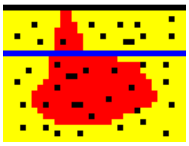

GGU-CONTAM-RW manual

Contaminant transport analysis (random walk)

Exported on 23.7.2026

GGU Software

Technische Umsetzung, Layout und Vertrieb:
Civilserve GmbH, Steinfeld

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Theorie. Und Praxis.

Geotechnische Softwarelösungen können so einfach sein. Denn Theorie und Praxis lassen sich mit **GGU-Software** und den neuen Angeboten der **civilserve Academy** prima kombinieren: Knackige theoretische Aufgaben lösen und als Sahnehäubchen Ihr

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1 GGU-CONTAM-RW: Preface

The **GGU-CONTAM-RW** program allows modelling of contaminant transport in horizontal-plane, vertical-plane and axis-symmetrical groundwater systems according to the random walk method. A record containing the basic steady-state data must have been previously generated using the GGU-2D-SSFLOW program.

For evaluation and visualisation of analysis results, the GGU-PLGW program is available. It enables impressive, time-dependent animation or presentation of concentrations along sections through the system.

The program includes convenient data input. The system is permanently displayed on the screen. Every change to the data is displayed on the screen, so that optimum control of the input data is guaranteed.

There are "**?**" and "**Info**'" buttons in the dialog boxes for many technical and program-specific questions. Click on the "**?**" buttons or "**Info**" buttons to obtain the necessary information.

The graphic output supports the true type fonts provided by WINDOWS, so that an excellent layout is guaranteed. Colour output and numerous graphic formats (BMP, TIF, JPG etc.) are supported. PDF and DXF files can also be imported via the integrated **Mini-CAD** system (see "**Mini-CAD**" manual).

The program has been extensively tested. No errors have been found. Nevertheless, liability for completeness and correctness of the program and the manual, and for any damage resulting from incompleteness or incorrectness, cannot be accepted.

It is not the task of this manual to give an introduction to contaminant propagation modelling methods. For details, please refer to the literature.

The following general notes are important:

- The data forming the basis for contaminant transport modelling are records from steady-state modelling using **GGU-2D-SSFLOW**.
- Modelling is based on a rectangular array.

2 GGU-CONTAM-RW: Licence protection

To protect the GGU software from unauthorised access, each GGU program is equipped with the ***CodeMeter software protection system*** from WIBU-Systems. Each GGU program is bound to a so-called ***CmContainer*** via a licence with the corresponding product code.

To be able to use the GGU licences in a CmContainer, a runtime environment, the ***CodeMeter Runtime Kit***, must be installed on your computer via driver software. You can obtain the current version from Software for Users - Wibu-Systems (CodeMeter User Runtime for Windows).

You can work with the following CmContainer types on your PC with the CodeMeter Runtime Kit installed (= ***CodeMeter licence server***):

- **CmStick**
  The licence for your GGU program is stored in a USB dongle.
- **CmActLicense** (soft licence, not for virtual PC/servers)
  The licence for your GGU program is stored in a licence file that is linked to the hardware of a computer.
- **CmCloudContainer**
  The licence is located on a CmCloud server of WIBU-Systems and is mirrored to your CodeMeter licence server. The advantages of this type of licence binding are described on the following website: Licence binding | GGU Software.

The GGU programs check at start-up and during runtime whether a corresponding license is available in a CmContainer.

3 GGU-CONTAM-RW: Language selection

The GGU programs can be used in German and English. The program always starts with the language in which it was terminated.

The language preferences can be changed at any time in the "**Info**" menu, using the menu item "**Spracheinstellung**" (for German) or "**Language preferences**" (for English).

4 GGU-CONTAM-RW: Starting the program

After starting the program you will see two menus at the top of the initial window:

- File
- ?

After clicking on the "**File**" menu, a system processed with the **GGU-2D-SSFLOW** program can be loaded by means of the "**Load GW data**" menu item.

The processed system record is saved in **GGU-2D-SSFLOW** using the "**.da1**" extension, in order to make it available for **GGU-CONTAM-RW**. The program function to be activated for this purpose can be found in **GGU-SS-FLOW2D** in the "**System/Analyse**" menu item.

Then, the menu bar will show seven menus:

- File
- Editor
- Concentrations
- Modelling
- Graphics preferences
- Page size + margins
- ?

After clicking one of these menus, the so-called menu items roll down, allowing you access to all program functions.

The program works on the principle of ***What you see is what you get***. This means that the screen presentation represents, overall, what you will see on your printer. In the last consequence, this would mean that the screen presentation would have to be refreshed after every alteration you make. For reasons of efficiency and as this can take several seconds for complex screen contents, the screen is not refreshed after every alteration.

If you would like to refresh the screen contents, press either [**F2**] or [**Esc**]. The [**Esc**] key also resets the screen display to your current image zoom, which is usually preset to 1.0, which corresponds to an A3 or A4 sheet in most GGU programs (see menu item "**Graphics preferences/Refresh and zoom**").

5 Tips and tricks

5.1 GGU-CONTAM-RW: Keyboard and mouse

You can scroll the screen with the keyboard using the cursor keys and the [**Page up**] and [**Page down**] keys. By clicking and pulling with the mouse, with [**Ctrl**] pressed, you activate the zoom function, i.e. the selected section will fill the screen. Use the mouse wheel to zoom in or out of the screen view or to pan.

In addition, scale and coordinates of the system graphics (drawing area within the plotting margins) can be altered directly using the mouse wheel. The following mouse wheel functions are available

Change system graphics (new values can be checked in "Page size + margins/Manual resize (editor)"):

- [Ctrl] + mouse wheel up = enlarge system graphics (change of scale)
- [Ctrl] + mouse wheel down = shrink system graphics (change of scale)
- [Shift] + mouse wheel up = move system graphics up
  (change in system coordinates)
- [Shift] + mouse wheel down = move system graphics down
  (change in system coordinates)
- [Shift] + [Ctrl] + mouse wheel up = move system graphics right
  (change in system coordinates)
- [Shift] + [Ctrl] + mouse wheel down = move system graphics left
  (change in system coordinates)

Change screen coordinates:

- Mouse wheel up = move screen image up
- Mouse wheel down = move screen image down
- [Alt] + [Ctrl] + mouse wheel up = enlarge screen image (zoom in)
- [Alt] + [Ctrl] + mouse wheel down = shrink screen image (zoom out)
- [Alt] + [Shift] + mouse wheel up = move screen image right
- [Alt] + [Shift] + mouse wheel down = move screen image left

By double-clicking the left mouse button on legends or **Mini-CAD** objects, the editor for the selected object immediately opens, allowing it to be edited.

5.2 GGU-CONTAM-RW: Function keys

Some of the function keys are assigned program functions. The allocations are noted after the corresponding menu items. The individual function key allocations are:

- [**Esc**] refreshes the screen content and resets from a screen section to your current image zoom, which is usually preset to 1.0 (see “
- [**F1**] opens the manual file.
- [**F2**] refreshes the screen without altering the current magnification.
- [**F11**] activates the menu item "**Move objects**”, which appears in the GGU programs under various menu titles, e.g. “**Page size + margins**”, “**Graphics preferences**” or “**Output preferences**”.

In this GGU program, the following function keys are also assigned to program functions:

- [**F5**] opens the menu item "**Modelling/Start**".
- [**F9**] activates the menu item "**Page size + margins/Auto-resize**".

5.3 GGU-CONTAM-RW: "Copy/print area" icon

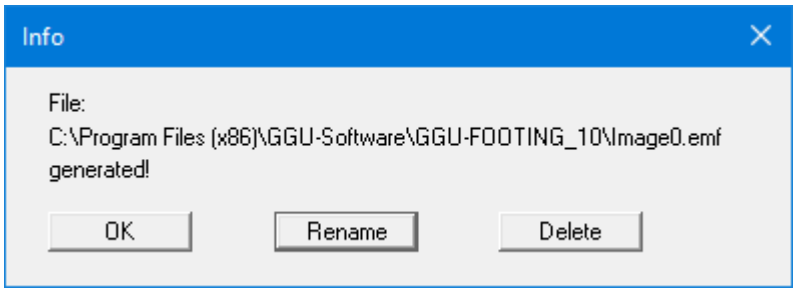
A dialog box opens when the "**Copy/print area**" icon

in the menu toolbar is clicked, describing the options available for this function. For example, using this icon it is possible to either copy areas of the screen graphics and paste them into the report, or send them directly to a printer.

In the dialog box, first select where the copied area should be transferred to: "**Clipboard**", "**File**" or "**Printer**". The cursor is displayed as a cross after leaving the dialog box and, keeping the left mouse button pressed, the required area may be enclosed. If the marked area does not suit your requirements, abort the subsequent boxes and restart the function by clicking the icon again.

If "**Clipboard**" was selected, move to the MS Word document (for example) after marking the area and paste the copied graphics using "*Edit/Paste*".

If "**File**" was selected, , the following dialog box appears after defining the area, shown here as an example for the **GGU-FOOTING** program:



The default location of the file is the folder from which the program is started (here: GGU-FOOTING_10) and, if several files are created, the file is given the file name "**Image0.emf**" with sequential numbering. If the
"**Rename**" button in the dialog box is clicked, a file selector box opens, and the copied area can be saved under a different name in a user-defined folder. Saving can be aborted by pressing the "**Delete**" button.

If the "**Printer**" button was pressed in the first dialog box, a dialog box for defining the printer settings opens after marking the area. Following this, a dialog box for defining the image output settings opens. After confirming the settings, the defined area is output to the selected printer.

6 GGU-CONTAM-RW: Program concept

There are a number of numerical methods available for contaminant transport modelling:

- finite-element method,
- finite-difference method,
- particle tracking method (and in particular the random walk method).

The finite-element method is the most powerful of these, not only due to the flexible mesh design. This gives rise to the most basic question: why use particle tracking at all (here the random walk method in particular)? The reason is numerical dispersion, which is not related to physical dispersion. Numerical dispersion occurs where the finite-element method and the finite-difference method are used. The reason for numerical dispersion is the generally linear approximation approach within an element. Where the contaminant front is discrete, such an approach is no longer capable of precisely modelling this front. The contaminant front ***smears***, an effect like physical dispersion and which is therefore known as numerical dispersion.

Particle tracking methods do not suffer from this problem. The particle tracking method is the simplest method. This method is incorporated in the **GGU-2D-SSFLOW** steady-state application in the shape of flow lines. The particle tracking method cannot consider either dispersion or diffusion effects. Only convection can be taken into consideration (movement of particles at groundwater speed). If, in addition, you wish to consider dispersion, diffusion, etc., the random walk method is generally used. The analytical solution of simple flow processes with contaminant transport leads to functions that correspond to a Gaussian distribution. This function can be modelled with a random generator if sufficient attempts are made. This mathematical effect is utilised by the random walk method (random path method). The method first assumes propagation at groundwater flow velocity. This underlying velocity is superimposed upon by a dispersion (diffusion) velocity, the direction of which is determined by a random generator integrated in the application. In order to model the Gaussian curve mentioned above adequately, it is no longer sufficient to simply consider one contaminant particle. Rather, a multitude of particles is started, and their courses recorded. This also has the result that the accuracy of the analyses increases with the number of started particles. Because of the integrated random generator, you will not get the same result for any two different runs.

For contaminant propagation modelling a flow field is required (velocity magnitude and direction). **GGU-CONTAM-RW** gets this data from a record (e.g. "**plgw.da1**") generated in a previous analysis using the **GGU-2D-SSFLOW** application. It is therefore necessary to load this file first after opening the program. The flow field contained in this file remains constant for subsequent analyses.

Also typical for the random walk method is that analyses must be based on a rectangular mesh. This requirement does not conform to the flexibility of the triangular elements used in FEM (**GGU-2D-SSFLOW**), which forms the basis of the flow data for modelling. **GGU-CONTAM-RW** solves this problem by placing a rectangular array over the whole FEM mesh. It is possible to edit the rectangular array subdivisions within broad limits. In this system of triangular mesh and rectangular array, you now define the initial concentrations and any contaminant sources. The definition of time-dependent changes, such as performed in **GGU-CONTAM-FE** by means of polygon courses, is not possible using the random walk method. Once the initial concentrations have been defined, you must still specify how many particles to start. The program then assigns each particle a corresponding partial concentration. Now, during analysis, the paths of the contaminant particles are traced, and the number of particles found in each rectangular cell counted for each time step. The summation of all partial concentrations within a cell then provides the total concentration that applies for that cell. These explanations demonstrate,

- that numerical dispersion cannot occur with this procedure,
- that the accuracy of the analysis is increased with the number of started particles,
- that the accuracy of contaminant distribution is not increased with the number of rectangular cells.

Because of the discrepancies between the triangular mesh and the rectangular array, the results from the rectangular cells are always converted to fit the triangular mesh. GGU-CONTAM-RW therefore generates two records:

- **Record 1 ("plgw_ras.plw")**
  contains all results from the rectangular array. So, during subsequent evaluation using the **GGU-PLGW** application, a ***rectangular triangle mesh*** is displayed.
- **Record 2 ("plgw_fe.plw")**
  contains the values from the rectangular array recalculated to fit the triangular mesh.

Besides the flow field, the **GGU-CONTAM-RW** program requires information on the initial contaminant distribution conditions at time t = 0. These so-called initial concentrations can be arbitrarily defined. If you do not define any values, the program will assume an initial concentration of "0" at all nodes.

Apart from the flow field, the "**RW vertical.da1**" file also includes the effective pore space neff, upon which steady-state modelling is based. This ***steady-state*** soil property (neff) cannot be edited in the **GGU-CONTAM-RW** application. If amendment of this value were allowed, the flow field would no longer correlate to the calculated potentials and the contaminant transport modelling would produce nonsensical results. However, you must enter the additional soil properties required for contaminant propagation modelling.

Besides additional soil properties the **GGU-CONTAM-RW** application also allows you to assign temporally constant concentration sources to individual nodes. Soil properties (contaminant transport modelling), as well as the allocation of initial concentrations and concentration sources to system nodes (so-called boundary values), can be saved in a separate file in order to make them available again for later analyses.

Generally, when modelling contaminant propagation in groundwater systems, a flood of result values is generated. The modelling results are saved in a file (generally "**_ras.plw**" and "**_fe.plw**") by **GGU-CONTAM-RW**. Contaminant propagation data cannot be evaluated using the **GGU-CONTAM-RW** program. The **GGU-PLGW** program is available for this purpose; it is described in a separate user-manual. For example, it is possible to evaluate the results using isolines, animations, sections or hydrographs.

The **GGU-CONTAM-RW** program is opened by conventional WINDOWS operations. The program is equipped with a large amount of error queries. Even highly nonsensical input will usually be detected by the program and an error message be displayed on the screen. Independently of this you should, for security reasons, intermittently save extensive input, if only to save renewed input in the case of a power cut.

7 GGU-CONTAM-RW: Short description

Since I know from personal experience that reading user-manuals is quite a chore, there will now follow a short description of the main program functions. After studying this section, you will be in a position to model contaminant transport based on steady-state groundwater flow. You can learn about the details of the program in the subsequent chapters.

- In order to be able to use the system entered in your **GGU-2D-SSFLOW** groundwater flow program for contaminant transport modelling using the **GGU-CONTAM-FE** program, you must create a file in the **GGU-2D-SSFLOW** program with the file extension "**.da1**". You can create this file by going to "S**ystem/Analyse**" and activating the check box "**Generate record for transient modelling**".
- Start the **GGU-CONTAM-RW** program and using the menu item "**File/Load GW data**", select the desired record of a flow system.
- Using the "**Editor**" menu you can define your "**Soil properties**". A description of the individual constants can be found in the "**Info**" function field.
- The initial concentrations and any concentration sources are defined using the "**Concentrations**" menu. This is possible individually or in a section. You will be shown an info box with instructions. After being queried on whether you want to assign or delete concentrations, a dialog box opens in which you must define whether it is an initial concentration or a concentration source. In the first instance, the concentration only applies at time t = 0 and is subsequently displaced, whilst a concentration source displays a constant concentration. If you do not define an initial concentration or a concentration source for any nodes, an initial concentration of "**0**" will be assumed.
- In "**Modelling/Preferences**", you can apply preferences for the precision and extent of analysis by specifying the size of the array subdivisions. The smaller the array is defined, the more precise, but also time-intensive, the analysis. Moreover, by activating the analysis with the "**Element velocities**" option and deactivating the "**Exact velocities**" box you achieve fast, but less precise, analysis, whilst modelling using node velocities and the additional option of "Exact velocities" will give very precise analysis results.
- Commence contaminant transport modelling for your groundwater system with "**Modelling/Start**". In the dialog box that then opens you can enter the name of the output file for the rectangular array, as well as generating a record for the FEM mesh if you want an additional analysis based on the triangular array. The program then calculates several basic parameters. You then define an end time, the size of the time steps and the number of particles. A large number of particles also means more precise results but longer computing time.
- With the aid of the **GGU-PLGW** evaluation program, you can evaluate and display the modelling results. To facilitate this, load the file generated by **GGU-CONTAM-RW** ("**_ras.plw**") or the file ("**_fe.plw**") with the results recalculated based on the FEM mesh in **GGU-PLGW**.

8 Contaminant propagation theory

8.1 GGU-CONTAM-RW: Overview

The primary aim of contaminant transport modelling is the prognosis of future conditions based on given initial data and, on occasion, pre-specified countermeasures.

Using a numerical analysis approach, even complicated systems can be investigated and assessed. Precise modelling of the natural conditions is difficult, due to the multitude of initial parameters required and the inhomogeneity of aquifers. Before any contaminant transport modelling, you should therefore ensure that your initial data justify this.

8.2 GGU-CONTAM-RW: Mechanisms relevant to contaminant propagation

Five important mechanisms describe contaminant propagation in groundwater and must be entered as initial data for propagation simulation:

- **Convection**
  is the migration of contaminants in the direction, and with the apparent flow velocity, of groundwater flow. This propagation mechanism is normally dominant in a flowing system but is superimposed upon and influenced by others. Mathematically, this mechanism enters the differential equation in the shape of the apparent flow velocities ux and uy.
- **Dispersion**
  includes the local deviation from the mean flow velocity. One differentiates between dispersion caused by the grain skeleton, which describes, amongst other factors, deviations in the flow course around the grain skeleton, and macro-dispersion, which is the dominant mechanism in wide-area contaminant propagation, e.g. in sand lenses and layering. This mechanism is described by the mathematical values of longitudinal (in flow direction) dispersivity αL (m) and transverse (perpendicular to flow direction) dispersivity αT (m).
- **Diffusion**
  This type of propagation is determined by the concentration gradient. It is normally only effective in systems with extremely low velocity. In water at 10 °C, the diffusion coefficient Dm is 10-9 m/s².
- **Adsorption**
  expresses the inhibition of contaminant migration due to adsorption onto the grain skeleton and is described by the sorption constant sorp (-). The sorption constant is the product of grain density and the adsorption coefficient. Contaminant propagation is retarded by adsorption.

- **Decay**
  As a result of physical, chemical and biological reworking, contaminants are eliminated from the groundwater. This process is described by the decay constant λ (l/s).

A mass balance equation and a space- and time-dependent, analysable differenzial equation results from these values:

Mass balance:

Increase in dissolved contaminant mass =

net input by convection

- net input by diffusion and dispersion
- input from contaminant sources
- extraction from wells
- loss through decay reactions
- adsorption onto the grain matrix

8.3 GGU-CONTAM-RW: The Courant criterion

The precision of all numerical procedures is influenced by the time step Dt. Precise results can be achieved with small time steps, but analysis time increases correspondingly. The optimum time step size can be derived from the "**Courant criterion**".

After starting analysis, the program examines the Courant criterion and suggests the determined time step.

9 File menu

9.1 GGU-CONTAM-RW: "Load GW data" menu item

To form the basis for your contaminant transport modelling, load the data of a steady-sate groundwater model previously analysed using the **GGU-2D-SSFLOW** program using this menu item. This file has the default name of "**.da1**". In order to enable generation of this record by the **GGU-2D-SSFLOW** program, you must activate the "**Generate record for transient modelling**" check box in the "**System/Analyse**" menu item.

9.2 GGU-CONTAM-RW: "Save as" menu item

For parameter studies - e.g. when adopting various polygon courses - it is advisable to generate individual "**.da1**" initial records, because you cannot influence the naming of your transient analysis result files. The program stores the base data automatically in a "**.dat**" file under the name of the initial file and extended by a "**_t**". The results required for subsequent evaluation in **GGU-PLGW** are automatically saved in a "**_t.plw**" file. It is therefore possible that different transient systems are mistakenly exported to the same result files if the same initial record is used.

Using this menu item the data are saved in an existing or a new file with the file extension ".**da1**". If you do not enter an extension when saving ".**da1**" will be used automatically.

9.3 GGU-CONTAM-RW: "System info" menu item

Upon opening this menu item, you will be presented with information on the currently loaded system, the number of triangular elements and on the nodes.

9.4 GGU-CONTAM-RW: "Load boundary values" menu item

Using this menu item, you can reload a file containing boundary values which was previously defined and saved with the "**File/Save boundary values**" menu item, in order to further process this or to use it as the basis for contaminant transport modelling. The file contains the soil properties and the polygon courses, as well as the allocations of the polygon courses to the system nodes.

9.5 GGU-CONTAM-RW: "Save boundary values" menu item

After selecting this function, you can save the defined boundary values in order to have the data available again at a later date. The file with the suffix "**_ras.rdw**"contains the soil properties and the polygon courses, as well as the allocations of the polygon courses to the system nodes.

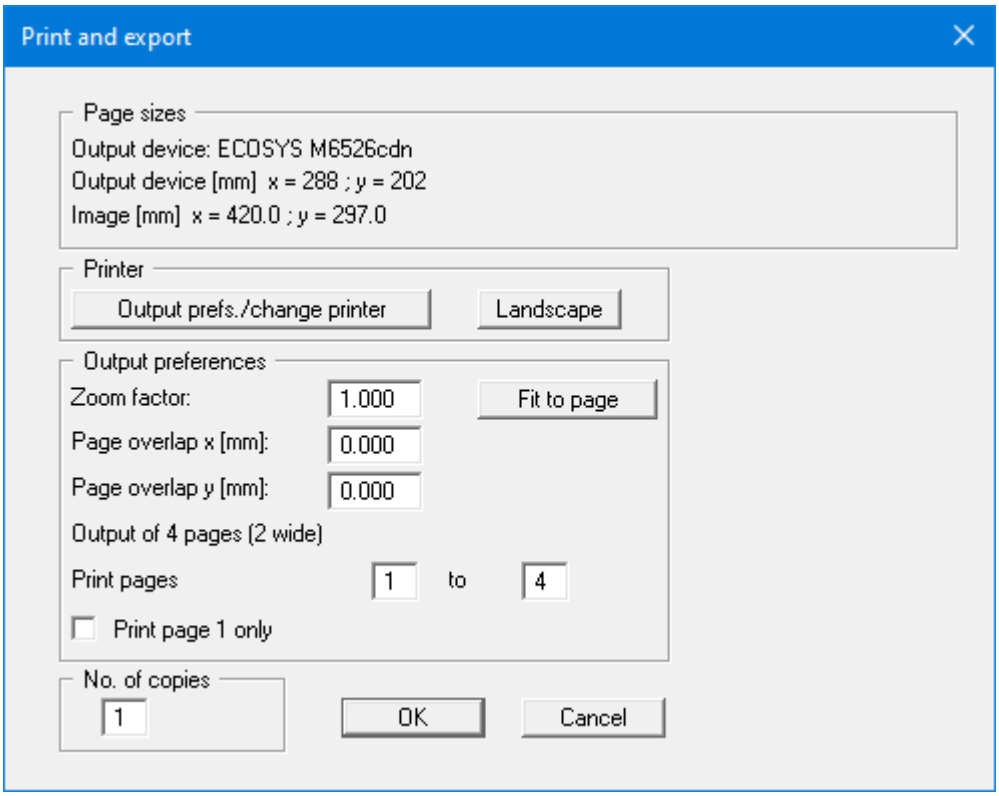
9.6 GGU-CONTAM-RW: "Output preferences" menu item

You can edit output preferences (e.g. swap between portrait and landscape) or change the printer in accordance with WINDOWS conventions.

9.7 GGU-CONTAM-RW: "Print and export" menu item

You can select your output format in a dialog box. You have the following possibilities:

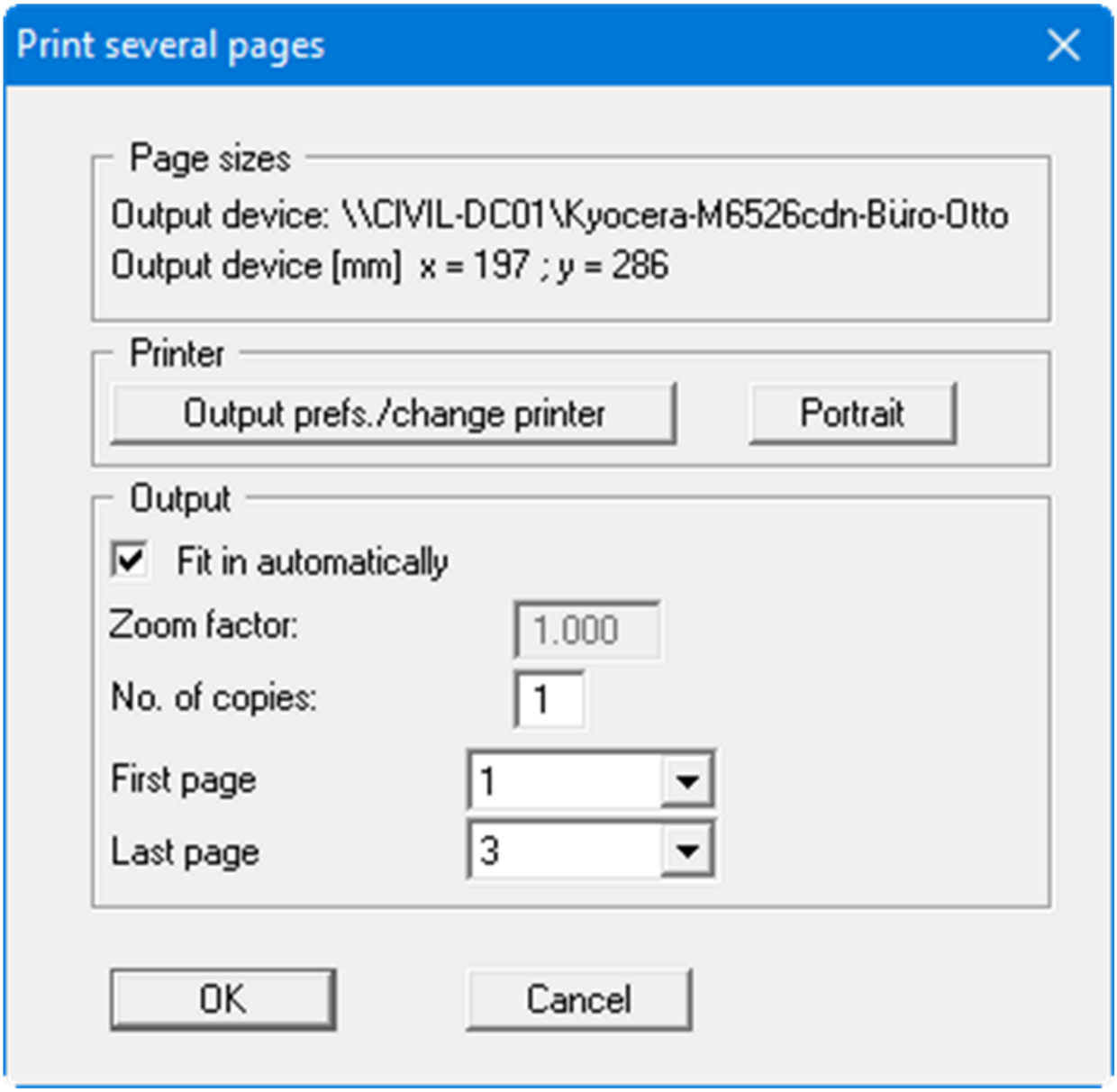
- "**Printer**"
  allows graphic output of the current screen contents (graphical representation) to the WINDOWS standard printer or to any other printer selected using the menu item "**File/Output preferences**". But you may also select a different printer in the following dialog box by pressing the "**Output prefs./change printer**" button.



In the upper group box, the maximum dimensions which the printer can accept are given. Below this, the dimensions of the image to be printed are given. If the image is larger than the output format of the printer, the image will be printed to several pages (in the above example, 4). To facilitate better re-connection of the images, the possibility of entering an overlap for each page, in x and y direction, is given.

Alternatively, you also have the possibility of selecting a smaller zoom factor, ensuring output to one page ("**Fit to page**" button). Following this, you can enlarge to the original format on a copying machine, to ensure true scaling. You can also print only the 1st page with zoom factor = 1.0, in which case the bottom left-hand area is printed. Furthermore, you may enter the number of copies to be printed.

If you have activated the ***table representation*** on the screen, you will see a different dialog box for output by means of the "**File/Print and export**" menu item button "**Printer**".



Here, you can select the table pages to be printed. In order to achieve output with a zoom factor of 1 (button "**Fit in automatically**" is deactivated), you must adjust the page format to suit the size format of the output device. To do this, use the dialog box in "**File/Print output table**" button "**Output as graphics**".

- "**DXF file**"
  allows output of the graphics to a DXF file. DXF is a common file format for transferring graphics between a variety of applications.
- "**GGU-CAD file**"
  allows output of the graphics to a file, in order to enable further processing with the **GGU-CAD** program. Compared to output as a DXF file this has the advantage that no loss of colour quality occurs during export.
- "**Clipboard**"
  The graphics are copied to the WINDOWS clipboard. From there, they can be imported into other WINDOWS programs for further processing, e.g. into a word processor. In order to import into any other WINDOWS program, you must generally use the "*Edit/Paste*" function of the respective application.

- "**Metafile**"
  allows output of the graphics to a file in order to be further processed with third party software. Output is in the standardised EMF format (Enhanced Metafile format). Use of the Metafile format guarantees the best possible quality when transferring graphics.

If you select the "**Copy/print area**" tool

from the toolbar, you can copy parts of the graphics to the clipboard or save them to an EMF file. Alternatively you can send the marked area directly to your printer (see "**Tips and tricks**").

Using the "**Mini-CAD**" program module you can also import EMF files generated using other GGU applications into your graphics (see menu item "**Graphics preferences/Mini-CAD**").

- "**Mini-CAD**"
  allows export of the graphics to a file in order to enable importing to different GGU applications with the Mini-CAD module.
- "**GGUMiniCAD**"
  allows export of the graphics to a file in order to enable processing in the GGUMiniCAD program.
- "**Cancel**"
  Printing is cancelled.

9.8 GGU-CONTAM-RW: "Exit" menu item

After a confirmation prompt, you can quit the program.

9.9 GGU-CONTAM-RW: "1, 2, 3, 4" menu items

If you have not stored a working directory for the program icon, the program jumps to the program directory after starting to load or save a file.

Under the menu items "**1,2,3,4, ...**", the most recently edited files are displayed with the respective storage path. Selecting one of these files loads the selected file. The next time you call up the menu items "**File / Load**" or "**File / Save**", the program is automatically located in the directory of the last file loaded.

10 Editor menu

10.1 GGU-CONTAM-RW: "Soil properties" menu item

After going to this menu item, a system-specific dialog box opens allowing input of the soil properties. The ***steady-state*** property neff imported from the **GGU-2D-SSFLOW** program can no longer beamendedhere

In the example above, one soil has been defined for the system (groundwater modelling with **GGU-2D-SSFLOW**). Enter the soil parameters relevant to contaminant transport in the input boxes:

- "**Info**"
  This item provides information on the meaning of the parameters and the units used by them. Please ensure that you always use the same length and time units as those you applied to the permeability in the steady-state modelling in **GGU-2D-SSFLOW**. You can define the mass dimension at will; you must, however, use the same dimension for all parameters. This also applies to the subsequent definition of initial concentrations and concentration sources.
- "**alph_l**"
  Enter the value of the longitudinal dispersivity alph_l. This is a function of grain size and varies between a few centimetres (laboratory tests in sand) and over 100 metres (jointed rocks).
- "**alph_t**"
  The transversal dispersivity alph_t is generally a magnitude smaller than the longitudinal. In field tests, ratios around 0.01 were determined. Values of up to 0.3 are given in the literature.
- "**Dm**"
  Enter the value of the diffusion coefficient Dm. This value only influences contaminant distribution at very low flow velocities. For water at 10°C, this value is 10-9 m/s².
- "**Sorp**"
  Enter the value of the sorption constant sorp. The sorption constant is dimensionless and is the product of grain density and the adsorption coefficient.
- "**lambda**"
  Enter the value of the decay constant lambda.

10.2 GGU-CONTAM-RW: "Define concentrations individually" menu item

This menu item first generates a dialog box, in which you specify the font size and the number of decimal places. After confirmation you can click on nodes to which you want to assign an initial concentration (> 0.0) or a concentration source, using the left mouse button. A concentration source is constant over time.

Please ensure that you always use the same length and time units as those you applied to the permeability in the **GGU-2D-SSFLOW** steady-state modelling. You can define the mass dimension at will; you must, however, use the same dimension for all parameters. This also applies to soil properties.

If you click a node with the right mouse button, any initial concentrations existing at the node are deleted.

10.3 GGU-CONTAM-RW: "In section" menu item

In a similar manner to the previous menu item, you can assign initial concentrations or concentration sources to sections of the system. This is done by clicking four points in an anti-clockwise direction with the left mouse button. The concentration, which you enter into the following dialog box, then applies to all nodes within the specified section.

Alternatively, it is possible to delete all defined initial concentrations, i.e. to set them to '**0**'.

10.4 GGU-CONTAM-RW: "From file" menu item

You can import concentrations from a previous analysis as initial concentrations. The first time step after the given time will be read.

11 Check menu

11.1 GGU-CONTAM-RW: "Visualisation format" menu item

Using the functions provided in this menu item you can alter the system and mesh display according to your wishes. This permits some control but does not allow manipulation of the analysis.

By selecting this menu item, the following dialog box appears:

Activate the information you want to have displayed.

12 Modelling menu

12.1 GGU-CONTAM-RW: "Preferences" menu item

In this menu item's dialog box, preferences can be defined for subsequent modelling.

First, define the array subdivisions to stipulate the size of the cells. Read Section 4, "**Program concept**" to find out what influence the rectangular array has on the analysis.

You can also decide whether the analysis should be based on the node velocities or on the element velocities. Again, the principal difference here is in the analysis precision. The element velocity is constant for each element, whilst the node velocity is calculated from the mean of the velocities in the neighbouring elements. This increases the precision of the analysis, but also the time and effort required.

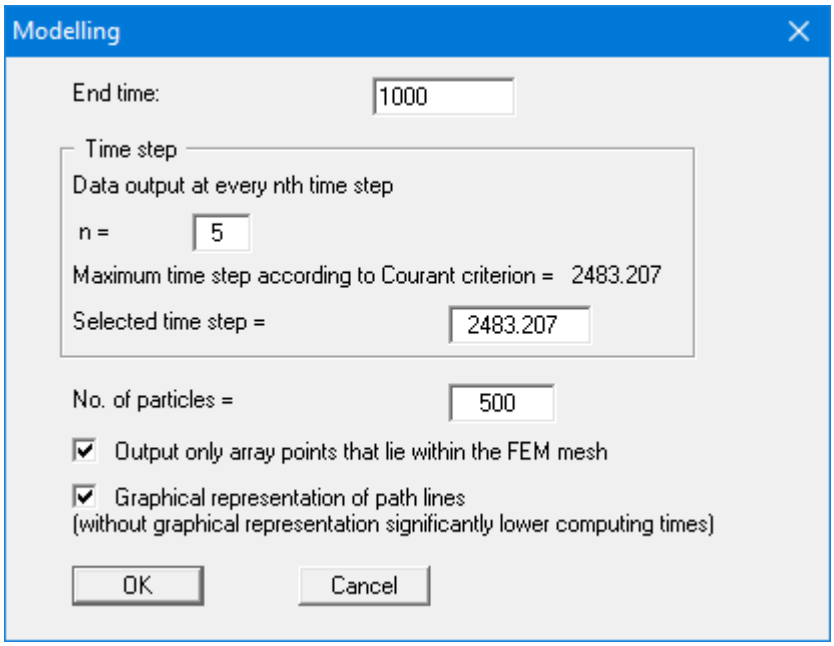
By activating the "**Exact velocities**" option the precision of the analysis is increased yet again. The program then determines the velocity of each contaminant particle at its current location. Otherwise, mean velocities are utilised for the corresponding cell.

12.2 GGU-CONTAM-RW: "Start" menu item

After clicking this menu item or, alternatively, by pressing **[F5]**, a dialog box opens showing the names of the output files.

- **Record 1 ("plgw_ras.plw")**
  contains all results from the rectangular array. So, during subsequent evaluation using the **GGU-PLGW** application, a ***rectangular triangle mesh*** is displayed.
- **Record 2 ("plgw_fe.plw")**
  contains the values from the rectangular array recalculated to fit the triangular mesh (FEM mesh).

Start your analysis by clicking "**OK**". Several basic parameters are first calculated. The following dialog box is subsequently displayed:



Generally, a flood of result values is generated during analysis. You can define an interval (i) for data output. In addition, you must also enter the end time for the analysis.

The precision of all numerical procedures is influenced by the size of the time step. More precise results can be achieved with small time steps, but modelling time increases correspondingly. The maximum allowable time step size can be derived from the "**Courant criterion**". You can modify this time value but should not increase the proposed time step.

You then enter the number of particles to be started and whose paths are to be traced. By activating the "**Graphical representation of path lines**" check box the path lines can be traced on the computer screen during analysis (very impressive, but also increases computation time).

Finally, you have the opportunity of suppressing output of data for recalculation of the array data to the triangular mesh (FEM mesh).

After selecting the "**OK**" button the calculation proper will begin. A dialog box with a "**Cancel**" button will inform you of analysis progress. If you select this button, analysis will not cease immediately, but instead you can edit specific program data and then carry on the analysis.

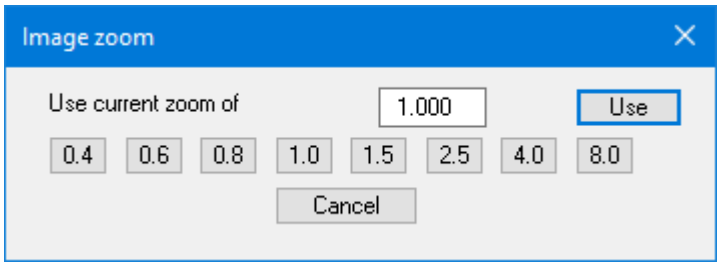
The record is generated for the evaluation application during modelling. If, after commencing modelling, you open the **GGU-PLGW** program, you can check and evaluate the current results while modelling is still in progress. The "**Animation**" function is particularly impressive here; it can be executed parallel to the running modelling process.

13 Graphics preferences menu

13.1 GGU-CONTAM-RW: "Refresh and zoom" menu item

The program works on the principle of ***What you see is what you get***. This means that the screen presentation represents, overall, what you will see on your printer. In the last consequence, this would mean that the screen presentation would have to be refreshed after every alteration you make. For reasons of efficiency and as this can take several seconds for complex screen contents, the screen is not refreshed after every alteration.

If, e.g., after using the zoom function (see below), only part of the image is visible, you can achieve a complete view using this menu item.



A zoom factor between 0.4 and 8.0 can be entered in the input box. By then clicking on "**Use**" to exit the box the current factor is accepted. By clicking on the "0.4", "0.6", etc. buttons, the selected factor is used directly, and the dialog box closed.

It is much simpler, however, to get a complete overview using [**Esc**]. Pressing [**Esc**] allows a complete screen presentation using the zoom factor specified in this menu item. The [**F2**] key allows screen refreshing without altering the coordinates and zoom factor.

13.2 GGU-CONTAM-RW: "Zoom info" menu item

By clicking two diametrically opposed points you can enlarge a section of the screen in order to view details better. An information box provides information on activating the zoom function and on available options.

13.3 GGU-CONTAM-RW: "Pen colour and width" menu item

In order to enhance the clarity of the graphics you can preset the pen settings for various graphic elements in the GGU programs

You can change the pen widths for the elements listed in the dialog box and adjust the pen and/or fill colours by clicking on the button with the element name. In some GGU programs you can also define a line colour for selected elements.

For the graphic output of colours on ***monochrome printers*** (e.g. laser printers), colours are replaced by an equivalent shade of grey. In the case of very light colours, the corresponding graphic elements are then barely visible on the printer. In such cases, it makes sense to change the colour setting to darker colours.

13.4 GGU-CONTAM-RW: "Legend font selection" menu item

With this menu item you can switch to a different true-type font. All available true-type fonts are displayed in the dialog box.

13.5 GGU-CONTAM-RW: "Mini-CAD toolbar" and "Header toolbar" menu items

Using this menu item you can add free text, lines, circles, polygons and images (e.g. files in formats BMP, JPG, PSP, TIF, etc.) to the main program graphics. PDF files can also be imported as images. A pop-up menu opens, the icons and functions used are described in more detail in the **Mini-CAD** manual saved in the "**C:\Program Files (x86)\GGU-Software\ Manuals**" folder during installation.The differences between the Mini-CAD and Header CAD are as follows:

- Drawing objects created with **Mini-CAD** refer to the coordinate system (generally in [m]) in which the drawing is created and are displayed accordingly. You should therefore select this menu item if you wish to enter additional information on the system. These objects can be saved in a "**.mcd**" file using the

  icon in the pop-up menu and loaded as such in other GGU programs using the

  icon in the pop-up menu.

- Drawing objects created with the **Header CAD** refer to the sheet format (in [mm]). They therefore always remain at the same sheet position, regardless of the coordinate system of the measuring points. You should select this menu item if you want to enter general information on the drawing (e.g. company logo, report number, system number, stamp). If you save this so-called header data in a "**.kpf**" file using the icon

  in the pop-up menu, you can reload this header data for a completely different system (with different system coordinates) and also in other GGU programs using the icon

  in the pop-up menu. The saved header data can then be found in the same position. This considerably simplifies the creation of general sheet information.

14 Page size + margins menu

14.1 GGU-CONTAM-RW: "Auto-resize" menu item

This menu item provides a to-scale visualisation, in both x and y coordinates, of the system and result graphics. If you have previously altered the image coordinates graphically or via editor, you can quickly achieve a complete view using this menu item.

This function can also be accessed using the [**F9**] function key.

14.2 GGU-CONTAM-RW: "Manual resize (mouse)" menu item

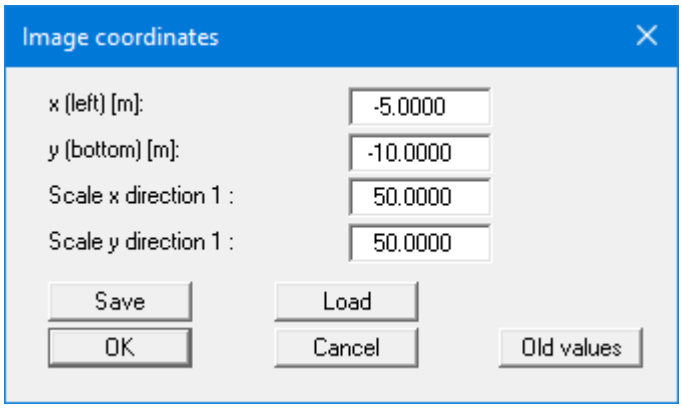
You can transfer the coordinates of a section of your previous graphic display as new image coordinates by holding down the [**Ctrl**] and [**Shift**] keys and marking the desired area with the left mouse button. The scales of the x-direction and y-direction are adjusted accordingly.

In the default setting, the "**Proportional section**" check box is activated. This retains the previous proportions (scale x-direction/scale y-direction).

If you activate the "**Redefine origin**" check box, you can adjust the image coordinates without changing the scale. In this way, you can quickly achieve the desired visualisation without having to try out the x/y coordinates if the scale is set appropriately.

14.3 GGU-CONTAM-RW: "Manual resize (editor)" menu item

You can alter the current image coordinates by direct numerical input in a dialog box. This allows precise scale input. The coordinates refer to the drawing area. This can be defined in the "**Page size + margins/Page size and margins**" menu item by means of the plot margins.



The image coordinates entered here can be saved in a file with the extension "**.bxy**" and be reloaded later for the same file or for different files.

If you want to recover the previous values during input or use the menu item again after editing the coordinates, you can do this by pressing the "**Old values**" button.

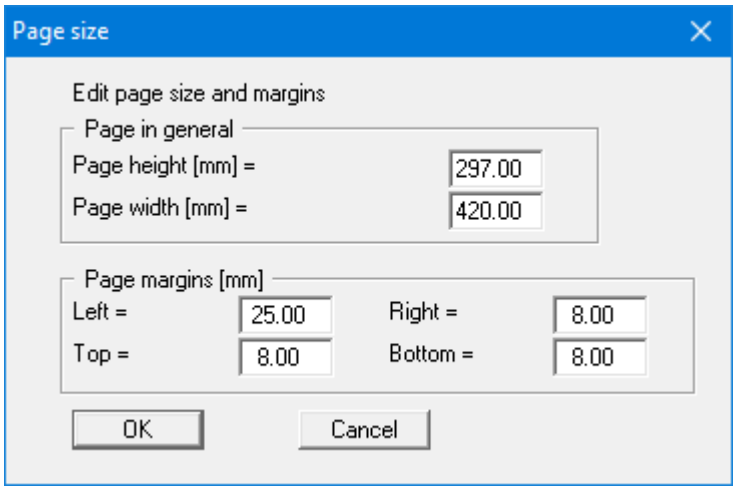
14.4 GGU-CONTAM-RW: "Font size selection" menu item

You can edit font sizes for labelling the various drawing elements.

The font sizes of text within legends are edited in the respective legend editor. Just double-click in a legend to do this.

14.5 GGU-CONTAM-RW: "Page size and margins" menu item

The program uses A3 format as default. You can edit the page format in the following dialog box.



- "**Page in general**" defines the size of the output sheet. The program automatically draws thin cutting borders around the page, which are required when using a plotter on paper rolls. The borders can be switched off using the menu item "**Graphics preferences/Margins and borders**".
- "**Page margin**" defines the position of a frame as a distance to the margins. This frame en-closes the subsequent diagram. The margins can be switched off using the menu item "**Graphics preferences/Margins and borders**".
- The "**Plot margin**" define a set distance between the page margin and the actual ***drawing area*** in which the graphical evaluation of your input is presented.

15 ? menu

15.1 GGU-CONTAM-RW: "Copyright" menu item

You will see a copyright message and information on the program version number.

The "**System**" button shows information on your computer configuration and the folders used by the GGU program.

15.2 GGU-CONTAM-RW: "Maxima" menu item

A message box displays the program's default maximum number of nodes and the elements for the FEM mesh, soils, polygon courses and the times within the polygon courses.

15.3 GGU-CONTAM-RW: "Help" menu item

The manual is opened as a PDF document. The help function can also be accessed using the [**F1**] function key.

15.4 GGU-CONTAM-RW: "GGU on the web" menu item

Using this menu item, you can access the GGU Software website.

Check the page of your program module at regular intervals for information about updates and changes. On the "**Changelogs**" subpage, you can also subscribe to an e-mail notification that informs you of all changes on a monthly basis.

15.5 GGU-CONTAM-RW: "GGU support" menu item

This menu takes you directly to the GGU Software Support Portal.

Here you can enter your support request directly and upload your edited GGU program file.

15.6 GGU-CONTAM-RW: "What's new?" menu item

You will see information on program improvements in comparison to older versions.

15.7 GGU-CONTAM-RW: "Language preferences" menu item

This menu item allows you to switch the menus and the graphics from German to English and vice versa. To work in German, deactivate the two check boxes "**Dialoge + Menüs übersetzen (translate dialogues, menus)**" und "**Graphiktexte übersetzen (translate graphics)**".

Alternatively, you can work bilingually, e.g. with German dialog boxes but with graphic output in English. The program always starts with the language setting applicable when it was last ended.