1.3.2 Revision 0.3

Added more functional requirements.

- Create Design project.
- Create Calamity project
- Perform Design calculation - No adaption.
- Perform Design calculation - With adaption.
- Display results in graphic view.
- Open individual D-Stability projects.
- Multi-language.
- Multi-core calculation.
- Changing units.
- Real-time validation.
- Calculation log.
- Undo-Redo.

# 2 Non-functional requirements

# 3 Functional requirements

Main purpose of the DAM UI The DAM UI can import data and combines this data to make geotechnical calculations. After calculations (made by DAM Engine) the DAM UI shows the results and make analyzation possible.

## 3.1 User story Data format

As a geotechnical engineer I want to store my data in a predescribed format, so that I can reuse the data. The design of this functionality is described in chapter 6.

## 3.2 User story GIS Data combination

As a geotechnical engineer I want to combine GIS data per location, so that I don't have to do that by hand. The design of this functionality is described in section 7.2

## 3.3 User story Soil Data combination

As a geotechnical engineer I want to combine subsoil with surfaceline per location, so that I don't have to draw 2D geometries. The design of this functionality is described in section 7.3

## 3.4 User story Create Design project

As a geotechnical engineer I want to create a Design project in which I can import project information and perform calculations with certain settings and for given situations. I can either just calculate the safety factors of the current situation or design (adapt geometry) to a required safety factor. The design of this functionality is described in section 4.1.

## 3.5 User story Create Calamity project

As a geotechnical engineer I want to create a Calamity project in which I can import project information and perform calculations based on a time serie of water levels and evaluate the results. The design of this functionality is described in section 4.2.

## 3.6 User story DAMLive configuration

As a geotechnical engineer I want to make a DAMLive configuration, so that I can make calculations with DAM engine, using sensors for the input of piezometric lines. The design of this functionality is described in section 4.3.

## 3.7 User story Save and Open project

As a geotechnical engineer I want to save the current state of a project and open existing projects to see what data is used and which calculations are made with what result. The design of this functionality is described in chapter 5.

## 3.8 User story Data display

As a geotechnical engineer I want to see the data per location in tables, cross section and map view, so I can check the data before calculation. The design of this functionality is described in chapter 8.

## 3.9 User story Data editing

As a geotechnical engineer I want to edit the data per location, so I can adapt the data before calculation. The design of this functionality is described in chapter 9.

## 3.10 User story Calculation settings

As a geotechnical engineer I want to see and be able to adapt the calculation settings, so I can decide what calculations are made. The design of this functionality is described in chapter 10.

## 3.11 User story Perform Design calculation - No adaption

As a geotechnical engineer I want to be able to make a calculation in a Design project based on the input parameters. The most important outcome of the calculation are the safety factors. The design of this functionality is described in section 11.1.

## 3.12 User story Perform Design calculation - With adaption

As a geotechnical engineer I want to be able to make calculations in a Design project with adaption of the geometry of the dike if the calculated safety factor is lower than the required safety factor. The adaptation must have the options to increase the crest, change the angle of the slope, create a berm or a combination of these options according to given settings. The design of this functionality is described in section 11.2.

## 3.13 User story Perform Calamity calculation

As a geotechnical engineer I want to be able to make a calculation in a Calamity project. After importing a time series of water levels the safety factors will be calculated for all locations and for all time steps. The design of this functionality is described in section 11.3.

## 3.14 User story Display results in table form

As a geotechnical engineer I want to see the results of the calculations, so I can evaluate the calculations. The design of this functionality is described in section 12.1.

## 3.15 User story Display results in graphic view

As a geotechnical engineer I want to see the results of the calculations in a graphic view, so I can evaluate the calculations. This includes the adapted surfaceline and the resulting slipcircle. The design of this functionality is described in section 12.2.

## 3.16 User story Export data

As a geotechnical engineer I want to export data as tables (CSV-format) and/or shapes, so I can use the data for other purposes. The design of this functionality is described in chapter 13.

## 3.17 User story Open individual D-Stability projects

As a geotechnical engineer I want to be able to open each individual stability calculation in D-Stability. The design of this functionality is described in section 12.3.

## 3.18 User story Multi-language

As a geotechnical engineer I want to be able to set the language of the User Interface to Dutch or English. The design of this functionality is described in section 14.1.

## 3.19 User story Multi-core calculation

As a geotechnical engineer I want to be use multiple processor cores during the calculations to decrease the total calculation time. The design of this functionality is described in section 14.2.

## 3.20 User story Changing units

As a geotechnical engineer I want to be be able to change the units that are used in the User Interface. The design of this functionality is described in section 14.3.

## 3.21 User story Real-time validation

As a geotechnical engineer I want the input data to be validated during the use of the application (real-time/on the fly) given the (calculation) settings. The validation results are shown in a validation overview. The design of this functionality is described in section 14.4.

## 3.22 User story Calculation log

As a geotechnical engineer I want to see a log of the errors and warnings that are generated during a calculation. The design of this functionality is described in section 14.5.

## 3.23 User story Undo-Redo

As a geotechnical engineer I want to be able to undo and redo my changes of the data in the User Interface. The design of this functionality is described in section 14.6.

# 4 Create Project

The user can create a project by defining different sources, see chapter 6 and chapter 7

## 4.1 Create Design project

When the data sources are correctly defined, the user should be able to create a Design project. If the creation fails a log should display the problems encountered. This project can be used to perform a calculation of safety factors in different locations. It is also possible to make a calculation where the user defines a required safety factor. When this value is not met with the initial calculation, then a new surfaceline is determined, which will result in a safety factor that complies to the required value.

## 4.2 Create Calamity project

When the data sources are correctly defined the user should be able to create a Calamity project. If the creation fails a log should display the problems encountered. This project can be used to perform a calculation of safety factors during a certain amount of time. A time series of waterlevels has to be provided for this calculation.

## 4.3 DAMLive configuration

When the data sources are correctly defined and a separate configuration file for the sensor data is provided, the user should be able to create a DamLive configuration. If the creation fails a log should display the problems encountered. This configuration can be used in DamLive, which will be part of an operational system, assessing in real-time the condition of the dikes in the specified locations. An example of such an operational system is FEWS.

# 5 Save and Open Project

## 5.1 Saving a project

The project can be saved at a location defined by the user.

## 5.2 Opening a project

The user must be able to open an existing project. When calculations were made, also the calculation results must be shown. The results will not be shown when made by a previous version of DAM UI, because the results can be outdated.

**Note:** In version 25.1 it is not possible to open previous DAM UI (*.damx) projects because there were too much changes. A workaround for this is to recreate the project again with the original source data (see section 4.1 or section 4.2).

# 6 Data format

Validation is done during three phases: import, editing in UI and for calculation.

## 6.1 Validation during import

All required and optional import data is placed in table OverviewDataUIAndEngine.xlsx, tab DAM_input.

DAM UI can import data from csv files and shape files The sequence of import is 1. csv files (except scenarios.csv), overwritten by: 2. shape files, overwritten by: 3. scenario.csv If data is not present during import the default value is used, when a default is available. Default values are mentioned in OverviewDataUIAndEngine.xlsx

Required data Data can be required when importing and/or required when calculating. In OverviewDataUIAndEngine.xlsx is described what data is required and when. Example: crosssection and dikering_ are only required when using shapefiles (see column remark).
If data is required for import and is missing or invalid, the exception handling is dependent of the kind of data, see Table 6.1. Messages are given in the log window.

| Parameter | Exception handling |
|---|---|
| location_id in location.csv (or via shape) | All locations with missing location_id are not imported and message is given. |
| location_id in scenarios.csv (or via shape) | All scenarios with missing location_id are not imported and message is given. |
| surfaceline in location.csv_id | All locations with missing surfaceline_id are not imported and message is given. |
| Profielnaam in surfacelines.csv_id | All surfacelines with missing surfaceline_id are not imported and message is given. |
| dikering_id via shape | Project is not imported and message is given. |
| segment_id in locations.csv or via shape | All locations with missing segment_id are not imported and message is given. |
| segment_id in segment.csv | All locations using segments with missing segment_id are not imported and message is given. |
| calculation_type in segments.csv | All locations using segments with missing calculation_type are not imported and message is given. |
| soilprofile_id in segments.csv | All locations using segments with missing soilprofile_id are not imported and message is given. |
| top_level in soilprofiles.csv | All locations linked (via segment) to soilprofiles with missing top_level are not imported and message is given. |
| location_scenario_id | All scenarios with missing location_scenario_id are not imported and message is given. |
| characteristic points (required) | All locations with missing required characteristic points are not imported and message is given. |
| crosssection (via shape) | All locations with missing cross section are not imported and message is given. |
| SigmaTau curve (via csv) | When needed (as defined in the soils.csv) the curves must each meet the validation requirements as given in OverviewDataUIAndEngine.xlsx. All incorrect curves are not imported and a message is given. |

Table 6.1 Exception handling required data during import

In OverviewDataUIAndEngine.xls, tab DAM_input also the optional data is listed. If these parameters are not present, no error or warning is given. When a default is available, this value is used, otherwise the parameters is NULL. If the parameter is required for calculation and the value is NULL and the kernel does not provide a default, an error message is given.

### 6.1.1 Editing characteristic points

When the characteristic points are edited by the user in the UI, they must be validated by rules in following table. Blue text validations are not implemented yet.

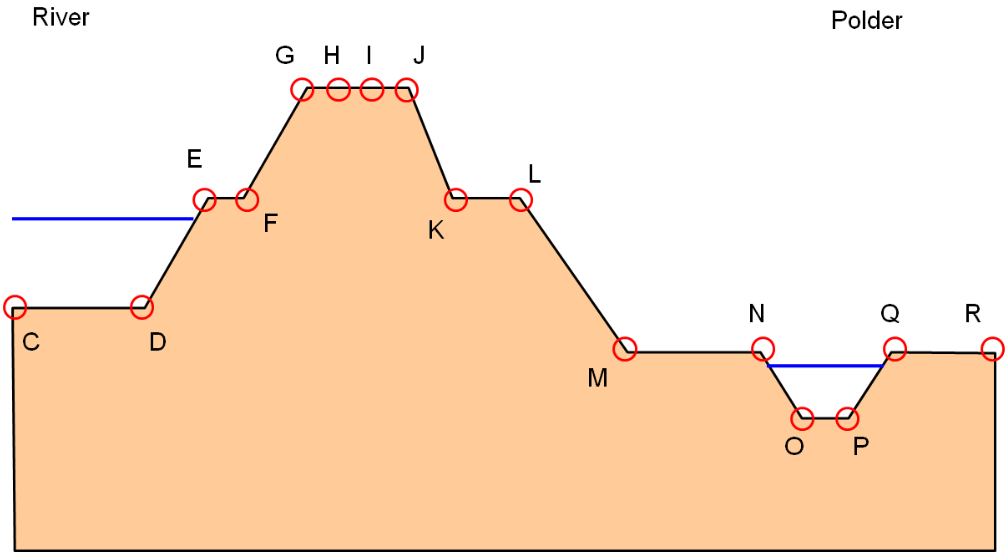


Figure 6.1 Characteristic points on the surface line

| **Name EN** | **Name NL** | **Symbol** | **Unit** | **Min value** | **Max value** |
|---|---|---|---|---|---|
| Surface level outside | Maaiveld buitenwaarts | $X_C$ | m | - | - |
| | | $Z_C$ | m NAP | - | - |
| Dike toe at river | Teen Dijk buitenwaarts | $X_D$ | m | $>X_C$ | $<X_E$ |
| | | $Z_D$ | m NAP | $>Z_C$ | $<Z_G$ |
| Shoulder top outside | Kruin buitenberm | $X_E$ | m | $>X_D$ | $<X_F$ |
| | | $Z_E$ | m NAP | $>Z_D$ | $<Z_F$ |
| Shoulder base outside | Insteek buitenberm | $X_F$ | m | $>X_E$ | $<X_G$ |
| | | $Z_F$ | m NAP | $>Z_E$ | $<Z_G$ |
| Dike top at river | Kruin buitentalud | $X_G$ | m | $>X_F$ | $<X_H$ |
| | | $Z_G$ | m NAP | $>Z_D$ | - |
| Traffic load outside | Verkeersbelasting buitenwaarts | $X_H$ | m | $>X_C$ | $<X_I$ |
| | | $Z_H$ | m NAP | $>Z_G$ | $<Z_I$ |
| Traffic load inside | Verkeersbelasting binnenwaarts | $X_I$ | m | $>X_H$ | $<X_S$ |
| | | $Z_I$ | m NAP | $>Z_H$ | $<Z_J$ |
| Dike top at polder | Kruin binnentalud | $X_J$ | m | $>X_I$ | $<X_K$ |
| | | $Z_J$ | m NAP | $>Z_M$ | - |
| Shoulder base inside | Insteek binnenberm | $X_K$ | m | $>X_J$ | $<X_L$ |
| | | $Z_K$ | m NAP | $>Z_J$ | $<Z_L$ |
| Shoulder top inside | Kruin binnenberm | $X_L$ | m | $>X_K$ | $<X_M$ |
| | | $Z_L$ | m NAP | $>Z_K$ | $<Z_M$ |
| Dike toe at polder | Teen dijk binnenwaarts | $X_M$ | m | $>X_L$ | $<X_N$ |
| | | $Z_M$ | m NAP | $>Z_L$ | $<Z_J$ |
| Ditch dike side | Insteek sloot dijkzijde | $X_N$ | m | $>X_M$ | $<X_O$ |
| | | $Z_N$ | m NAP | $>Z_M$ | $<Z_O$ |
| Bottom ditch dike side | Slootbodem dijkzijde | $X_O$ | m | $>X_N$ | $<X_P$ |
| | | $Z_O$ | m NAP | $>Z_N$ | $<Z_P$ |
| Bottom ditch polder side | Slootbodem polderzijde | $X_P$ | m | $>X_O$ | $<X_Q$ |
| | | $Z_P$ | m NAP | $>Z_O$ | $<Z_Q$ |
| Ditch polder side | Insteek sloot polderzijde | $X_Q$ | m | $>X_P$ | $<X_R$ |
| | | $Z_Q$ | m NAP | $>Z_P$ | $<Z_R$ |
| Surface level inside | Maaiveld binnenwaarts | $X_R$ | m | - | - |
| | | $Z_R$ | m NAP | - | - |

If a required characteristic point is missing, (validation)message must be given:
Characteristic point <Name> is missing.
Required characteristic points are:

- Surface level outside
- Dike toe at river
- Dike top at river
- Dike top at polder
- Dike toe at polder

- Surface level inside

If a set of characteristic points is not complete, (validation)message must be given: Set Characteristic points <Name> is not complete. NL: Set karakteristieke <Naam> is niet compleet.
Sets of characteristic points (Name and points from table) are:
- TrafficLoad (H and I in table) NL: Verkeersbelasting
- ShoulderOutside (E and F in table) NL: Buitenberm
- ShoulderInside (K and L in table) NL: Binnenberm
- Ditch (N,O,P and Q in table) NL: Sloot

Note: All sets are optional, but when one of the characteristic points is asigned, the others of the set must also be present.

## 6.2 Validation during editing

DAM UI validates during the import of the data and during editing by user in the User interface. Minimal and maximum values are given in OverviewDataUIAndEngine.xlsx. The data is also validated by the used kernels when calculations are started.

## 6.3 Validation for calculation

DAM UI validates during the import of the data and during editing by user in the User interface. The data is also validated by the used kernels when calculations are started. Messages are given in the log window.

# 7 Data combination

DAM can generate input for the kernels by combining the data from the source files. This is done by linking via the location id and via GIS-files (see section 7.2).

## 7.1 Id/Name

The data is combined by matching Id's (Names) between the several data sources.
Not all characters can be used when defining Id's. The following characters are valid:
"ABCDEFGHIJKLMNOPQRSTUVWXYZ"
"abcdefghijklmnopqrstuvwxyz"
"01234567879"
"!#$% &()*+,-."
":;<=>?@"
"[\]^_` "
"{|}~"
" " (space)
A validation of the Id's must be done when performing the data combination.

## 7.2 Data extraction

The locations are described with a name and RD-coordinates; a point element in GIS files. Each location is connected to a crosssection; a line element in GIS files.

The combination of data from GIS files is made based on these point and line elements.
If the input data is available in a GIS file with line elements the data is collected at the intersection of the crosssection with the line element, see Figure 7.1.

When a parameter is available in a line shape, DAM UI will check, during import of data, if the cross section of a location intersects the shapefile of the parameter. When so, this parameter is connected to this location. If a cross section intersects more than one line of the shapefile, no parameters are connected at all and a message is given that this location is not imported.

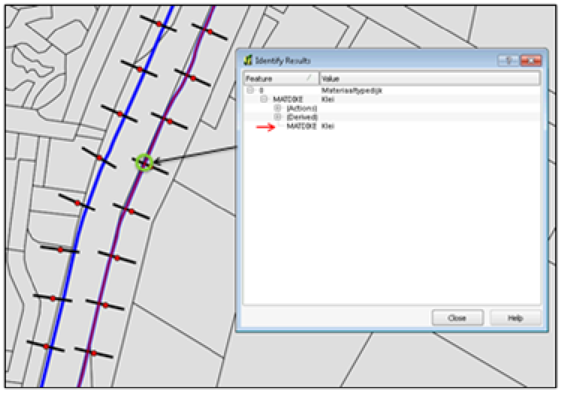

Figure 7.1 Data is collected from the line element at the intersection

If the input data is available in a GIS file with area elements the data is collected at from the area where the location point is situated, see Figure 7.2.

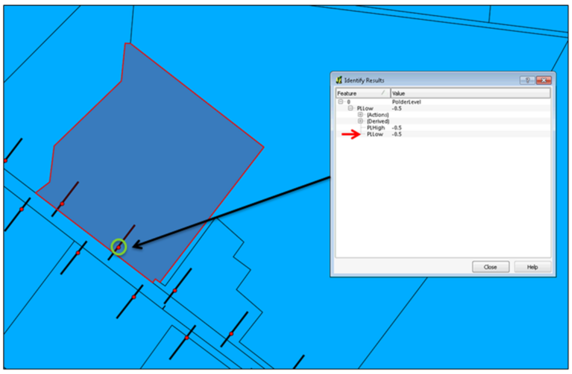

Figure 7.2 Data is collected from the area element where the location point is situated

If the inputdata is not available in GIS files, all input data can be linked to each location via a table (csv-format).

## 7.3 Geometry Generation

The DAM UI can combine a surface line with a subsoil scenario. The result is a geometry, usable for the failure mechanism Macrostability.

## 7.4 Subsoil

The subsoil model is made up of the following elements:
- Soil segments
- Soil profiles
- Soil layers
- Soil materialparameters

A soil segment is located on a map and can contain several soil scenarios. A soil scenario is a combination of a soil profile and its probability. Each soil profile is build up from layers (1D- profile) or areas (2D-profile). A layer (or area) has the name of a material. And finally this material is described via soil type and several parameters (such as strength parameters).
All is displayed in Figure 7.3.

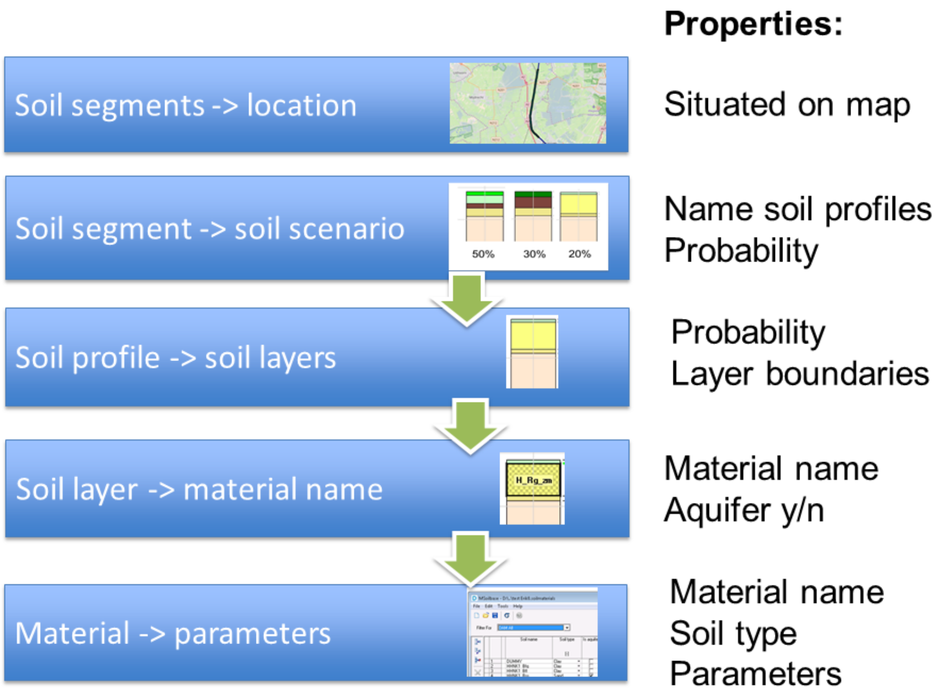


Figure 7.3 The elements of the subsoil model and their properties

By linking the location to a soil segment via the locations.csv column segment_id, DAM UI combines the location to all soil profiles of the soil segment. The procedure for combining a surfaceline with a soil profile is described in section 7.5.

## 7.5 Combination of surface line with soil profile

### 7.5.1 Combination of surface line with a 1D soilprofile

A 1D soil profile is a summation of layers with layer boundaries (Z-values) and materialnames. Combination with a surfaceline is uncomplicated if all the Z-values of the surface line are within the boundaries of the soil profile. If not, the user can define a filling material.

### 7.5.2 Transfer of 1D soilprofile

The user can vertically transfer the 1D profiles by defining a characteristic point as a reference level. This means that the Z-value of the characteristic point is the top of all 1D-soilprofiles of that location. This reference level is given per project. So if the surfacelevelinside is the reference, for each location the 1D-soilprofiles will start at the Z-value of the surfacelevelinside of that location. On top of the 1D soilprofile the filling material is used.

### 7.5.3 Combination of surface line with a 2D soilprofile

A 2D profile already has a topboundary with different Z-values. Combination with a surface line is more complicated since this top boundary and surfacel may differ in X and/or Z-values. The origin of the surfaceline can differ from the origin of the top boundary of the soil profile. The user can define this difference. The surfaceline is determing the final length of the combinated 2D-profile. If the surface line xxx soil profile length: subsoil at the right side will be deleted If the surface line xxx soil profile length: subsoil at the right side will be generated with Z-values at boundary.

# 8 Data display

## 8.1 Navigator

Give an overview of all imported locations. Make the locations selectable for calculation

## 8.2 Tables

Show per row the imported data per location, see https://repos.deltares.nl/repos/dam/DamOverall/trunk/doc/DAM General/OverviewDataUIAndEngine.xlsx for the data to be shown. If column csv contains 'locations', item must be shown in the table.

## 8.3 Cross section

Show the cross section of the selected location (selected in either the navigator window or the table window). Make it possible to scroll throw the different soilprofiles.

Show the soilprofiles with material colors.

Show the characteristic points on the surfaceline.

## 8.4 Properties

Show location data in a tab, named Location (NL: Locatie) Show location scenarios in a tab, named Location scenarios (NL: Locatie scenarioś) Show surfacelines points in a tab, named Surfaceline (NL: Hoogtegeometrie). This tab contains a table named Points (NL: Punten) with columns:

- Characteristic point (NL: Karakteristiek punt) editable via pull down menu with characteristic points, see OverDataUIAndEngine.xls

m
m NAP

Example: see D-Soil Model.

## 8.5 Map

Show the locations as a dot on a map with a PDOK map as background (when selected). The background can also be empty. Display imported shapefiles when selected by user.

## 8.6 General

When selecting a location in navigation, table or map window, the other windows must 'follow': selecting same location. When selecting a soilprofile in the calculations table or in the cross section window, the other window must 'follow': selecting same soil profile.

Show popup of source of data if the mouse is above textedit or cell of table. The text of the popup is placed in https://repos.deltares.nl/repos/dam/DamOverall/trunk/doc/DAM General/OverviewDataUIAndEngine.xlsx.

# 9 Data edit

## 9.1 Navigator

Data in Navigator window is not editable. Only locations are selectable.

## 9.2 Tables

In https://repos.deltares.nl/repos/dam/DamOverall/trunk/doc/DAM General/OverviewDataUIAndEngine.xlsx column Editable in UI is given which data should be editable It is not possible to add locations.

## 9.3 Cross section

Data in cross section is not editable.

## 9.4 Properties

How the data is editable varies from tab:

- Tab Location
  Data is similar editable as locations tab in table window.
- Tab Location scenarios
  Data is editable, but it is not possible to add scenarios.
- Tab Surface line (NL-Hoogte geometrie)
  The column characteristic points is editable via a pull down menu with characteristic points. The pull down menu contains all possible characteristic points. The validation is done directly; so if an user changes something incorrect in the surface line window, validation message appears in Validation window. Validation rules are described in section 6.1.1. Note: The surface line points can not be edited, so after import it is not possible to let a traffic load point coincide with another characteristic point. Traffic load points can only coincide with a another characteristic point when it is defined in the import files.
- Tab Calculations
  Data is not editable.

# 10 Calculation settings

All calculation settings are the same for all dike rings and locations within the project. So there is only one set of calculation settings.

## 10.1 Macrostability

In DAM the following models for Stability Inside can be used:

- *Bishop*
- *UpliftVan*
- *Bishop-UpliftVan*

Next to Stability Inside, one model (*Bishop*) is offered for Stability Outside.

Note that for both *Bishop* and *UpliftVan* a brute force search method based on moving grids is offered. For *UpliftVan*, the search method *Bee Swarm* is an alternative option. The combi model *Bishop-UpliftVan* always uses the brute force search method for the *Bishop* calculations whereas for the *UpliftVan* a choice can be made between brute force and *Bee Swarm*.

The determination of position the grid(s) must offer automatic positioning next to a user steered method. In the latter case, the user defines the dimension of the grid(s) by entering the number of grid points and the distance between the points (in both X- and Z-direction; for both grids when required).

The combi model *Bishop-UpliftVan* performs the calculations as follows. For each calculation that is to be made (a combination of location, scenario, subsoil/surface line and iteration step), first of all a short calculation is performed to determine whether uplift does occur for the given case. If so, an *UpliftVan* calculation is to be performed next to the *Bishop* calculation that is always part of this model. If not, only the *Bishop* calculation is done.

For each calculation, at least one stix file is written to a calculation folder per model. This (result) stix file hold the input as passed to the *Macro Stability* kernel as well as the resulting slip circle (*Bishop*) or slip plane (*UpliftVan*). This file can be used to replicate the result as obtained using DAM by performing the calculation with *D-Stability*. This of course will only be true when the same version of *Macro Stability* kernel is used by both programs.

Possible second stix = input.

## 10.2 Piping

### 10.2.1 Models

In DAM the following piping models can be used:

- Bligh
- Sellmeijer revised (WBI)

For the description of the models, see https://publicwiki.deltares.nl/display/DAM/Piping

# 11 Calculation

There a different calculations possible, depending on the type of the project.

## 11.1 Perform Design calculation - No adaption

It should be possible to make a calculation in a Design project based on the input parameters. The most important outcome of the calculation are the safety factors.

## 11.2 Perform Design calculation - With adaption

It should be possible to make calculations in a Design project with adaption of the geometry of the dike, if the calculated safety factor is lower than the required safety factor. The adaptation must have the options to increase the crest, change the angle of the slope, create a berm or a combination of these options according to given settings.

## 11.3 Perform Calamity calculation

It should be possible to make a calculation in a Calamity project. After importing a time series of water levels the safety factors will be calculated for all locations and for all time steps.

# 12 Display results

The user must be able to view the results of the calculations within DAM UI.

## 12.1 Display results in a table

The overall results at main level must be presented in a table so these can be exported and/or copy pasted in an excel sheet. Unless stated otherwise, all results are read only.

Next to that, the individual results of a single calculation must be presented in a property view. This view must show the relevant information about the calculation (i.e. what location, profile, scenario etc. it represents) as well as the main results. An optional graphic presentation of the results must be offered when applicable (e.g. the picture of the final slip circle for a bishop stability calculation). It must also be possible to open/recalculate the individual result in the original program from within DAM UI when applicable.

### 12.1.1 Stability results

The results presented in the table for the stability calculations must be (at least but not limited to):

- name of the location
- name of the scenario
- calculation result (succeeded, failed, not calculated)
- location coordinates (in RD)
- type of analysis (no adaption/adapt geometry)
- uplift (yes/no)
- profile name
- profile probability
- the safety factor
- entry point of the slip plane
- exit point of the slip plane
- Result messages (e.g. error messages from calculation/validation)
- Number of iterations (important for Design with adapt geometry)
- Notes (free remarks by user, editable)
- Evaluation (Not evaluated/Accepted/Rejected, editable)

In the technical design ((The and Bokma, 2022b)), a full list of all required results is presented.

### 12.1.2 Piping results

The results per individual calculation presented using a table for the piping calculations must be (at least but not limited to):

- name of the location
- name of the scenario
- calculation result (succeeded, failed, not calculated)
- location coordinates (in RD)
- type of analysis (no adaption/adapt geometry)
- uplift (yes/no)
- profile name
- profile probability
- safety factor (= piping factor)
- required safety factor
- River level
- Piping Model
- Entry point piping X (local)
- Exit point piping X (local)
- Seepage length piping
- Hcritical
- Uplift safety factor
- Backward erosion safety factor
- Backward erosion safety factor (WBI*)
- Backward erosion CCreep (WBI*)
- Backward erosion hc (WBI*)
- Backward erosion delta hc (WBI*)
- Backward erosion reduced delta hc (WBI*)
- Uplift safety factor (WBI*)
- Uplift hc (WBI*)
- Uplift delta hc (WBI*)
- Heave safety factor (WBI*)
- Heave hc (WBI*)
- Heave gradient (WBI*)
- Piping hc (WBI*)
- Effective stress exit point (WBI*)
- Result messages (e.g. error messages from calculation/validation)
- Number of iterations (important for option Design with adapt geometry)
- Notes (free remarks by user, editable)
- Evaluation (Not evaluated/Accepted/Rejected, editable)

**Note:** *: Should only be visibile when the WBI model is used. A full list of all parameters and their dependency on the used model is provided in the technical design (The and Bokma, 2022b).

In the property view (per result) the next items must be displayed and for a part be editable:

- name of the location
- profile name
- Piping Model
- name of the scenario
- safety factor (= piping factor)
- calculation result (succeeded, failed, not calculated)
- Number of iterations (important for Desing with adapt geometry)
- Evaluation (Not evaluated/Accepted/Rejected, editable)
- Notes (free remarks by user, editable)

In order to be able to (re-)display the results mentioned above when loading a project file that already calculated them, these results must be part of the damx project file itself.

Finally, some extra information that can be useful to examine the results further (such as the profile and surface line used in the analysis) are written to an external file per location, scenario, profile. Note that the name of the file must be added to the individual results per calculation as part of the damx project file. The data in this file will be used to display the adapted surfaceline graphically when this is available. For this purpose, the file should be read upon selection of the result.

## 12.2 Display results in a graph view

### 12.2.1 Cross section view

Based on the results of the calculation it should be possible to display the following items in a cross section view per calculated (design and/or subsoil) scenario per location.

- The adapted surfaceline when a design calculation has been performed with adaption.
- The resulting slipcircle when a stability calculation has been performed.

### 12.2.2 Time series of safety factors

When a Calamity project has been calculated it should be possible to view a chart per location with a time series of the safety factors.

## 12.3 Open individual D-Stability projects

When a stability calculation has been performed it should be possible to open the stability calculation in D-Stability for each calculated (design and/or subsoil) scenario per location. D-Stability should be installed on the same system and is not part of DAM UI.

# 13 Data export

The user must be able to export the following data from DAM UI:

- The calculation log (the log that is produced during the calculations with all errors and warnings provided by kernel validation and calculation) must be saved as text file. This needs to be done automatically for every performed calculation. In order to keep the files traceable and apart, a time stamp will be incorporated in the filename.
- Redesigned surface lines after calculation with characteristic points. The during calculation redesigned surface lines and the corresponding characteristic points must be exported in the same format as the import files. It is a complete set of all calculated locations.
- Location scenarios file(s). The location scenario data can be exported to a csv file per location.
- Calculation result file(s). For stability calculations these are both the sti and the std file as used/produced by D-Geo Stability. For Piping, these are the xml files containing the redesigned surface line and its belonging 1D profile.
- Calculation image when available. This is only for stability calculations. The image shows the critical slip plane. In case of design, Adapted geometry, the slip plane will be projected on the adapted geometry.

# 14 Application options

These are requirements for adapting the User Interface of DAM UI.
- Multi-language.
- Multi-core calculation.
- Changing units.
- Real-time validation.
- Calculation log.
- Undo-Redo.

## 14.1 Multi-language

It should be possible to change the display language of the User Interface. Two options are possible.
- Dutch.
- English.

## 14.2 Multi-core calculation

It should be possible to use multiple processor cores during the calculations to decrease the total calculation time.

## 14.3 Changing units

It should be possible to change the units that are used in the User Interface. Below a list of quantities and their units.
- Fraction (÷, %, ‰, ppm).
- Length (m, cm, mm, km, inch, ft).
- Tiny length (mm, µm).
- Angle (deg, rad, grad, tan, cot).
- Weight (Kn/m3, N/m3, MN/m3, lb/in3, lb/ft3).
- Pressure per length (Kn/m3, N/m3, kN/cm3, lb/in3, lb/ft3, kip/inch3, MPa/m).
- Pressure (Kn/m2, N/m2, Pa, KPa, MPa, kN/cm2, psi).
- Permeability (m/s, m/min, m/h, m/d, cm/s, mm/s).

## 14.4 Real-time validation

The input data should be validated during the use of the application (real-time/on the fly) given the (calculation) settings. The validation results are shown in a validation overview.

## 14.5 Calculation log

After the calculaton a log of the errors and warnings that are generated during the calculation will be shown.

## 14.6 Undo-Redo

It should be possible to undo and redo changes of the data in the User Interface.

# 15 Literature


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