# DECIPHeR-GW v1

# User Manual

Yanchen Zheng[1], Gemma Coxon[1], Mostaquimur Rahman[2], Ross Woods[2], Saskia Salwey[1], Youtong Rong[1], Doris E Wendt[1]

[1]School of Geographical Sciences, University of Bristol, Bristol, BS8 1SS, UK
[2]School of Civil, Aerospace and Design Engineering, University of Bristol, Bristol, BS8 1TR, UK

*Email Contact*: Yanchen Zheng (yanchen.zheng@bristol.ac.uk)

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University of BRISTOL

# Disclaimer

The DECIPHeR-GW version 1 model can be downloaded from: https://github.com/YanchenZheng/DECIPHeR-GW_V1.0.

Before using DECIPHeR-GW v1, please read the following terms of use carefully. Downloading the DECIPHeR-GW v1 model code ("the Software") onto your computer indicates your acceptance of the following terms:

1. The developers do not guarantee that the software will meet your requirements, operate without interruption, or be error-free. They do not warrant that all errors can be corrected.

2. You install and use the Software at your own risk. The developers are not liable for any loss or damage, including lost profits or any indirect, incidental, or consequential loss arising from the use or inability to use the Software, or from errors or deficiencies in it, whether caused by negligence or otherwise.

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# Summary

This document is the user manual for the open source DECIPHeR-GW version 1 model. It documents the code workflows, data requirements, and input data formats, and provides an example for running through the codes.

DECIPHeR-GW is a coupled surface-subsurface hydrological model with improved representation of surface-groundwater interactions. The DECIPHeR-GW model is built on the original DECIPHeR model (Coxon et al., 2019), DECIPHeR-MPR model (Lane et al., 2021) and also a large-scale gridded groundwater model (Rahman et al., 2023). The model has an automated build and is computationally efficient to provide hydrological simulation and prediction including streamflow and groundwater level at large scales. We tested the model and provided examples using data from UK catchments, but the model can be applied to other regions and adapted according to specific hydrologic settings or data availability.

**DECIPHeR model**

DECIPHeR is documented in an open-access paper published in *Geoscientific Model Development* (https://doi.org/10.5194/gmd-12-2285-2019) (Coxon et al., 2019). The original DECIPHeR code and user manual are available on GitHub (https://github.com/uob-hydrology/DECIPHeR). The original DECIPHeR code is based on and uses code from Dynamic TOPMODEL (Beven and Freer, 2001).

**DECIPHeR-MPR model**

The application of multiscale parameter regionalisation (MPR) to DECIPHeR is introduced in a paper published in *Water Resources Research* (https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2020WR028393) (Lane et al., 2021) and also a PhD thesis available at https://research-information.bris.ac.uk/ws/portalfiles/portal/268576642/Final_Copy_2021_01_21_Lane_R_A_PhD_Redacted.pdf. The code for DECIPHeR-MPR is available at https://zenodo.org/records/4646179.

**Large-scale gridded groundwater model**

The paper published in *Hydrological processes* (https://onlinelibrary.wiley.com/doi/10.1002/hyp.14849?af=R) (Rahman et al., 2023) records the details of the gridded groundwater model. The code for this groundwater model is available at https://github.com/ShamsRahman-Groundwater/Groundwater-model-Code.

**Two stages to running the DECIPHeR-GW**

Digital Terrain Analyses (DTA) needs to be performed first to define the gauge network, river network and routing, and discretise the catchment into HRUs (See Section 1 for more details). The hydrological model is then run to provide streamflow and groundwater level timeseries for locations specified by the user (See Section 2).

**Minimum data requirements**

For the surface component of the DECIPHeR-GW model, a digital elevation model (DEM), locations for streamflow output, rainfall and potential evapotranspiration data are required.

As for the groundwater component, hydrogeology data, i.e., transmissivity and specific yield are needed to parameterise the model.

# Section 1 Digital Terrain Analysis

Digital terrain analyses in DECIPHeR-GW are essential for delineating hydrological response units (HRUs), analyzing hydrological connectivity across the landscape, configuring the river network and routing, and determining output locations for both gauged and ungauged sites. DECIPHeR-GW uses the same set of codes as DECIPHeR for DTA. Details of DTA implementation and walkthrough workflow can be found in the user manual of the original DECIPHeR.

It should be noted that after performing the basic DTA operations, it is necessary to rerun the second step of the DTA process to establish the relationship between each HRU and model parameter required for the MPR version. The modifications needed are as follows.

In the original DECIPHeR model, parameter calibration is conducted at the catchment scale, so it is not necessary to set this parameter PARAM_CLASS in hru_class.dat file, and it was commented out.
However, in the MPR version, model parameter calibration is performed at the HRU scale, so this additional setting is required.
It is necessary to modify the hru_class.dat file to ensure that PARAM_CLASS corresponds to each catchment's hru_array.asc file. Each catchment should have its own hru_class file, such as hru_class39101.dat. This way, when rerunning the second step of DTA with the Run_DTA_Example_Script_2_39101.sh file, the hru_class39101.dat file needs to be called.

Example of hru_class39101.dat file:

```
!---------------------------
! HRU CLASSIFIERS
!---------------------------
TOPO_CLASS=/DECIPHeR/DTA_Step2_example/classinc.dat
INPUT_RAIN_CLASS=/DECIPHeR/DTA_Step2_example/UK_input_grid_UKCP18_local.asc
INPUT_PET_CLASS=/DECIPHeR/DTA_Step2_example/UK_input_grid_UKCP18_local.asc
!MODELSTRUCT_CLASS=/data/REF_GRIDS/UK_modelstruct_grid_hydrogeo.asc
PARAM_CLASS=/DECIPHeR/DTA_Step2_example/39101000_hru_array.asc
```

Example of Run_DTA_Example_Script_2_39101.sh file:

```
echo ''
echo '#==============================================================================='
echo '# STEP 0: DEFINE PATHWAYS AND KEY VARIABLES'
echo '#==============================================================================='
echo ' '

# ------------------------------------------------------------------------------
# Define paths to directories and filenames
# ------------------------------------------------------------------------------

# Full directory to folder containing source code
CODE_DIR=/DECIPHeR/UK_Res_MPR_Merge/DTA

# Your working folder for the first part of the DTA analysis and the root file name for the DEM
ROOT_FN=/DECIPHeR/DTA_R1/GB_dem_50m

#The output folder you want to put the results in - YOU MUST CHANGE THIS!!
OUTPUT_DIR=/DECIPHeR/DTA_Step2_NEW

#Text file listing NRFA Gauge IDs that you want to model
GAUGELIST=${OUTPUT_DIR}/gauge_list39101.txt

#HRU Class file listing which classifiers you want to use to split up the catchment
HRU_CLASS_FILE=${OUTPUT_DIR}/hru_class39101.dat
```

After performing the above steps, the hru_meta.dat file in the DTA output, such as 39101000_hru_meta.dat, should contain 15 columns. This will include two additional columns compared to the original DTA output: PARAM_ID and PARAM_NUM.

Example of 39101000_hru_meta.dat file:

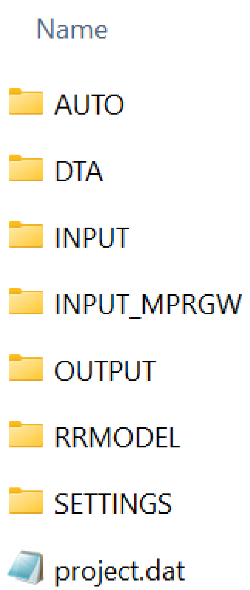
```
! HRU Meta File for Gauge 39101000
HRUs    176
NUM_COLS        15
!
HRU_ID  NUM_CELLS  MEAN_ATB  MEAN_SLOPE  GAUGE_ID  MEAN_ELEV  AREA_ID  SLOPE_ID  RAIN_ID  PET_ID  PARAM_ID  GAUGE_NUM  RAIN_NUM  PET_NUM  PARAM_NUM
1       23      5.92530 .14119325       1       231.36  1       3       2       2       7       39101000        7396    7396    1
2       73      6.06277 .12984206       1       175.24  1       3       21      21      145     39101000        6890    6890    2
3       36      6.08553 .11752866       1       173.78  1       3       23      23      168     39101000        6892    6892    3
4       46      6.10507 .12608146       1       218.39  1       3       6       6       36      39101000        7270    7270    4
5       8       6.15025 .10620710       1       194.42  1       3       18      18      128     39101000        7019    7019    5
6       156     6.16420 .11893716       1       210.32  1       3       4       4       23      39101000        7269    7269    6
7       10      6.28740 .11988326       1       206.45  1       3       1       1       4       39101000        7395    7395    7
8       112     6.29711 .10406752       1       192.17  1       3       17      17      118     39101000        7018    7018    8
9       268     6.35875 .11723475       1       199.06  1       3       8       8       55      39101000        7143    7143    9
10      169     6.37150 .10654456       1       174.48  1       3       22      22      154     39101000        6891    6891    10
11      164     6.38454 .10732576       1       227.62  1       3       3       3       29      39101000        7268    7268    11
12      133     6.45902 .10586887       1       225.69  1       3       7       7       43      39101000        7142    7142    12
13      196     6.63440 .09124522       1       168.79  1       3       16      16      105     39101000        7017    7017    13
14      224     6.64477 .09319325       1       188.42  1       3       15      15      97      39101000        7016    7016    14
15      35      6.67303 .08560187       1       206.08  1       3       10      10      78      39101000        7145    7145    15
```

Once the hru_meta.dat file for each study catchment includes the above two new columns, all DTA steps are complete, and hydrological modelling simulations can begin.

# Section 2 Hydrological modelling

DECIPHeR-GW model generates streamflow estimates at any specified location on a user-defined river network and produces groundwater level time series at a 1 km grid scale. The simulation process can be fully automated, allowing for easy execution across multiple catchments or customized catchment configurations. Example settings and project files are available on GitHub. This document provides detailed instructions and examples to help you prepare the files required to set up DECIPHeR-GW model simulations.

The source code of the model, example configuration files, and the required folder structure for running the model are shown in the figure below.




The DTA and RRMODEL folders contain the DECIPHeR-GW model's source code. Users generally do not need to modify the contents of these two folders when running the model but will need to compile them to generate an .exe file to enable model simulations.

The SETTINGS folder includes all the configurations required for model simulations, with specific preparation details provided in Section 2.1.

The INPUT/INPUT_MPRGW folder primarily contains the information needed to run the model, such as the DTA river network, HRU delineation, input P/PET data, and parameter files necessary for MPR and groundwater simulations. Section 2.2 details the steps to prepare these files. Example files for catchment 39101 are available upon request.

The project.dat file and the files in the AUTO folder outline the process for configuring batch runs of the model. Section 2.3 shows how to set up the runs for different catchments.

The OUTPUT folder stores all output results for streamflow, groundwater simulations and model parameters.

## 2.1. SETTINGS folder

The files in the 'SETTINGS' folder are mainly used to set the paths for DTA output files, model input timeseries files such as precipitation, basic settings like model structures, MPR related parameter sampling control, and controlling the clipping of groundwater related data.
The files 'params_v2.dat', 'parammap_pert_mpr.dat', 'dynatop_parameters.dat', and 'model_structure.dat' in this folder are some basic settings of the DECIPHeR model, which remain unchanged in running DECIPHeR-GW.

### 2.1.1 Settings.dat File

The same as the DECIPHeR model settings, which is used to specify the location of the output files from DTA steps and the location of the input precipitation (P), potential evapotranspiration (PET) and streamflow (Q) files.

Example settings.dat file:

settings.dat

```
! DECIPHeR settings file

param_file  :   SETTINGS\params_v2.dat
mstruct_file:   SETTINGS\model_structure.dat
n_cat_setups:   002
n_flow_setps:   002

--- DATA LOCATIONS AND SETTINGS FOR ALL CATCHMENT SETUPS -----------------------

setup_name: Gauge 52016
HRU_filepath:   INPUT\DTA_R2\52016000_dyna_hru.dat
HRU_filepath:   INPUT\DTA_R2\52016000_hru_meta.dat
HRU_filepath:   INPUT\DTA_R2\52016000_flow_conn.dat
HRU_filepath:   INPUT\DTA_R2\52016000_riv_data.dat
HRU_filepath:   INPUT\DTA_R2\52016000_flow_point.dat

setup_name: Gauge 39101
HRU_filepath:   INPUT\DTA_R2\39101000_dyna_hru.dat
HRU_filepath:   INPUT\DTA_R2\39101000_hru_meta.dat
HRU_filepath:   INPUT\DTA_R2\39101000_flow_conn.dat
HRU_filepath:   INPUT\DTA_R2\39101000_riv_data.dat
HRU_filepath:   INPUT\DTA_R2\39101000_flow_point.dat

--- DATA LOCATION AND SETTINGS FOR ALL INPUT SETUPS (must be n_flow_setups entries) : ----------

setup_name  :   52016
flow_file   :   INPUT\52016000_obsq.dat
precip_file :   INPUT\52016000_rain.dat
evap_file   :   INPUT\52016000_PET.dat

setup_name  :   39101
flow_file   :   INPUT\39101000_obsq.dat
precip_file :   INPUT\39101000_rain.dat
evap_file   :   INPUT\39101000_PET.dat
```

### 2.1.2 MPR_control.dat file

This file sets the number of model runs, specifies the method used for model parameter sampling, determines whether to save the clipped groundwater data, and includes some parameter settings for the iterative groundwater model solver. The following variable names in bold represent the key parameters that control the model's operation and may need to be adjusted frequently depending on different model run conditions. Other variables not in bold generally do not need to be modified.

Line 1: Comment line ignored by DECIPHeR-GW

Line 2 ->: **n_pm_maps**: The number of model runs. In the DECIPHeR-GW model description paper, we run the model 5000 times for every catchments. If you only want to run the model once, set 1 here.

Line 3 ->: **start_seed**: Starting seed for random number generator for global parameter. Usually set to 1, but can start from any number in the sequence.

Line 4 ->: save_pm_maps: Controls whether to save high spatial resolution maps of model parameters. It is usually set to 0, meaning they do not need to be saved.

Line 5 ->: **save_bp_maps**: Set to 1 if you require to save basin predictor maps such as soil texture maps (i.e., sand, slit), clipped to the same area as your HRU input map. Set to 0 if you already saved the maps, these can later be used as inputs, for faster runs.

Line 6-Line 23 ->: These are mainly used to select which method to use for model parameter sampling, and they generally do not need to be changed.

Line 24 ->: **save_GW_maps**: This is used to set whether to save clipped groundwater data, such as geology type index, fixed parameters like T/Sy, and to determine whether the GW observation gauge is located within the catchment. Generally, for each catchment, it needs to be set to 1 for the first run, then can be set to 0 for faster runs.

Line 25 ->: set_GW_buffer: The buffer parameter for clipping the groundwater simulation domain. We set to 3 km as the default value. Users can change this to their needs.

Line 26 ->: GW_maxiteration: The maximum iteration number in the groundwater model solver. We set to 1500 as the default value. Users can change this to their needs.

Line 27 ->: GW_tolerance: The tolerance of the groundwater model solver. Default 0 represents the tolerance is set to 1e-6 m in the groundwater model solver. Users can change this to their needs.

Example MPR_control.dat file:

MPR_control.dat

```
! Settings file for MPR application to Dynamic TOPMODEL.
n_pm_maps,  1   ! number of parameter maps to produce/ simulations
start_seed, 1   ! starting seed for random number generator for global parameters. Usually set to 1, but can start from any
save_pm_maps,   0   ! Set to 2 if you require saved high-res and upscaled param maps, 1 if you require saved high-res param
save_bp_maps,   0   ! Set to 1 if you require saved basin predictor maps, clipped to the same area as your HRU input map. T
pedo_tf_SZM,    5   ! Pedo-transfer equation for SZM    Options:    0: fixed parameter  1: global parameter 2: f(sand, clay
pedo_tf_LnTo,   3   ! Pedo-transfer equation for LnTo,  Options:    0: fixed parameter  1: global parameter    2: f(sand,
pedo_tf_SRmax,  2   ! Pedo-transfer equation for SRmax  Options:    0: fixed parameter  1: global parameter 2: f(LU,porosit
pedo_tf_SRinit, 1   ! Pedo-transfer equation for SRinit Options:    0: fixed parameter  1: global parameter
pedo_tf_CHV,    1   ! Pedo-transfer equation for CHV    Options:    0: fixed parameter  1: global parameter
pedo_tf_Td, 2   ! Pedo-transfer equation for Td     Options:    0: fixed parameter  1: global parameter 2: f(lnT0)
pedo_tf_Smax,   3   ! Pedo-transfer equation for Smax   Options:    0: fixed parameter  1: global parameter 2: f(soil_depth
pedo_tf_B,  2   ! Pedo-transfer equation for B, GWmodel needed   Options: 0: fixed parameter  2:f(soil texture)
pedo_tf_Ks, 2   ! Pedo-transfer equation for Ks, GWmodel needed   Options: 0: fixed parameter  2:f(soil texture)
pedo_tf_T,  2   ! Pedo-transfer equation for T, GWmodel needed   Options: 0: fixed parameter (estimated value map) 2:f(geol
pedo_tf_Sy, 2   ! Pedo-transfer equation for Sy, GWmodel needed   Options: 0: fixed parameter (estimated value map) 2:f(geo
n_runs_SZM, 0   ! number of extra runs to do per SZM parameter map - will modify the parameter map each time.
n_runs_LnTo,    0   ! number of extra runs to do per lnTo parameter map - will modify the parameter map each time.
n_runs_SRmax,   0   ! number of extra runs to do per SRmax parameter map - will modify the parameter map each time.
n_runs_SRinit,  0   ! number of extra runs to do per SRinit parameter map - will modify the parameter map each time.
n_runs_CHV, 0   ! number of extra runs to do per CHV parameter map - will modify the parameter map each time.
n_runs_Td,  0   ! number of extra runs to do per Td parameter map - will modify the parameter map each time.
n_runs_Smax,    0   ! number of extra runs to do per Smax parameter map - will modify the parameter map each time.
save_GW_maps,   1   ! Set to 0 for faster runs. Set to 1 if you require saved GW data maps, clipped to the same area as you
set_GW_buffer,  3   !Default:Set GW buffer to 3km, this is a user-defined parameter.
GW_maxiteration,  1500   !Default:Set max iteration number to 1500 in GW model, this is a user-defined parameter.
GW_tolerance,   0     !Default 0:Set tolerance to 1e-6m in GW model, this is a user-defined parameter.
end, 0          !must have this to signify end of control file
```

Note that since MPR requires clipping high-resolution parameter maps, and the groundwater model needs to be clipped according to catchment boundaries to determine the simulated domain, it is recommended that for the first model run on a catchment, you should run the model once with **n_pm_maps** and **start_seed** set to **1**, and **save_bp_maps** and **save_GW_maps** set to **1**. This will save the results of the MPR parameter clipping and the groundwater model related data clipping.

After saving the clipped data, for large-scale model runs, you need to set **n_pm_maps** to **5000**, **start_seed** to **1**, and **save_bp_maps** and **save_GW_maps** to **0**. This way, the model will skip the parameter clipping step and directly read the already clipped data, allowing for faster model simulations.

### 2.1.3 MPR_filemgr.dat file

The MPR_filemgr.dat file primarily sets the file locations and name for the soil maps data that are needed in MPR parameter sampling and the data required for groundwater clipping.

As mentioned above, the model settings for the first run on a catchment and for large-scale runs that have already undergone data clipping are different, so the corresponding MPR_filemgr.dat files are also different.

Example of MPR_filemgr.dat file for the first run on a catchment:

MPR_filemgr_39101nonclip.dat

```
1  ## Key filenames for use in MPR
2  dir_root....     'C:\GWmodel\NewModelCp\'
3  dir_input...     'C:\GWmodel\NewModelCp\INPUT_MPRGW\'
4  dir_output..     'C:\GWmodel\NewModelCp\OUTPUT\'
5  dir_settings     'C:\GWmodel\NewModelCp\SETTINGS\'
6  name_hru_map     '39101000_hru_array.asc'
7  name_pm_stng     'dynatop_parameters.dat'
8  name_pm_pert     'parammap_pert_mpr.dat'
9  name_gp_file     'GlobalParameters_39101.dat'
10
11 ## List of all basin predictor files
12
13 lnto_sand_dl     'lnto_SAND_gapfilled_gb'
14 lnto_clay_dl     'lnto_CLAY_gapfilled_gb'
15 lnto_orgm_dl     'lnto_ORGM_gapfilled_gb'
16 lnto_silt_dl     'lnto_SILT_gapfilled_gb'
17 lnto_bulk_dl     'lnto_Db_H_gapfilled_gb'
18 lnto_isorg..     'lnto_surfsoil_above55ORpeat_gb'
19 szm_musids..     'szm_newMUSIDgapfilled_gb'
20 szm_table_dl     'szm_soilinfo_000_010'
21 szm_table_d2     'szm_soilinfo_011_025'
22 szm_table_d3     'szm_soilinfo_026_050'
23 szm_table_d4     'szm_soilinfo_051_100'
24 szm_table_d5     'szm_soilinfo_101_150'
25 srmax_lcm...     'srmax_lcmceh_myclasses1_50m2015_gb'
26 srmax_table.     'srmax_rootdLookup_myclasses50m2015'
27 sr_smax_poro     's_porosity_L_gapfilled_gb'
28 smax_d2b_map     'smax_d2r_gapfilled_gb'
29 hydrogeology     'Hydrogeo_productive_gb'
30 B_Ks_table..     'B_Ks_lookuptable2023'
31 T_Sy_table..     'T_Sy_LookuptableNEWIndex101'
32 GW_topo_clip     '39101_GWtopo_clipped'
33 GW_mask_clip     '39101_GWmask_clipped'
34 GW_Sy_clip..     '39101_GWSy_clipped'
35 GW_T_clip...     '39101_GWT_clipped'
36 GW_Hini_clip     '39101_GWiniH_clipped'
37 GW_GEO_clip.     '39101_GWGEOindex_clipped'
38 GW_obsgauge.     '39101_GWobs_gaugeID'
39
40 end          :   0
```

Line 1- Line 5 ->: Set the correct file path for input, output, and settings folders.

Line 6 ->: name_hru_map: Specify the filename for the catchment's hru_array file. This file is typically generated during the DTA step and is usually found in the input folder. Since the MPR parameter sampling requires this file, it needs to be copied to the Input_MPRGW folder.

Line 7- Line 8 ->: 'dynatop_parameters.dat' and 'parammap_pert_mpr.dat' these two files remain the same with DECIPHeR model in the Settings folder.

Line 9 ->: name_gp_file: Specify the filename for the catchment's Global Parameters dat file. This will be generated with the simulations in the output folder.

Line 11- Line 29 ->: These specify the filename of soil maps that are needed for MPR parameter sampling. These files remain the same with DECIPHeR-MPR model.

Line 30- Line 31 ->: These specify the filename of the lookup table for model parameter B, Ks, T and Sy sampling. These lookup tables need to be prepared in the Input_MPRGW folder. Details described in section 2.3 and 2.4.

Line 32- Line 38 ->: These specify the filenames of the clipped groundwater-related data. These clipped groundwater data will be generated and saved in the Input_MPRGW folder. For the model first run, the original Great Britain national-scale groundwater data (i.e., geology types, topography and hydrogeological data at 1 km grid scale) needs to be prepared in the Input_MPRGW folder for performing the clip step. Details are described in section 2.1.

Please note that the MPR clipped data shares the same filename across different catchments. Therefore, it is essential to move the clipped files for each catchment into their respective folders, such as the 39101_clipped folder. The following command line provides an example of how to accomplish this.

```
./DECIPHeR_GW.exe -auto AUTO/auto_39101.dat
mv /DECIPHeR_GW/INPUT_MPRGW/*_clipped.asc  /DECIPHeR_GW/INPUT_MPRGW/39101_clipped
```

The groundwater clipped data includes the catchment ID in the filename, so there is no need to move these clipped files. They can be saved in the Input_MPRGW folder.

Another example of MPR_filemgr.dat file for large-scale runs that have already saved the clipping data:

MPR_filemgr_39101.dat

```
1   39101_clipped/## Key filenames for use in MPR
2   dir_root....    'C:\GWmodel\NewModelCp\'
3   dir_input...    'C:\GWmodel\NewModelCp\INPUT_MPRGW\'
4   dir_output..    'C:\GWmodel\NewModelCp\OUTPUT\'
5   dir_settings    'C:\GWmodel\NewModelCp\SETTINGS\'
6   name_hru_map    '39101000_hru_array.asc'
7   name_pm_stng    'dynatop_parameters.dat'
8   name_pm_pert    'parammap_pert_mpr.dat'
9   name_gp_file    'GlobalParameters_39101.dat'
10
11  ## List of all basin predictor files
12
13  lnto_sand_dl    '39101_clipped\lnto_SAND_gapfilled_gb_clipped'
14  lnto_clay_dl    '39101_clipped\lnto_CLAY_gapfilled_gb_clipped'
15  lnto_orgm_dl    '39101_clipped\lnto_ORGM_gapfilled_gb_clipped'
16  lnto_silt_dl    '39101_clipped\lnto_SILT_gapfilled_gb_clipped'
17  lnto_bulk_dl    '39101_clipped\lnto_Db_H_gapfilled_gb_clipped'
18  lnto_isorg..    '39101_clipped\lnto_surfsoil_above55ORpeat_gb_clipped'
19  szm_musids..    '39101_clipped\szm_newMUSIDgapfilled_gb_clipped'
20  szm_table_dl    'szm_soilinfo_000_010'
21  szm_table_d2    'szm_soilinfo_011_025'
22  szm_table_d3    'szm_soilinfo_026_050'
23  szm_table_d4    'szm_soilinfo_051_100'
24  szm_table_d5    'szm_soilinfo_101_150'
25  srmax_lcm...    '39101_clipped\srmax_lcmceh_myclassesl_50m2015_gb_clipped'
26  srmax_table.    'srmax_rootdLookup_myclasses50m2015'
27  sr_smax_poro    '39101_clipped\s_porosity_L_gapfilled_gb_clipped'
28  smax_d2b_map    '39101_clipped\smax_d2r_gapfilled_gb_clipped'
29  hydrogeology    '39101_clipped\Hydrogeo_productive_gb_clipped'
30  B_Ks_table..    'B_Ks_lookuptable2023'
31  T_Sy_table..    'T_Sy_LookuptableNEWIndex101'
32  GW_topo_clip    '39101_GWtopo_clipped'
33  GW_mask_clip    '39101_GWmask_clipped'
34  GW_Sy_clip..    '39101_GWSy_clipped'
35  GW_T_clip...    '39101_GWT_clipped'
36  GW_Hini_clip    '39101_GWiniH_clipped'
37  GW_GEO_clip.    '39101_GWGEOindex_clipped'
38  GW_obsgauge.    '39101_GWobs_gaugeID'
39
40  end         :   0
```

Line 1- Line 9 ->: Same with the first model run. Set the correct file path for input, output, and settings folders. Specify the filename for the catchment's hru_array file. 'dynatop_parameters.dat' and 'parammap_pert_mpr.dat' remain the same with DECIPHeR model in the Settings folder. Specify the filename for the catchment's Global Parameters dat file.

Line 11- Line 29 ->: These specify the filename of soil maps that are needed for MPR parameter sampling. These files need to be read from the catchment respective folders, such as the 39101_clipped folder.

Line 30- Line 31 ->: Same with the first model run. These specify the filename of the lookup table for model parameter B, Ks, T and Sy sampling.

Line 32- Line 38 ->: Same with the first model run. These specify the filenames of the clipped groundwater-related data. The model will directly read the clipped groundwater data from the Input_MPRGW folder for further simulations without performing the clip steps.

### 2.2. INPUT file folders

The INPUT/INPUT_MPRGW folder primarily contains the input files needed to run the model.

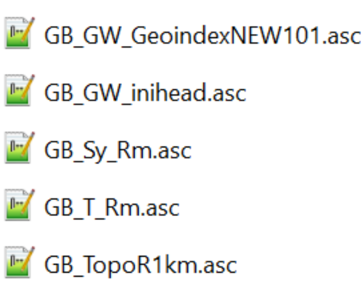
The INPUT folder contains output files from DTA runs, such as HRU information files like hru_meta.dat, hru_array.asc, and river channel related files including flow_point.dat, flow_conn.dat, and riv_data.dat etc.. Additionally, the INPUT folder includes prepared files, such as precipitation, evapotranspiration, and observed streamflow data. These files are structured similarly to those in the original DECIPHeR model. For further details, please refer to the user manual of DECIPHeR.

The folder catchmentID_clipped in INPUT_MPRGW folder includes all the MPR related files for generating the model parameters. These files need to be clipped at the first run by setting **save_bp_maps** to **1** in **MPR_control.dat** file and then will be used as inputs for fast simulations (setting **save_bp_maps** to **0**).

This section details how to prepare the input data for the groundwater module in INPUT_MPRGW folder.

#### 2.2.1. Groundwater model needed data preparation

For a given catchment, if running the DECIPHeR-GW model for the first time, it is necessary to prepare 1 km grid-scale groundwater-related data for clipping to the catchment scale by setting **save_GW_maps** to **1** in **MPR_contol.dat** file. The required 1 km grid data includes geological type (GB_GW_GeoindexNEW101.asc), topography (GB_TopoR1km.asc), initial groundwater heads (GB_GW_inihead.asc) and estimated groundwater geological data such as transmissivity (GB_T_Rm.asc) and specific yield (GB_Sy_Rm.asc), as shown in the figure below.




After the first simulation, the groundwater related data have been clipped. Users could set **save_GW_maps** to **0** in **MPR_contol.dat** file for fast large-scale simulations. The clipped data will be output in the INPUT_MPRGW folder, the example clipped files for 39101 is shown in the figure below. The fast runs will use these clipped data as inputs.

39101_GWGEOindex_clipped.asc
39101_GWiniH_clipped.asc
39101_GWmask_clipped.asc
39101_GWSy_clipped.asc
39101_GWT_clipped.asc
39101_GWtopo_clipped.asc

### 2.2.2. Meta file for groundwater gauge

This file specifies the list of groundwater observation gauge IDs and XY locations in easting and northing format. The DECIPHeR-GW model will use these observed groundwater gauges to find the corresponding 1km groundwater grid for output their simulated groundwater level timeseries.

Line 1: Comment line ignored by DECIPHeR-GW

Line 2 ->: User defined parameter: Print_GW_table. Set to 1 for printing and saving all the simulated groundwater level timeseries results for these observed groundwater gauges. Set to 0 to switch off, only printing and saving the simulated streamflow in this case.

Line 3->: Gauges: set the total number of observed groundwater gauges here.

Line 4->: NUM_COLS: set the number of columns of this file that you want groundwater model to read here. Model only needs to the index and XY locations of these gauges.

Line 5->: No: index of the groundwater gauges; easting and northing: the XY locations; Name: groundwater gauges name.

Example GWgauge_meta.txt file:

GWgauge_meta.txt

File Edit View

```
! GW OBS 2046 gauge Meta File
Print_GW_table  1 !1:print GW results;0:switch off,only print Qsim
Gauges  2046
NUM_COLS        3
!
No      easting northing        Name
1       356404  368163  Abbey Arms Wood SJ56_129
3       575580  261351  Abbots Farm TL76_006
5       464946  131202  Abbotscroft Farm 142202722
6       455899  134977  Abbotstone Down 142203627
```

### 2.2.3. Lookup table file for sampling model parameters B and Ks

B (pore size distribution index, dimensionless) and Ks (Saturated hydraulic conductivity, m/d) are the model parameters, which mainly control the recharge. This file is the parameter range lookup table for these two parameters. These parameter range are determined by combining the range from Clapp and Hornberger (1978) and Rawls et al. (1982) paper. Users can change these parameter range for their needs.

Line 1: Set number of rows and columns for model to read. Specifically, 11 (nrows represents the number of soil texture class), 5 (ncolums).

Line 2: Comment line ignored by DECIPHeR-GW

Line 3: No_soil_class: index of different soil classes; B_lower: lower parameter bound of B; B_upper: upper parameter bound of B; Ks_lower: lower parameter bound of Ks; Ks_upper: upper parameter bound of Ks; Soil texture: the name of the soil class.

Example B_Ks_lookuptable2023.txt file:

B_Ks_lookuptable2023.txt

File Edit View

```
11,5,nrows,ncolumns
Combined range from Clapp 1978 and Rawls 1982
No_soil_class,B_lower,B_upper,Ks_lower,Ks_upper,Soil texture
1,0.01,1.9323,0.504,15.2064,Sand
2,0.01,2.2691,0.14664,13.5072,Loamy sand
3,0.01,1.9184,0.06216,2.9952,Sandy loam
4,0.01,1.7193,0.01632,0.62208,Silt loam
5,0.01,1.7898,0.03168,0.60048,Loam
6,0.01,1.37502,0.01032,0.54432,Sandy clay loam
7,0.01,1.2121,0.0036,0.14688,Silty clay loam
8,0.01,0.9895,0.00552,0.21168,Clay loam
9,0.01,1.925,0.00288,0.1872,Sandy clay
10,0.01,0.7703,0.00216,0.08928,Silty clay
11,0.01,0.8985,0.00144,0.11088,Clay
```

### 2.2.4. Lookup table file for sampling groundwater model parameters T and Sy

T (transmissivity, $m^2/d$) and Sy (Specific yield, dimensionless) are the groundwater model component parameters. This file is the parameter range lookup table for these two parameters. These parameter range are determined from Rahman et al. (2023) paper. Users can change these parameter range for their needs.

Line 1: Set number of rows and columns for model to read. Specifically, 101 (nrows indicates the total number of geology types), 5 (ncolums).

Line 2: Comment line ignored by DECIPHeR-GW

Line 3: NEWindex: index of the geology types; T_Low: lower parameter bound of T; T_High: upper parameter bound of T; Sy_Low: lower parameter bound of Sy; Sy_High: upper parameter bound of Sy; GeoName: the name of the geology type.

Example T_Sy_LookuptableNEWIndex101.txt file:

T_Sy_LookuptableNEWIndex101.txt

```
101,5,nrows,ncolumns
Range from Rahman 2023 supporting information
NEWindex,T_Low,T_High,Sy_Low,Sy_High,GeoName
0,25,75,0.00173,0.1,Gault clay
1,1.24,1565,0.003,0.1,Upper greensand
2,0.1,1,0.00004,0.004,Igneous
3,0.7,2.1,0.01,0.1,Kirkcolm
```

### 2.3 project.dat & AUTO folder

The project.dat file lists all your DECIPHeR-GW projects, specifying the locations of key settings files and output folder for each catchment to be simulated. Each project typically represents a different catchment, with varying inputs, configurations, settings, and parameters.

The project file must be stored in the same directory as the DECIPHeR-GW executable, and the filename project.dat cannot be changed, as it is hardcoded into the source code.

An example of the project.dat file is available, showing the structure for 2 projects. The preparation process follows the original DECIPHeR model, with more details in its user manual.

Example project.dat file:

```
! DECIPHeR-GW project file for catchments runs
2  ! total number of gauges

project_name:   Gauge id:52016
project_dir :   C:\GWmodel\NewModelCp\
projectfiles:   SETTINGS\settings
project_out :   OUTPUT\GW_52016
dir_mpr_ctrl:   SETTINGS\MPR_control.dat
mpr_filemgr :   SETTINGS\MPR_filemgr_52016.dat

project_name:   Gauge id:39101
project_dir :   C:\GWmodel\NewModelCp\
projectfiles:   SETTINGS\settings
project_out :   OUTPUT\GW_39101
dir_mpr_ctrl:   SETTINGS\MPR_control.dat
mpr_filemgr :   SETTINGS\MPR_filemgr_39101.dat
```

Each catchment requires an associated auto file to specify which catchment the model is running for. The AUTO folder contains the auto_catchmentID.dat files for all catchments.

The index in the auto file corresponds to the order of the respective catchment's project in the project.dat file.

Example auto_39101.dat file:

```
2       id_project
2       id_cat_file
2       id_flow_file
0       id_well_file
0       id_chem_fie
0       id_temp_file
0       id_lisflood_file
```

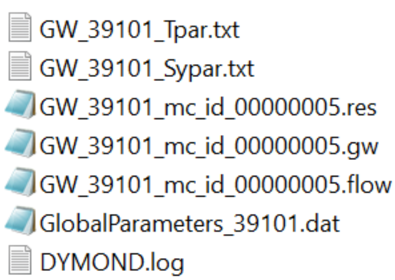
To run the DECIPHeR-GW model on a Linux system, use the following command line:

*./DECIPHeR_GW.exe -auto AUTO/auto_39101.dat*

As long as all file settings, input data, and paths are correct, the model simulation results should be obtained in the OUTPUT folder.

The simulation output results include the following files (as shown in the figure below):

Examples of output files:




- *.flow file: catchment streamflow simulation results. The unit should match that of the input rainfall/PET data, which in this case is m/day.
- *.gw file: catchment groundwater level simulation results, with units in meters (mAOD). mAOD stands for metres Above Ordnance Datum, i.e. sea level.
- *.res, *_Tpar.txt, *_Sypar.txt, and GlobalParameters*.dat: specific model parameters.
- DYMOND.log: the model's run log.

# References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