Modeling Urban Flood Risk Territories for Riga City

J.Seņņikovs, J.Virbulis, P.Bethers, A.Piliksere, A.Valainis, U.Bethers
University of Latvia

Abstract

The general aim of this study were identify territories of Riga city which are under flood risks nowadays, in near (2021-2050) and far (2071-2100) future taking into account climate changes. Flash floods from the large rainfall events and local snow melt floods were considered. Hydrodynamic, hydraulic and hydrological modeling was employed to assess the flooded territories. Maps of potentially flooded areas for the events with the given occurrence periods were prepared.

1. Area of study

Riga, the capital of Latvia, is located on River Daugava at the Gulf of Riga (see Fig. 1). The main flooding risks of Riga city are:
(1) storm caused water setup in South part of Gulf of Riga (storm event),
(2) water level increase caused by Daugava River discharge maximums (spring floods),
(3) strong rainfall or rapid snow melting in densely populated urban areas.

The first two flooding factors were discussed previously (Piliksere et al, 2011).

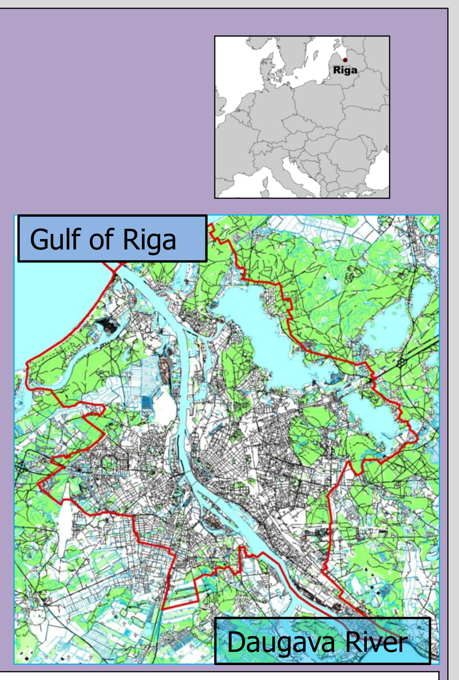


Figure 1. Location of area of studies

2. Aims of study

The aims of the study were (see Fig. 2)
(1) the identification of the flood risk situations in densely populated areas,
(2) the quantification of the flooding scenarios caused by rain and snow melting events of different return periods nowadays, in the near future (2021-2050), far future (2071-2100) taking into account the projections of climate change,
(3) estimation of groundwater level for Riga city,
(4) the building and calibration of the hydrological mathematical model based on SWMM (EPA, 2004) for the domain potentially vulnerable for rain and snow melt flooding events,
(5) the calculation of rain and snow melting flood events with different return periods,
(6) mapping the potentially flooded areas on a fine grid.

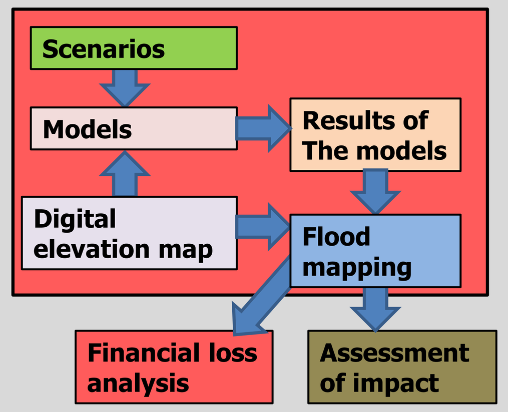


Figure 2. Scheme of system

3. Scenarios

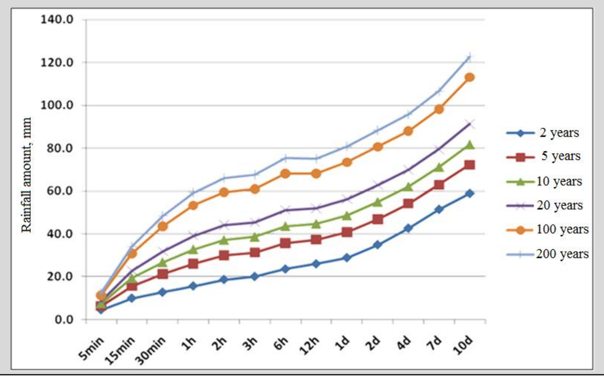


Figure 3. Rainfall amount (mm) for various durations and occurrence probabilities. Riga, nowadays climate

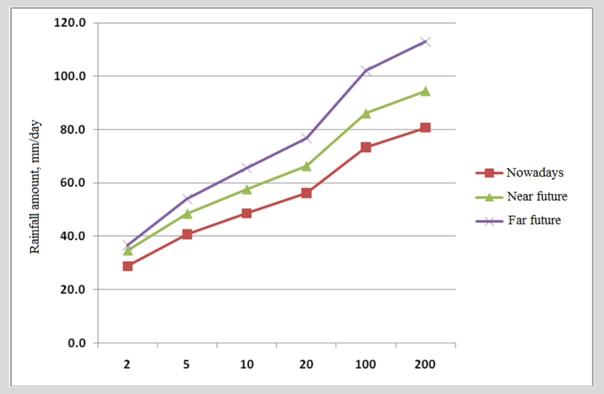


Figure 4. Daily rainfall amount (mm) for present (red), near future (green) and far future (blue) for various occurrence probabilities

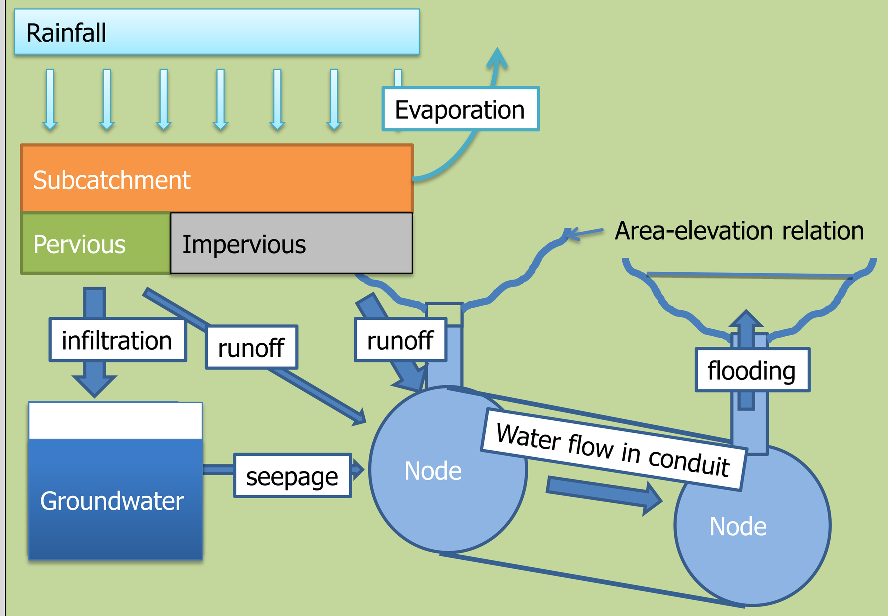
The time series of short term precipitation events during warm time period of year (i.e. rain events) were analyzed for 35 year long time period. Annual maxima of precipitation intensity for events with different duration (5 min; 15 min; 1h; 3h; 6h; 12h; 1 day; 2 days; 4 days; 10 days) were calculated (see Fig. 3, 4).

The time series of long term simultaneous observations of precipitation and reduction of thickness of snow cover were analyzed for 27 year long time period. Snow melting periods were detected and maximum of snow melting intensity for events with different intensity (1day; 2 days; 4 days; 7 days; 10 days) were calculated.

According to the occurrence probability six scenarios for each event for nowadays, near and far future with return period once in 5, 10, 20, 50, 100 and 200 years were constructed based on the Gumbell extreme value analysis.

The hydrological modelling driven by the temperature and precipitation data series from regional climate models were used for evaluation of rain event maximums in the future periods. The usage of the climate model data in hydrological models causes systematic errors; therefore the bias correction method (Sennikovs, Bethers, 2009) was applied for determination of the future rainfall intensities.

4. Scheme of hydrological modelling



Hydrological model of the Riga city is developed using SWMM software. The EPA Storm Water Management Model (SWMM) is a dynamic rainfall-runoff simulation model that computes runoff quantity and quality from primarily urban areas.

5. Hydrological model

Groups of objects required for the model are (1) **Nodes** - pump stations, weirs, junctions, outfalls; (2) **Lines** - water conduits – pipelines, streams, ditches; (3) **Areas** - catchments.

3 parts of the sewage system are (see Fig. 5):
• wastewater and combined sewer system (Red)
• rainwater sewer system (Green)
• streams and ditches – melioration system (Blue)

The type, size and elevation of the conduits are represented in the model. Waste water inflow volume (dry weather inflow) was applied.

Elements of sewage system are (see Fig. 6):
• Wastewater pumping stations (Red triangles)
• Rainfall water pumping stations (Green triangles)
• Outfalls (Black triangles)
• Combined sewer system overflow regulators (Purple rectangles)

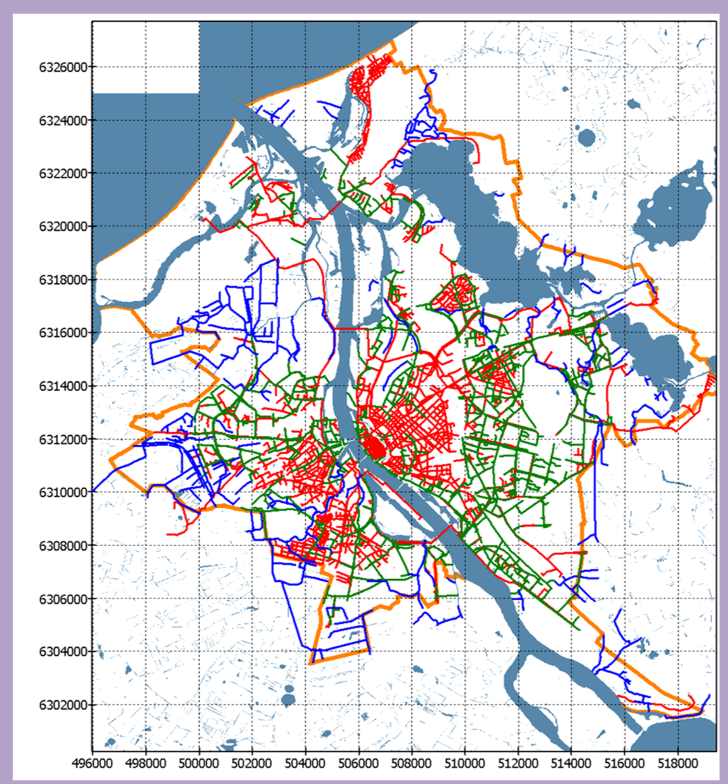


Figure 5. Sewage system

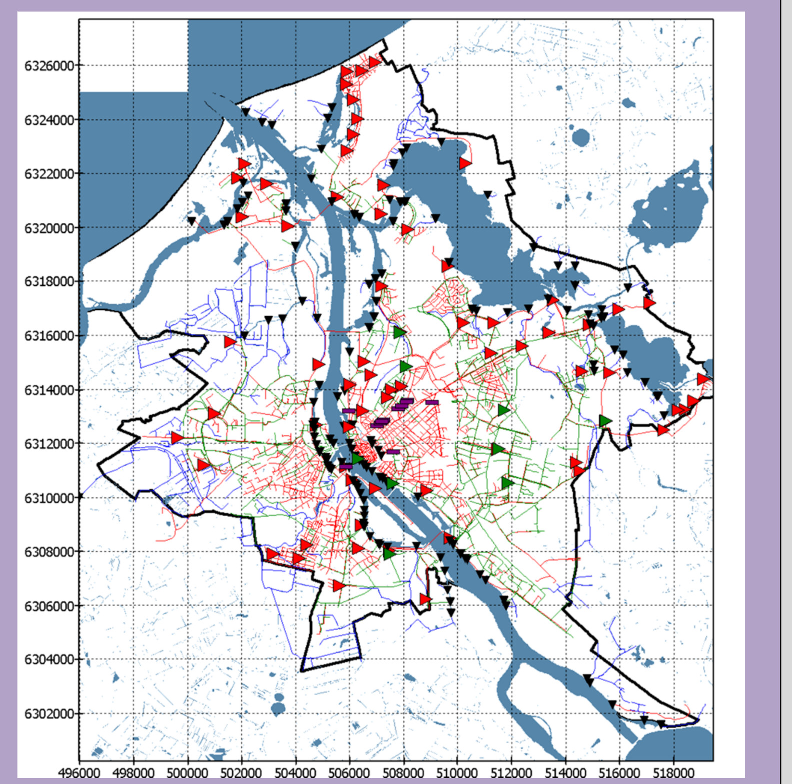


Figure 6. Elements of sewage system

• The receivers of the rainfall waters from the system are main water objects – Daugava River and lakes.
• Wastewaters (including rainfall waters from the combined system) are pumped to the main wastewater treatment plant.
• Part of the wastewaters during large rainfall overflows the regulators to the rainfall sewer system.

6. Sub-catchments

Sub-catchments are assigned to the nodes of the hydraulic model. The area, average width, average slope (see Fig. 8), maximal infiltration rate, fraction of impervious (buildings and roads) area (see Fig. 7) and area-elevation relationship are properties of the sub-catchments.

The flooding of the sub-catchment are represented by the volume of the water contained in it. Using area-elevation relation average elevation in the sub-catchment are calculated. Average elevation in the each of the sub-catchments are then mapped to the detailed mapping mesh. The threshold for territory to be defined as flooded: water depth > 15 cm at least for 30 minutes, the area larger than 200 m².

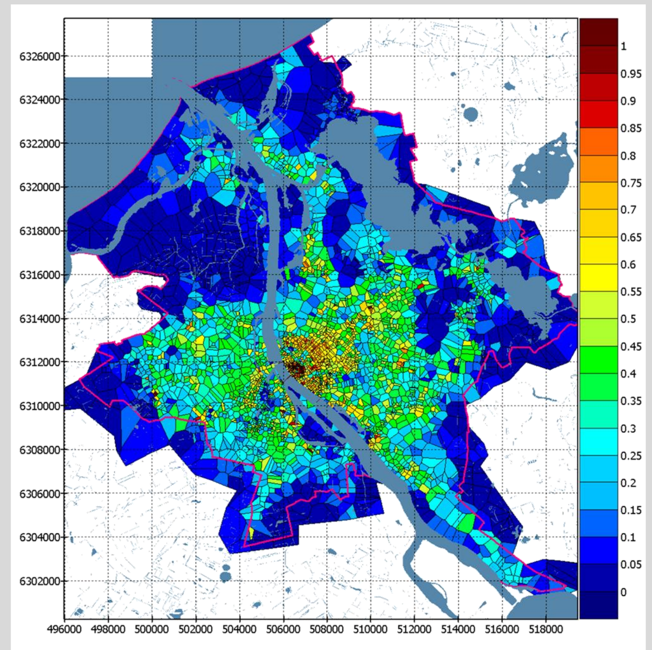


Figure 7. Fraction of impervious area

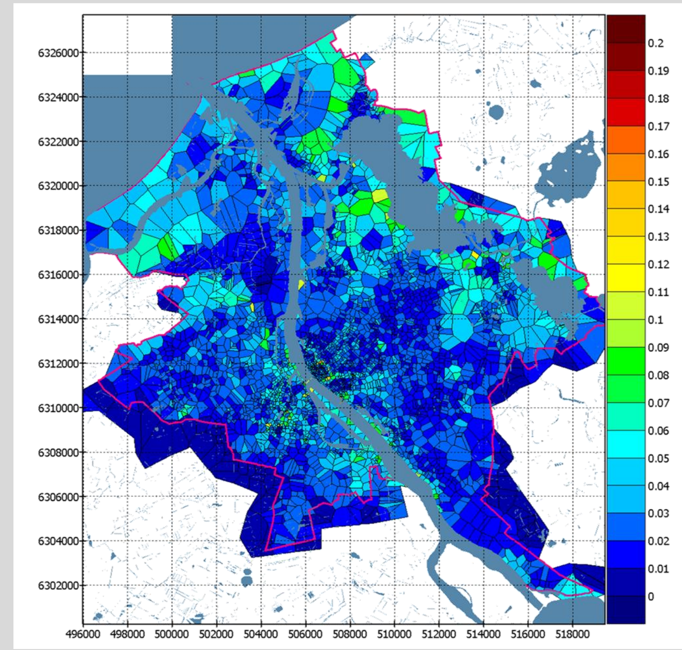


Figure 8. Average slope

7. Calculation results

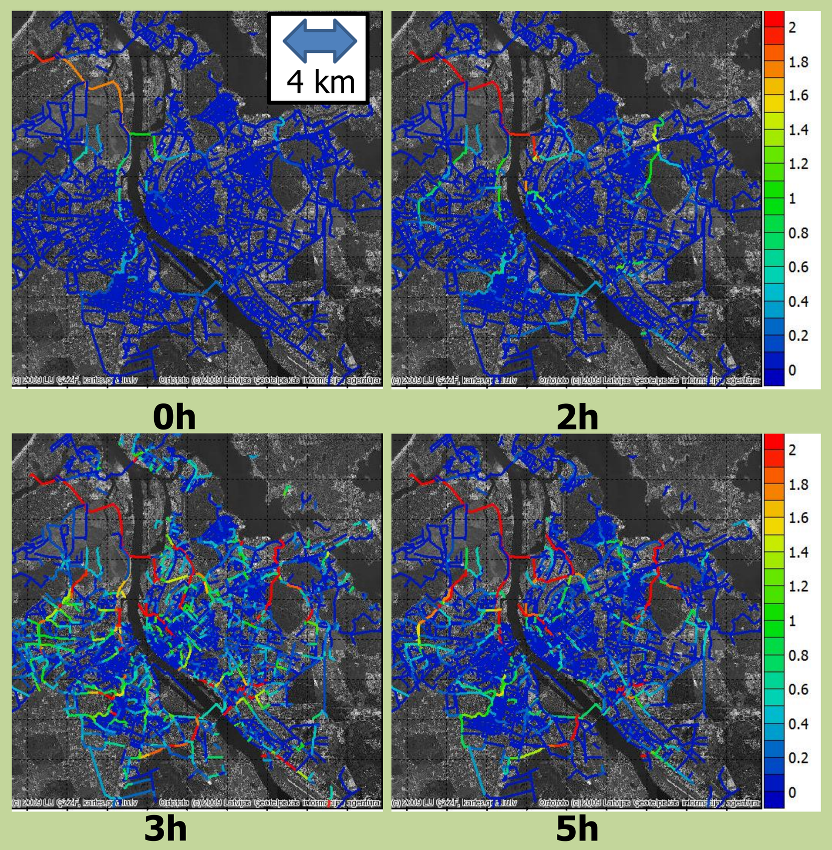


Figure 9. Time development of the rainfall scenario with 20% occurence probability (once in 5 years) nowadays

0h, Situation just after rainfall started - main sewage pipelines to the waste water treatment plant could be seen; some flow in the ditches.
2h, Increased water flow in the main ditches and streams and in the main pipelines of the sewer system.
3h, 10 minutes after rainfall intensity maximum. Increased water flow in nearly all parts of the system.
5h, Flow is decreased in the small branches of the system, while still elevated in the main pipelines and streams.

8. Mapping of results

The reason for the floods in Centre of City (see Fig. 10) is insufficient capacity of sewer system caused by closed (or not functioning) combined sewer system overflow weirs.

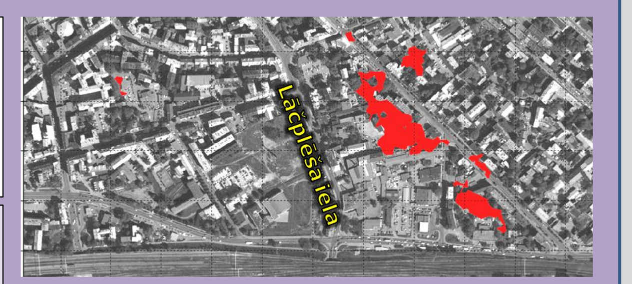


Figure 10. Fragment of flooded territory map for rainfall events 50% occurrence (once in 2 years) nowadays

In Fig. 11 is shown map of 0.5% occurrence (once in 200 years) far future maximal of considered scenarios for storm surge events, (Piliksere et al, 2011). Same occurrence for far future scenario of rain fall event is presented in Fig. 12.

The flooded area from the rainfall much more localized ("patchy") but could include more important territories (see Fig. 12).

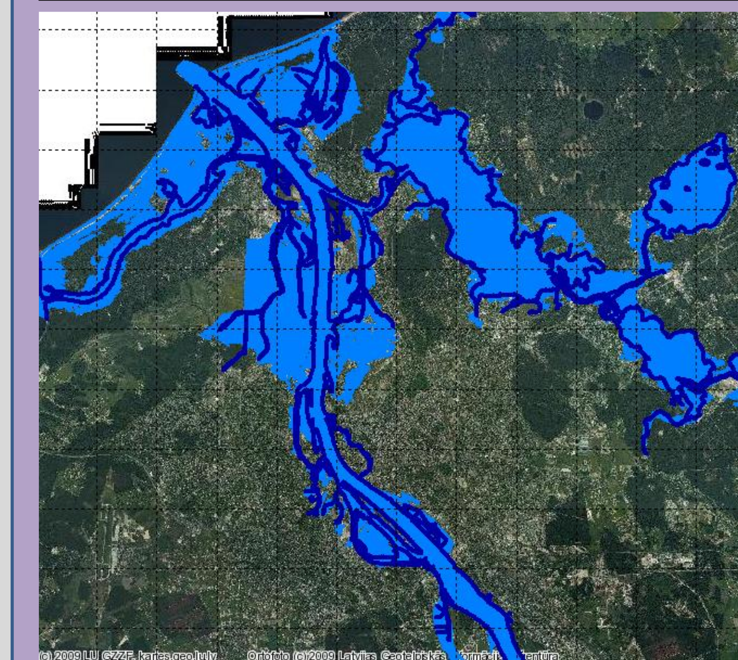


Figure 11. Flooded territory for storm surge event.

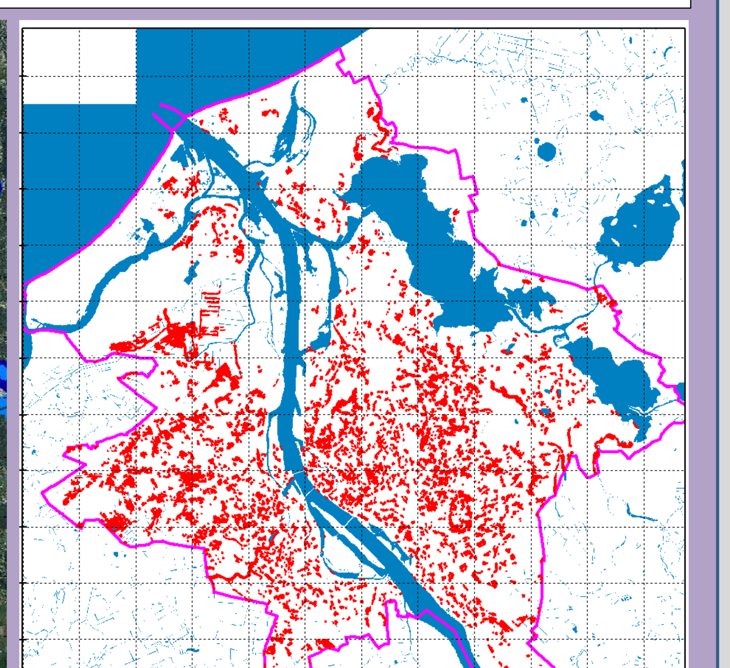


Figure 12. Flooded territory for rainfall event.

9. Conclusions

Main results of study are:
(1) detection of the hot spots of densely populated urban areas for nowadays and future;
(2) identification of the places with insufficient capacity of the melioration and sewage systems;
(3) mapping the elevation of ground water mainly caused by snow melting;
Main conclusions are:
(4) Flooding risks are higher for the storm surge situations comparing to spring floods, local flash floods and local snow-melt;
(5) Significant increase of extreme rainfall events in the future. Flooded area increase by up to 100% for the rainfall events;
(6) The ability to minimize the flooding risks from the strong rainfall events is dependent on the capacity of the drainage system in Riga.

References:

•A.Piliksere, A.Valainis, J.Seņņikovs, (2011), A flood risk assessment for Riga city taking account climate changes, EGU, Vienna, Austria.
•EPA, (2004), Storm water management model. User's manual version 5.0. US Environmental Protection Agency
•J.Sennikovs, U.Bethers, (2009), Statistical downscaling method of regional climate model results for hydrological modelling. 18th World IMACS/MODSIM Congress, Cairns, Australia.

ESF EIROPAS SOCIĀLAIS FONDS
EIROPAS SAVIENĪBA
LATVIJAS UNIVERSITATE ANNO 1919
VTPMML
INVESTING IN YOUR FUTURE

This study is supported by the European Social Fund project „Establishment of interdisciplinary scientist group and modelling system for groundwater research". Project No. 2009/0212/1DP/1.1.1.2.0/09/APIA/VIAA/060