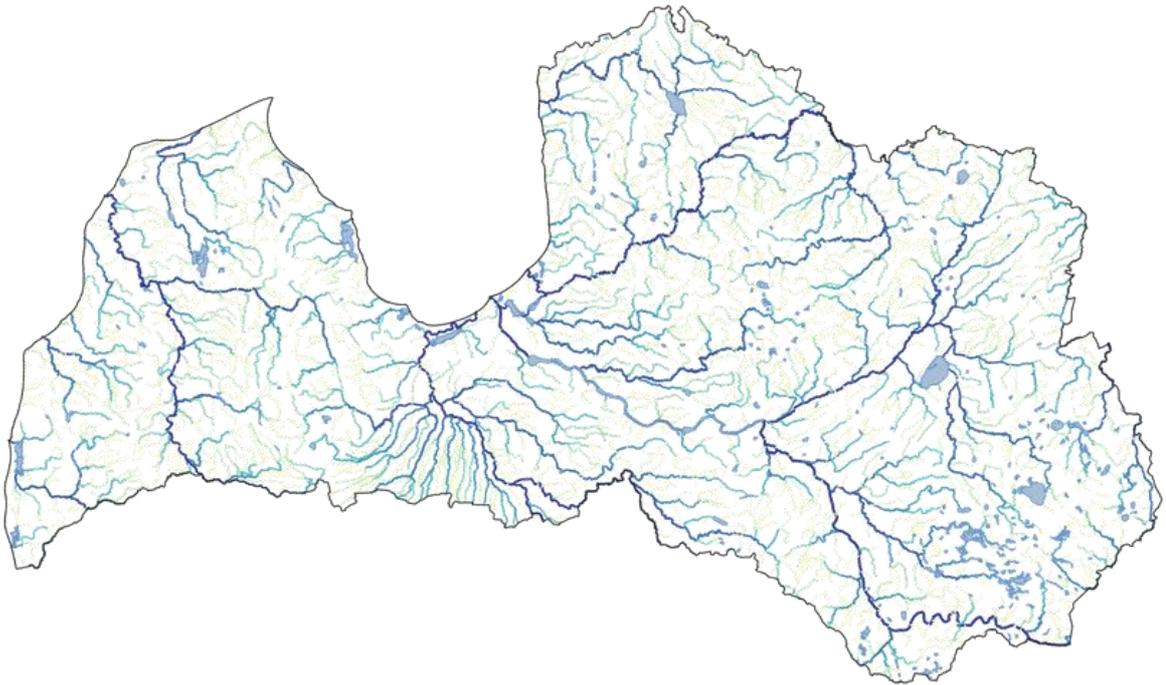


COMPLETE MODELLING SYSTEM – DATA, MODELS, RESULTS

DELIVERABLE R5



Prepared within the LIFE GoodWater IP Action C1: "Development of the water quality and quantity system for the territory of Latvia"

Rīga, 2023



Complete modelling system – data, models, results

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Summary

This document is a description of the electronic deliverable: Complete modelling system – data, models, results. This document describes the organization of this electronic deliverable.

Document is written in English, it contains 15 pages, 8 figures and 6 references.



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Introduction

This document is a description of the electronic deliverable R5: Complete modelling system – data, models, results. The complete modelling system comprises of the

- data prepared within Deliverable R1 – Data base for model implementation, PAIC (2020);
- water quantity and quality modelling tools described in Deliverable R3 – Modelling results for Reference and Baseline scenarios, PAIC (2022b);
- model setups of the calibrated and validated modelling system for the water quantity and quality in the territory of Latvia delivered as Deliverable R2 – Calibrated and validated modelling system in PAIC (2022a);
- modelling results delivered as Deliverable R2 – Calibrated and validated modelling system in PAIC (2022a) and described in the Deliverable R4 – Documentation of development, calibration, validation and results of SWAT modelling system in PAIC (2023).

The electronic deliverable R5 is a renewal and completion of the electronic deliverable R2.

This document outlines the elements of the modelling system in Chapter 1 and provides description of their organization in Chapter 2.



1. Development of the modelling system

The SWAT+ model has been adapted, and a specialized LVSWAT+ modelling system has been developed for comprehensive simulations of instream hydrological and nutrient dynamics throughout Latvia. The workflow of the system development may be divided into five steps: data preparation, model code development, modelling system development, simulations, and results processing and visualization. This approach allows for a systematic and structured workflow in order to effectively analyze and interpret the modelling outcomes.

The input data includes the following data blocks:

1. digital terrain model;
2. river network, see Figure 1;
3. meteorological observations;
4. atmospheric nitrogen deposition data;
5. land use data, see Figure 2;
 - a. agricultural support service data for agricultural land;
 - b. forest data;
 - c. topographic maps;
6. soil data, see Figure 3;
7. plant growth data;
8. fertilization model;
9. spatial distribution of organic fertilizer.

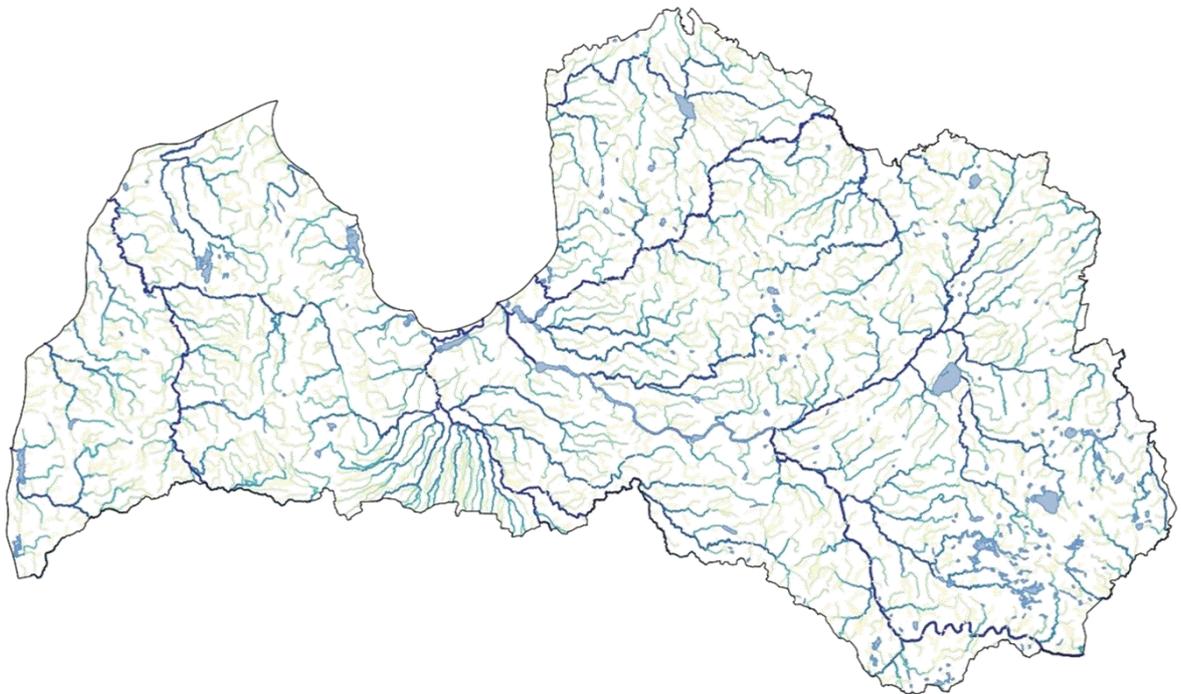


Figure 1: Model river network.



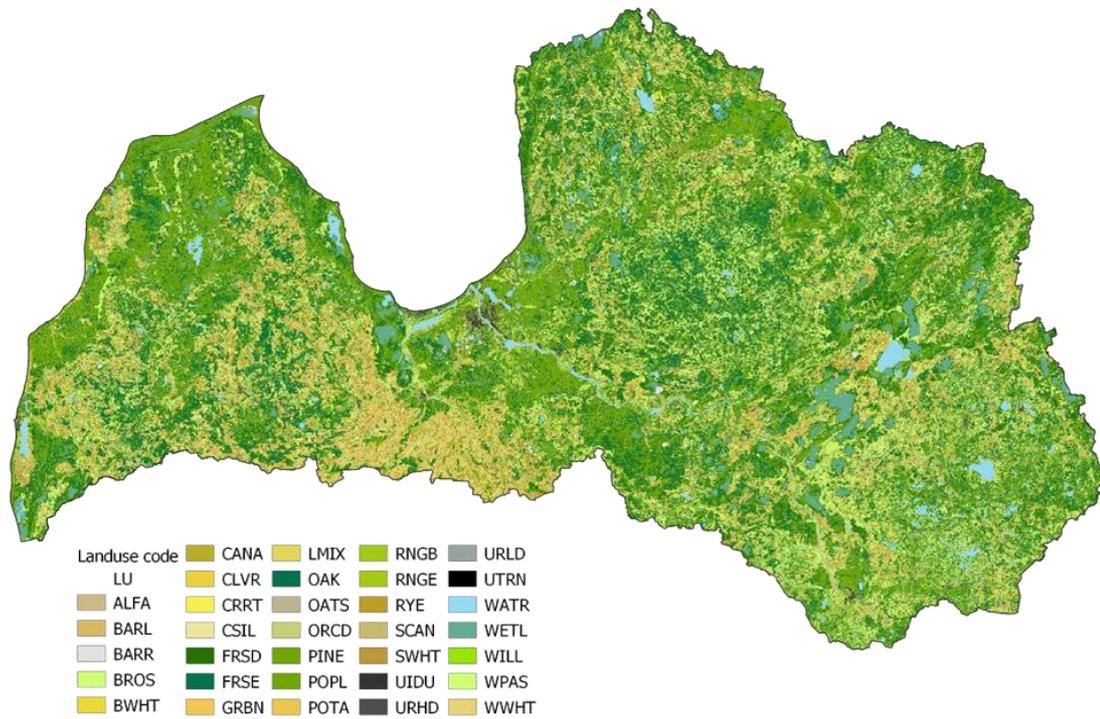


Figure 2: Land use distribution: 33 land use classes

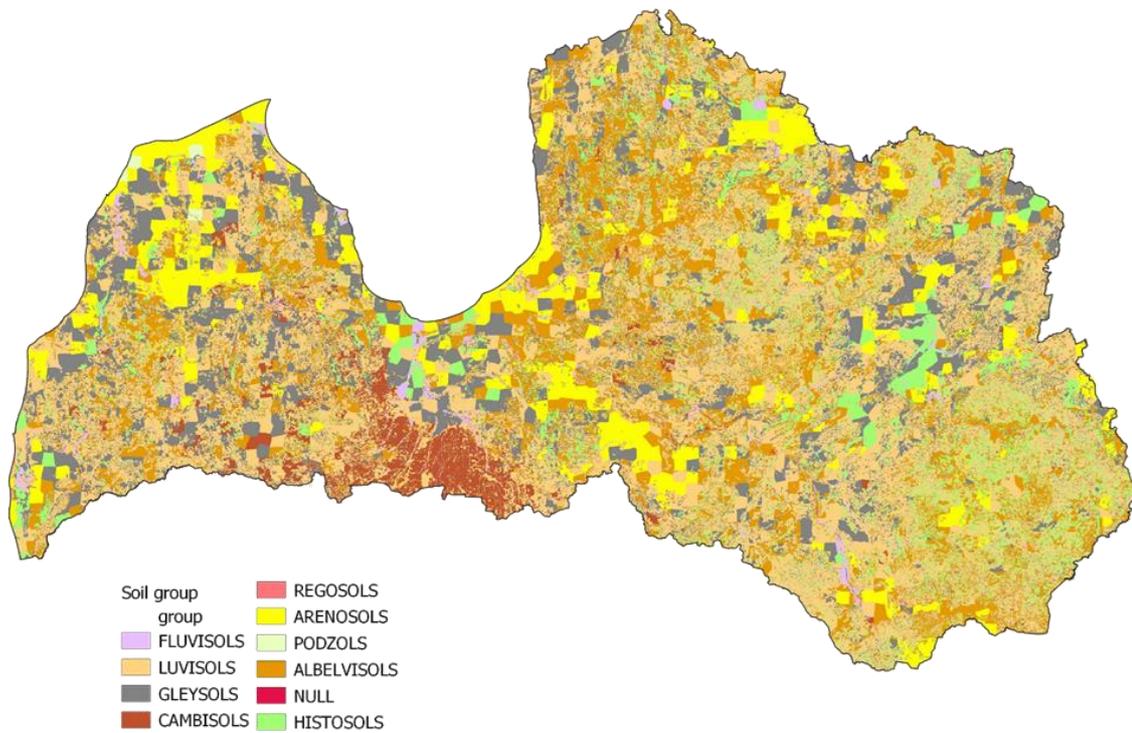


Figure 3: Soil distribution: 54 soil classes, 10 groups of soil classes.



The input data are preprocessed and transformed for use with the modelling system. The data and its preparation is described in Deliverable R1 – Data base for model implementation, PAIC (2020).

A data storage system has been implemented to efficiently store the input data. This system is built on the Postgre database and SVN versioning system. The underlying technologies used for the storage system are discussed in Chapter 1, while the organization of the data is explained in detail in Chapter 2.2 of Deliverable R2 – Calibrated and validated modelling system, PAIC (2022a). This ensures a robust and structured approach to managing and accessing the data throughout the Project.

We made **modifications to the original SWAT+ code**, specifically focusing on a command line tool. The FORTRAN code of the modelling software was debugged and stored in GitHub for version control and collaboration. The debugging process of SWAT+ and the changes we introduced are elaborated on in Chapter 1 of Deliverable R3 – Modelling results for Reference and Baseline scenarios, PAIC (2022b). This documentation provides a comprehensive account of the debugging process and the specific modifications made to enhance the functionality of the SWAT+ model.

To enable automatic system running, we implemented the **system functions controlling script main.py**. This script performs various tasks, including setting up the modelling system, running simulations, and generating modelling results. Detailed descriptions of the specific scripts developed for the modelling system can be found in Chapters 2.1, 2.2, and 3 of Deliverable R2 – Calibrated and validated modelling system, PAIC (2022a), while instructions on their usage are provided in Chapter 2 of Deliverable R3 – Modelling results for Reference and Baseline scenarios, PAIC (2022b). These chapters provide comprehensive documentation on the functionality and utilization of the scripts within the modelling system.

The model setups are automatically generated, and the process is described in Chapter 3 of of Deliverable R2 – Calibrated and validated modelling system, PAIC (2022a). The system setup includes various elements related to land and computational connectivity, such as stream segments, catchments, watersheds, and hydrological response units (HRUs). Additionally, the interconnection between watersheds and transboundary inflows has been defined.

- *Stream segments* represent distinct sections of the river between two measurement points or located upstream from the last water quality or quantity measurement point. In total, the system is partitioned into 3780 discrete segments.
- *Catchments*, on the other hand, are defined as land areas where all water flows into a specific stream segment, excluding the upstream catchment of the subsequent stream segment. A total of 3780 discrete catchments are delineated within the modelling system (Figure 5).

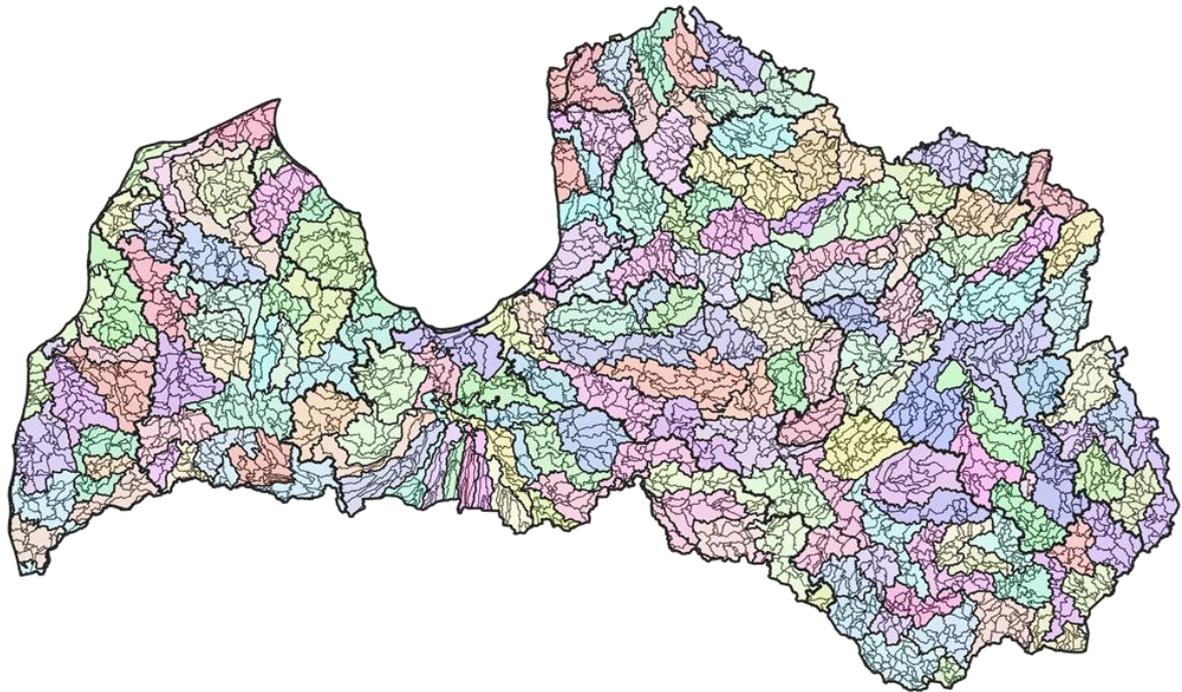


Figure 4: Catchments and watersheds of the modelling system

- *Watersheds* are defined as land areas that consolidate multiple upstream catchments. Watersheds of comparable area, and corresponding to either medium-size rivers or stretches of the larger rivers were aggregated from the catchments. Each watershed corresponds to a specific SWAT+ setup. Within the modelling system, there are a total of 179 watersheds, as shown in Figure 5.
- *Hydrological response units (HRUs)* represent the smallest land units that capture distinct combinations of land use, soil type, and slope within the catchment. The modelling system encompasses a total of 194,634 HRUs.
- *Connectivity between watersheds*, or individual SWAT+ setups defines the graph of the water flow between the watersheds. The connectivity ensures sequential upstream-to-downstream hydrological and nutrient process simulations.
- *Transboundary inflows* are considered as follows:
 1. From Lithuania - SWAT+ model data from PAIC (2022c), see Figure 5.
 2. The river Daugava inflow – observational data.
 3. Other inflows – catchment parts outside LV are assumed to contribute water and nutrients proportionally to their area.



Figure 5: Merging LV and LT SWAT+ models

In the modelling system, specific model parameters are assigned to each HRU. This assignment is accomplished using a script, ensuring that each HRU accurately represents its unique characteristics and behaviours within the model. The **parameter values are determined during the calibration process**, as detailed in the Deliverable R2 – Calibrated and validated modelling system, PAIC (2022a) and described in the Deliverable R4 – Documentation of development, calibration, validation and results of SWAT modelling system, PAIC (2023).

As a result, we have developed a functional model setup system with calibrated model parameters, allowing for simulations of instream hydrological and nutrient dynamics. The modelling results include time series data, and their simulations are automatically generated using the *main.py script*. The structure and functionality of the script are described in detail in Chapter 2 of the Deliverable R3 – Modelling results for Reference and Baseline scenarios, PAIC (2022b).

The visualization of simulated time series and the statistical analysis are facilitated by the PAICSWAT software (PAIC, 2012). Detailed information on the visualization of modelling

results, water quantity and quality observations, as well as the software used, can be found in Chapter 3 of the Deliverable R3 – Modelling results for Reference and Baseline scenarios, PAIC (2022b). Additionally, the simulation results are spatially visualized using QGIS, as demonstrated in the example shown in Figure 6.

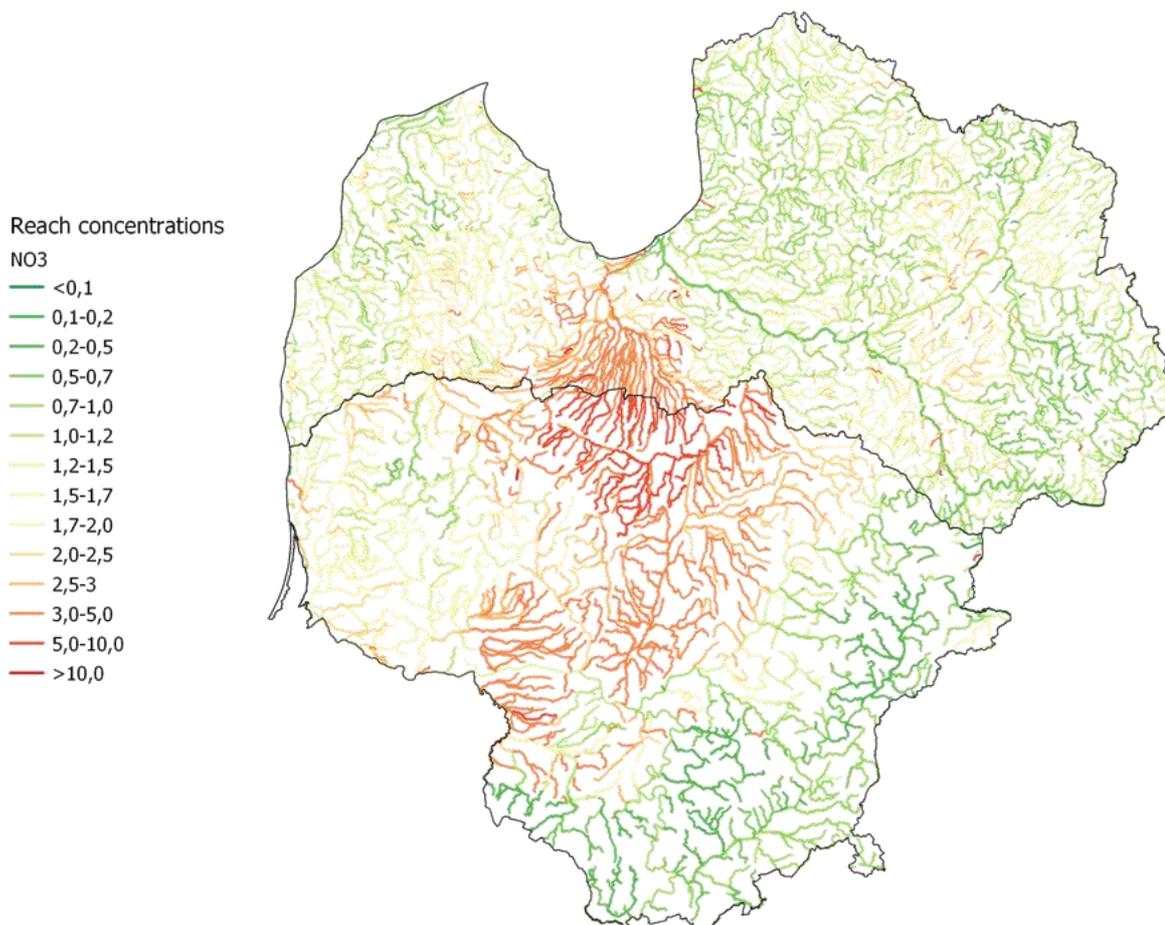


Figure 6: Nitrate concentration in reaches. Modelling results of LV and LT SWAT+ models.

2. Structure of the modelling system

The water quality modelling system is electronically delivered, containing all the data and scripts needed for the creation of the system, running models and producing results on the local machine. The structure of the electronic deliverables is outlined in Chapter 4 of PAIC (2022a); herewith, we extend and update this information.

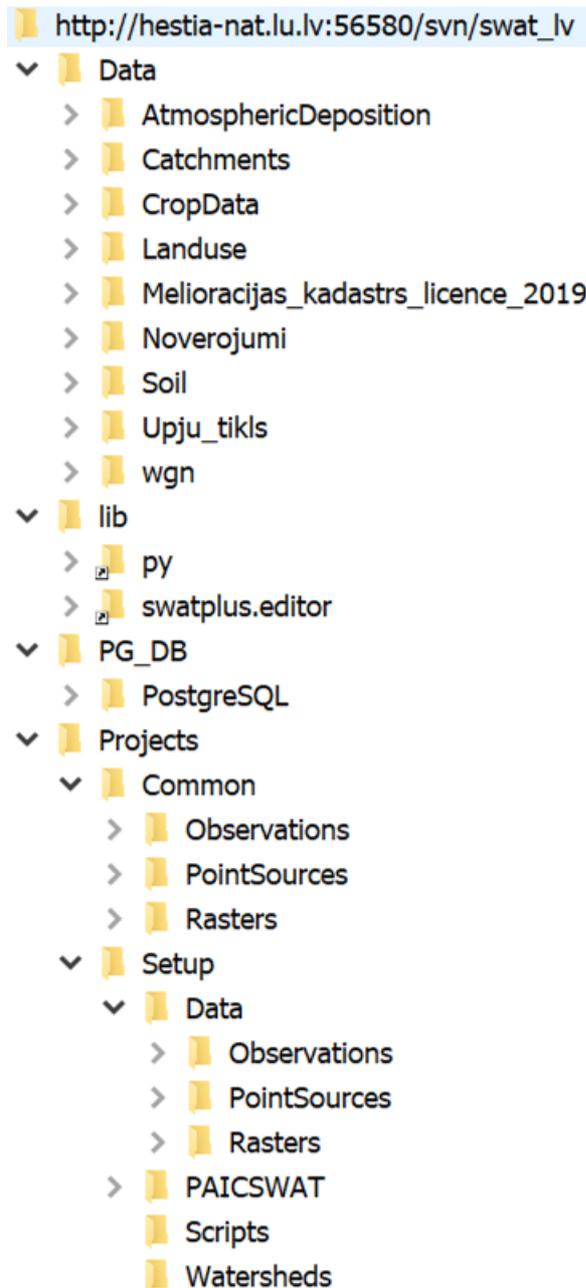


Figure 7: Folder structure of the modelling system.



The modelling system is delivered via subversion repository system (SVN). Repository access:
Address: http://hestia-nat.lu.lv:56580/svn/swat_lv
Username: swat_lv
Password: swat_lv

Read only mode is allowed for the partners.

Repository can be accessed by browsers, but recommended tool for the repository access is TortoiseSVN¹.

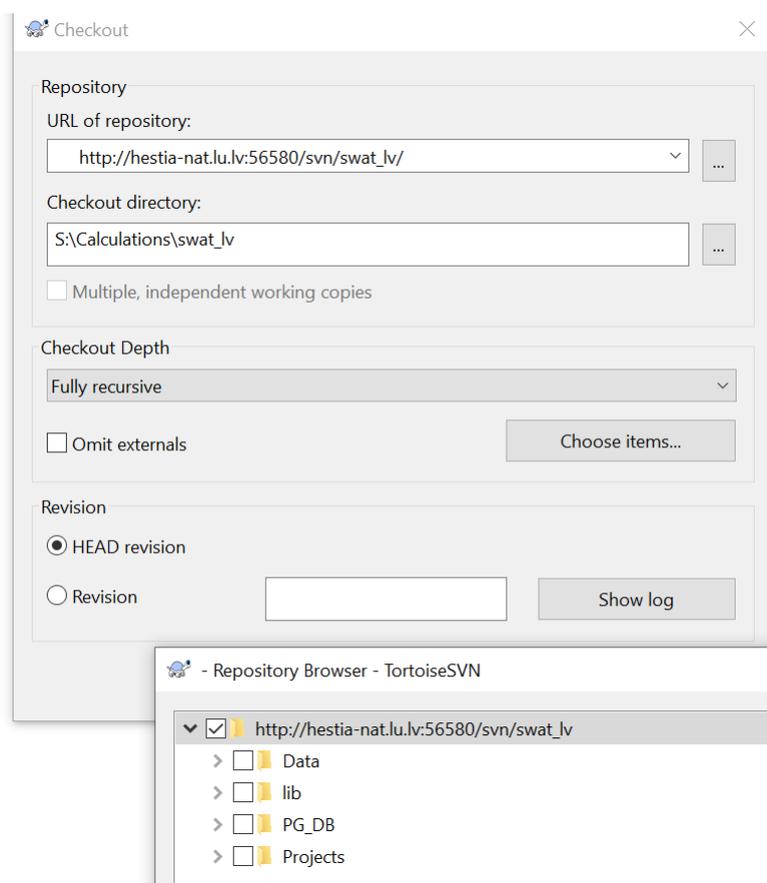


Figure 8: Screenshot of SVN checkout.

The repository contains 4 main folders, see Figure 7: *Data*, *PG_DB*, *lib* and *Project*.

- *Data* folder contains all necessary input data and preprocessing scripts.
- *PG_DB* folder contains PostgreSQL database.
- *lib* and *Project* folders contain all necessary data for running modelling system for calculation of water quality for the prepared setup. This data is described in the Chapters

¹ <https://tortoisesvn.net/downloads.html>

2 and 3 of the Deliverable R2 – Calibrated and validated modelling system, PAIC (2022a).

User actions for the use of the modelling system are summarized below:

- Download the system by SVN via Tortoise SVN Checkout, Figure 8.
- Run `\PG_DB\StartPostgreSQLService.bat`.
- Indicate the Python folder (e.g. `python=C:\WPY64-3860\python-3.8.6.amd64\python.exe`) and run `\Projects\Setup\Scripts\run_main.bat`
- Visualize the GIS results: `\Projects\Setup\GIS\Results\ postprocess_LV.qgz`
- Visualize the time series `\Projects\Setup\PAICSWAT\paicswat.exe`



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