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GREENPUMP

Work Package 4: Elaboration of studies

Deliverable 4.7. 1 (former 4.3.1): Elaboration of criteria for site selection (including a water/energy demands study)

Beneficiary: IHU (former TEICM)

INTERREG V-A COOPERATION PROGRAMME:

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About this document:

The target of the present Deliverable is to select an appropriate case/site suitable to employ the studies examined in the project, i.e. the use of pumped water for secondary purposes (toilet flushing) as well as achieve heating from shallow geothermal energy.

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1. Scope of Deliverable 4.7.1 (former 4.3.1) – IHU (former TEICM) contribution

The scope of Deliverable 4.7.1 (former 4.3.1) is to select an appropriate case/site suitable to employ the studies examined in the project, i.e. the use of pumped water for secondary purposes (toilet flushing, irrigation) as well as achieve heating from shallow geothermal energy. This case should ideally combine the following:

- Shallow depth of the water table level (close to the soil surface).
- Several constructions with basements located near the selected site.
- The shallow aquifer resulted in several problems in the past, related to basement flooding, deterioration of structural integrity, loss of building serviceability for specific time periods etc.
- Existing water pumps in the aforementioned constructions.
- Possibility to install and monitor measurement devices for the pumped water quantities in those constructions (preferably publicly owned buildings)

The campus of TEICM (Technological Educational Institute of Central Macedonia) fulfills satisfactorily almost all the above conditions, presenting an ideal case to study the use of pumped water for secondary purposes and heating. Details of the selected case are presented in the following paragraphs.

2. Hydrogeology of Serres basin

The case study area is located in the middle part of the prefecture of Serres, in the Region of Central Macedonia, in Greece (Figure 1).

Figure 1. Location of study area (https://www.google.gr/maps)

2.1 Basin Geomorphology

The Strymon River basin, which develops between the Rodopi geotectonic zone to the east and the Serbomacedonian to the west, was created by the action of tectonic-nontectonic processes and was then shaped by the action of the external factors of sedimentation, disintegration and erosion.

The total area of the Strymon basin is estimated at 17.150 km² and is shared between Greece, Bulgaria and FYROM. The Greek section owns 39.45%, corresponding to 6759 km², and includes the basin of Serres and its basin the river Aggitis, the largest part of which is occupied by the Drama basin. The basin of Serres, the area of which amounts to 3714.8 km², is a term attributed to it as a basin, in relation to the hydrographic and hydrological elements and as a ditch, in relation to the geological and tectonic elements of the draft. The shape of the basin resembles an oblique rectangle, with a long axis of NW-NA of about 80 km in length, and a short BA-SW direction and a length of about 50 km.

The lower part of the basin is occupied by the plain of Serres, which flows through the River Strymonas. The river, entering north of Bulgaria, between the Kerkini and Orvilos Mountains, crosses the lowland area and flows south into the Strymonikos Gulf, passing through the Kerdylia and Pangaeus Mountains. It has a total length of 360 km (of which 242 km in Bulgarian territory and 118 km in Hellas). Shortly before his estuary he receives the waters of Aggitis River, which drains the neighboring basin of Drama town.

The Strymon River is, essentially, the axis of symmetry of the Serres basin. The gradients of the various morphological segments of the basin range from very large to mountainous to very small in the low range. In lowland area, altitudes less than 60 m, the slopes range from 5% to 8% and in the zones of former lakes and stretches from 0% to 3%. This indicates that the water movement in the low sections is done at a very low speed, unlike the rest of the areas, thus depositing most of the weighed materials it transports. As a result of the large discrepancy between high and low areas, there is the creation of extensive alluvial ridges, when the torrents and rivers flow out of the mountain zone. Such ripples are located almost around in the basin of larger size than that of the river Strymon. The alluvial ripples, due to the high water permeability of the bulk materials, have ideal hydrogeological conditions for the development and supply of important underground aquifers

The Strymon River flow bed is the central branch of the hydrographic network (Figure 2) in which all the lateral branches of the torrents and streams, all of which are counted at sixty-eights (68).

2.2 Hydrographic network

Today, the hydrographic network of the low section (lowland) of the Serres basin is almost entirely artificial. The predominant element of this is the river Strymonas, which on its natural course, in the past and before the construction of the land reclamation works, coming from Bulgaria in the area of the basin, deposited sludges forming the great alluvial ripple of Strymon River. Then the river circulated its flow on it, creating temporary dwellings that abandoned them in periods of floods. Of the original recipients of its run-offs, it was the members that developed the Northwest of Lake Kerkinitida (or Boutkovo). It then formed a stable bed, near the western boundary of the basin, and approached the area of Achinos Lake to reach in Strymonikos Gulf. Characteristic of the river's broadest riverbed was the formation of islets and dunes, as a result of both the heavy load of sediment and the low speed of the river (small slopes). This gave a character of a breezy stream flowing into the river that resulted in the creation of a plethora of new dormitories. With the same mechanism, the largest torrents of the area (like the torrent of Belitsa), due to similar morphological conditions, have created extensive alluvial ripples, and a significant number of dormitories, and ended up with Strymon River in the Lake of Achinos. These morphological processes described above result in a heterogeneous distribution of materials throughout the flat portion of the alluvial deposits. Many of the dormitory beds of Strymon River or the most important torrents today are drainage or irrigation ditches. As a conclusion, the hydrographic system of the Strymon River is a mixed, natural and anthropogenic system.

The design and construction of major land reclamation projects, mainly in the low part of the basin, resulted in both the destruction of old abandoned dormitories and the integration of some of them into the irrigation network. In the natural environment of the basin, there were permanent lakes or lakes, which have played an important role in shaping the field of deposits that constituted the local basic level of the rivers Strymonas, Belitsa, Aggitis.

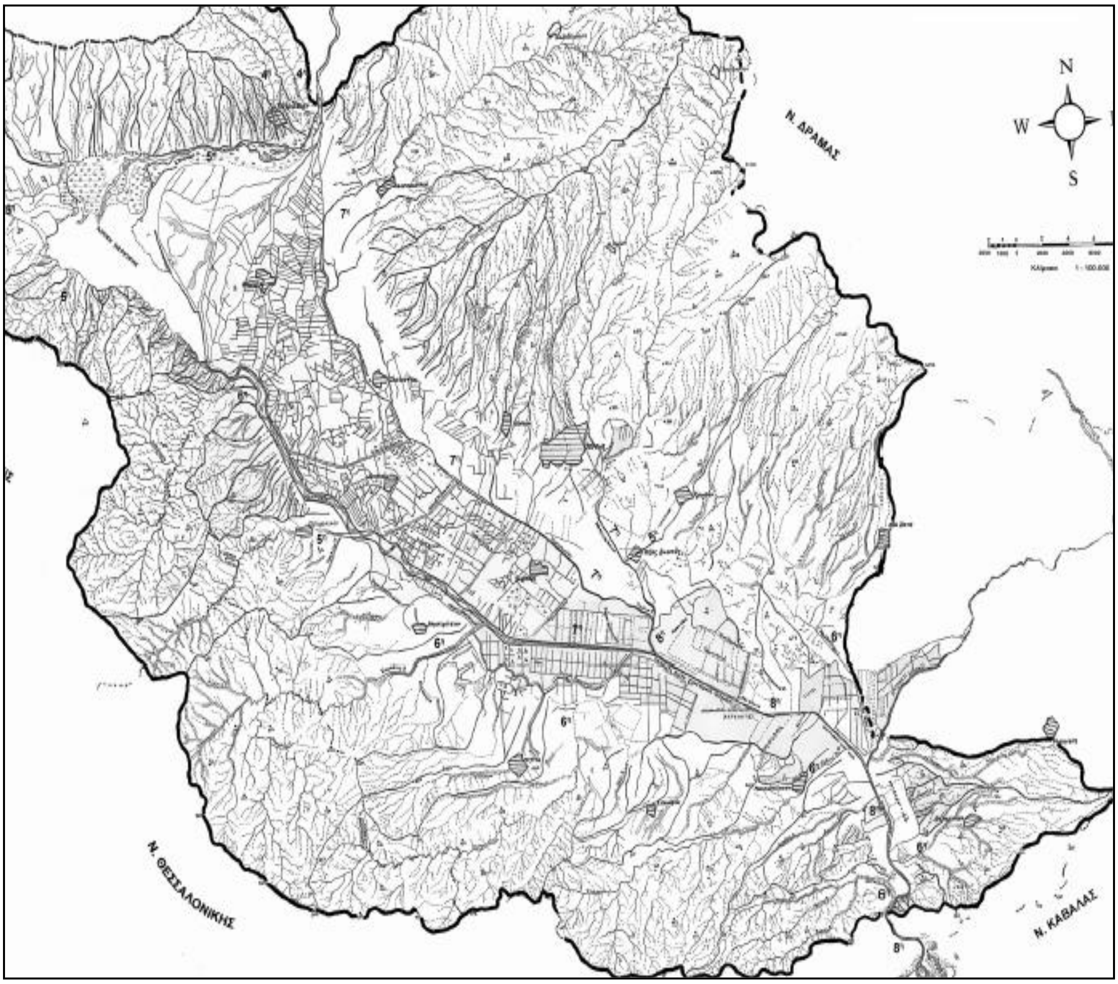

Figure 2. The hydrographic network

2.3 Geology

The tectonic draft of river Strimonas has been created between the geotectonic zones of Rodopi in the east and the Serbo-Macedonian mass in the west. The boundary of the two zones is the river Strymonas, while the tectonic contact line is not visible on the surface (over two restricted positions) due to its cover from the deposition of the Neogen and Quaternary sediments that have paid the tectonic draft. The basin of Serres consists of two basic systems:

- The system of the rocks of the background (The background of the basin of Serres is the transformed rocks of the Rhodopean zone to the east and the Sermakedonian to the west).
- The system of post-polar sedimentary deposits (Neogen, Quaternary).

2.4 Sedimentary deposits

The lithology of the sedimentary deposits of the Serres basin is of particular interest due to the geomorphological processes that took place in the area of the draft during the Neogen and the Quaternary. Based on these processes a peculiar structure has been created in sedimentary materials, with frequent variations of the different phases.

Sedimentary deposits based on the above processes consists of a wide variety of materials with complex and uneven distribution, spread and tectonic strain (of the oldest sediments) and is distinguished in two main groups:

- The group of neogenic sediments (minor and pleiocenical materials)
- The group of quaternary deposits (Celtic and Pleistocene).

The group of Neogen sediments is present in the inner perimeter hilly region, at the lower morphological sites with pleistocene materials and at the highest ones with minorokenes. Neogenous sediments form the basis of quaternary deposits of the central plains. They have a large spread, almost all of the eastern hilly part of the Serres Basin and limited development in the western part where they are located only in the hilly areas of Kerdyllia and Vertiskos mountains. The deeper lower-water layers consist mainly of alternations of fine-grained materials, clay-sludges, clay-lime, limestone lakes, with block grain horizons and conglomerates. This formation, which today builds the highest half-mountainous zone, corresponds to its deeper layers with coarse-grained layers (conglomerate-sandstone-sandstone), while in the upper layers it is predominantly fine-clay (aluminosilicates with lignites, clay mills). The newest pleiocene layers consist of alternations of both coarse grains materials (pebbles, gravel, sand, horizons) and fine materials (sludges, clays, marls with crocodile lenses, gravel and sand). The thickness of the neogene sediments is 800 m.

The group of Quaternary deposits grows in the central, lowland area of the basin of Serres. It consists of coarse grains materials (pebbles, gravels, sands) in the periphery and fine particles (sands, sludges, clays) in the central zone. These are sedimentary materials, products of erosion and erosion of the rocks of the mountainous masses and erosion of the old sedimentary deposits (neogeneous, quaternary) of the margins of the basin of Serres. These sheds were transferred from a dense network of lateral streams and torrents leading to the Strymon River to the central lowland area of the basin. Coarse grains materials were deposited, mainly in the periphery, where the torrents left the mountain valleys and entered the lowland area. Many small and complex alluvial ridges, with tongue-shaped protrusions towards the center of the Serres plain, have created a peripheral zone of considerable thickness and width, which favors for aquifer.

Of particular significance are the deposits of the rifts, in the northern marginal zone, at the foot of Mount Kerkini at the entrance of Strymonas in the plain area (Sidirokastro – Iraklia). Less hydrogeological significance has these deposits, in the southern marginal zone, in the Nigrita region, in certain positions of the submarines of mount Menikio . The fine materials were deposited in the central section of Serres plain, on either side of the Strymon's meander zone. In this zone, the floods and the presence of the lake of Achinos, develop a zone of limestones. Limestones had been developed in which the finely sludge materials of the sludges and clays were mixed with organic materials. These materials have created a thick system of practically impervious layers. Within this system are inserted sand lenses, which favor the development of local underground water supply. The largest thickness of fines, predominantly sediments, is located in the area where the lake of Achinos was located before being dried. The total thickness of the Quaternary deposits at the basin of Serres is estimated to exceed 400 m in the center of the lowland zone and it is reduced to 150-200 m in the marginal zone. Their surface spread is estimated at about 600 km^2.

In the northern area of the basin, Quaternary deposits are developed throughout the lowland zone, while in the southern area they are confined to the wider area of the old Meadershire zone of the River Strymon and the lake of Achinos.

2.5 Hydrogeological Conditions

Groundwater body included in this basin and associated with surface water is:

- GR1100010 Serres System.

This underground system, which extends to the development of neogen and quaternary deposits, is estimated to receive an average annual volume of about 350 million m³ of water.

In general, we can make the following assessments for the hydrogeology of the rocks of the Serres basin:

- In the E/NE department, the presence of marbles creates the conditions for the development of a significant potential for karstic aquifer, which contributes both to note numerous of sources.
- In the W/SW division, the dominance of shale-gnosis-ambivalence, creates the conditions for surface drainage and drainage of surface water in Strymon basin.

The absence of significant sources characterizes the above development. The tectonic fragmentation of all background rocks has created the conditions for the development of secondary porosity and the creation of local underground aquifers. These zones are either discharged surface by springs or feed the aquifers of the sedimentary deposits of the basin via lateral transfusions.

2.6 Neogenic sediments

From the neogeneous sediments, the pleiocene, occupy the lowest points of the hilly area and form the background of the quaternary deposits. The newest pleiocene layers consist of alternations of both coarse grains materials (pebbles, gravel, sands) and finely divided materials (sludges, clays, marls, gravel and sand lenses). This mixture of materials of different granulator and therefore permeability, in both cases, significantly reduces the total porosity and permeability of sediments, and thus also the development of a remarkable and unified potential of groundwater. For this reason, the group of pleiocene deposits is poorer in underground waters than the quaternary deposits group. Borehole yields, particularly in the eastern part, which have been severely cracked by such neogenous materials, with a low deposition of quaternary material, are limited. In those cases where the coarse pleiocene layers of the basin are at or below the basic level of flow of the river, they occupy significant aquifers in the conglomerates and sandstones due to their supply from the surface runoff.

The oldest neogeneous sediment of the mallow, grows in the upper regions of the hilly relief of the basin and is composed in the upper layers mainly of deposits of fine clay sludge, limestone, sandstone or conglomerate lenses, and in the deeper layers, chondrocyte material (conglomerate - sandstone - sandstone). These sediments have limited potential for underground water development, both because of the granulator composition of the material and because of the difficulty of feeding the coarse layers developing higher than the rivers flowing.

2.7 Quaternary deposits

Characteristic of quaternary deposits is the complex structure of their materials depending on their location and distance from the outlets of the torrents and rivers in the lowland zone. The periphery of the basin is dominated by the coarser materials deposited by the rivers in the creation of the alluvial ridges. Most torrents end up, without continuity, in the zone of complex alluvial ridges, where their runoff infiltration takes place. Because of these intense and important infiltrations, surface water primarily feeds underground aquifers. In addition, significant underground aquifers are also supplied via lateral transfusions from the underground aquifers grown in the karstic basins mainly. The major human hydrological interventions in the plain of Serres, caused the inactivation of the role of many alluvial ridges in the main supply of the underground aquifers. The rapid abstraction of surface water on the perimeter of the plain through the drainage ditches does not allow, as in the past, to filter the same quantities of water for the supply of groundwater. Fine materials were deposited in the central section of Serres plain, on either side of the broad metamerical zone of the river Strymon. There, due to repeated flooding and the presence of the lake of Achinos, a zone with a thick central layer system with low porosity and permeability was created. Within this system are discontinuous horizontal horizons or sand lenses, which favor the development of underground under pressure or partially under water pressure. The largest thickness of this system is located in the area where the lake of Achinos was located before being dried up. The exploitation of the underground aquifers of the lowland area, developed in quaternary and neogenous deposits, is carried out through a large number of irrigation and irrigation water wells.

The 1432 recorded irrigation boreholes, with a depth of more than 50 m, are located mainly in the marginal zone of the plain of Serres, where the most valuable aquifers meet. Approximately 300 water wells are grown based on settlements across the lowland area (Figure 3).

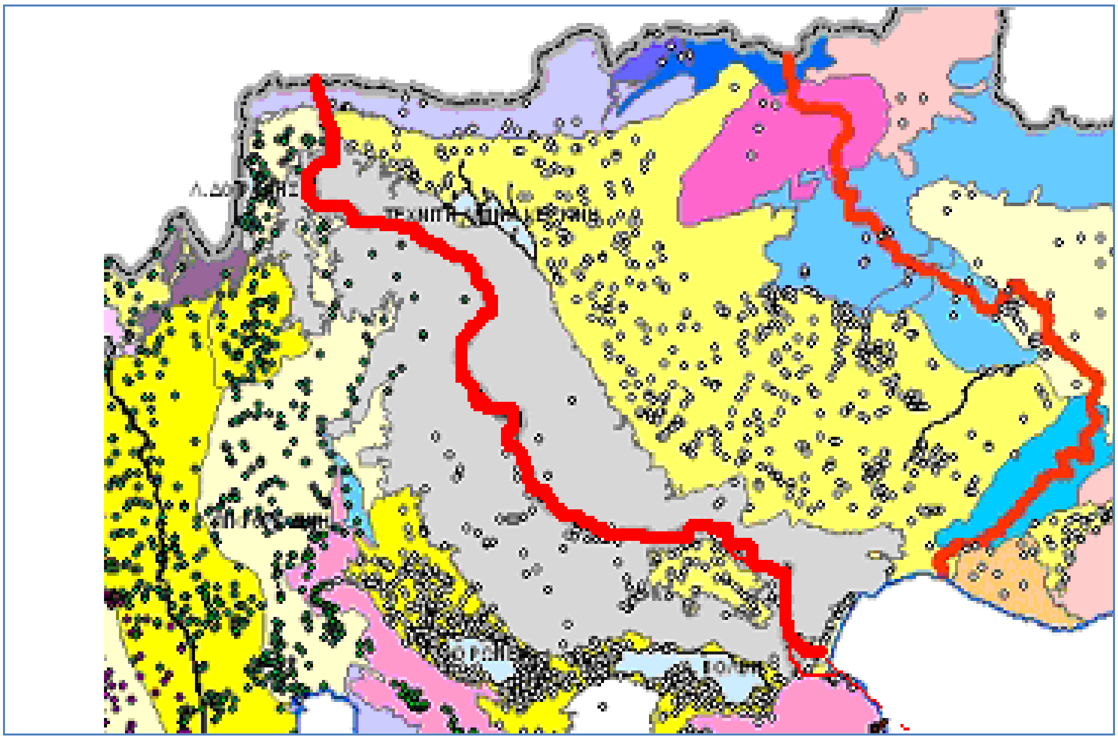

Figure 3. Map with the drilling census (IGME, Veranis, 2008). (The Strymon basin develops within the red limits and the quaternary deposits are given in yellow)

The distribution of irrigation drillings in the development of the lowland area of the basin is indicative of the dynamics of the underground aquifers in the area. The small number of drillings in the western part, placed in the small alluvial ridges or adjacent to the surface runways, suggest the absence of extensive, high-potential, underground aquifers both because of the nature of the materials (fine particles) and the unfavorable feeding conditions. On the contrary, in the eastern part of the plain, there is a number of depth drillings of more than 50 m, due to the high potential of underground aquifers that are associated with both the presence of coarse material and lateral transfers from the karst aquifer of the mountain zone.

The limited number of boreholes in the NW, N, NE low basin area is due to the satisfaction of the irrigation needs there, from the existing irrigation network of Lake Kerkini and the river Strymon. Based on existing piezometric maps in the region (Figure 4), south of the Serres town, where a higher drilling density is observed, the underground aquifer image of the low zone is visible from the lateral transfusions of the underground aquifers. The small, also dropping level between dry and wet period, confirms the continuous lateral feeding of the Northeastern and Quaternary aquifers from the growing karst limestones.

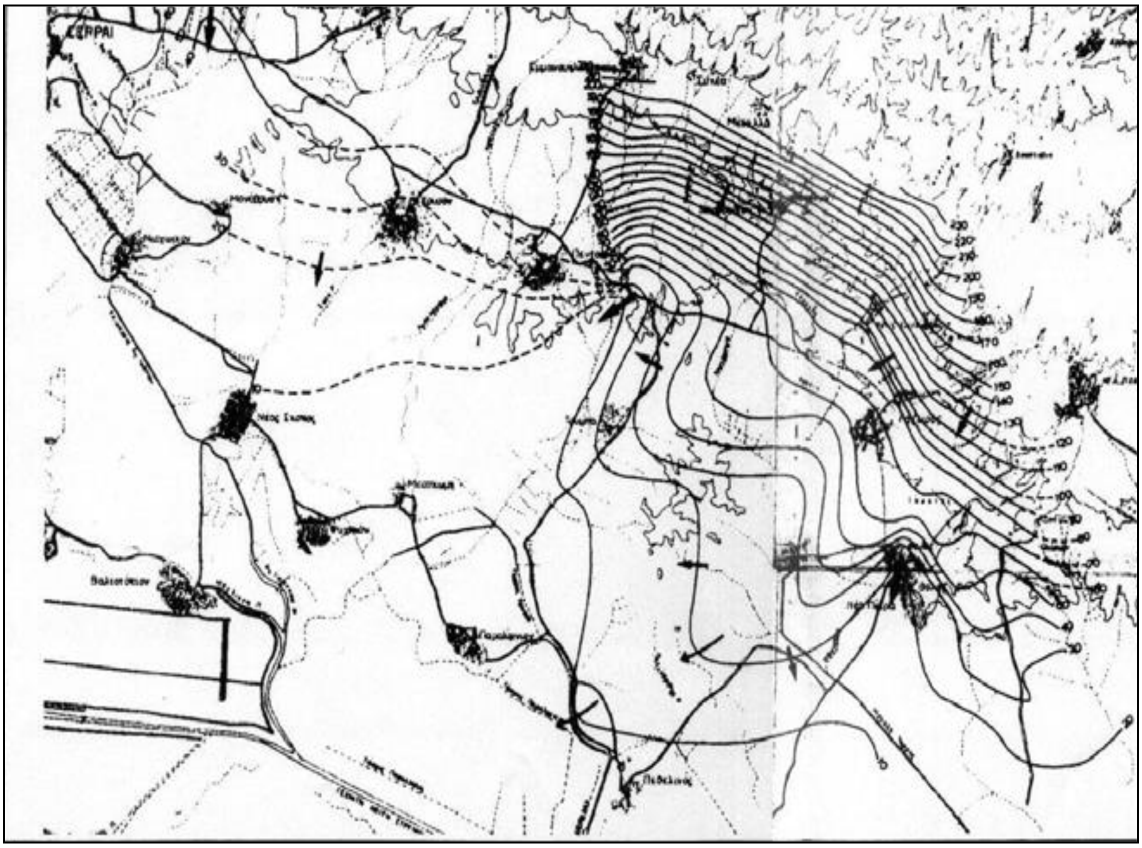

Figure 4. Piezometric map of the southern city of Serres , (Lazaridou et al., 2001).

In conclusion, we can make the following assessments of the hydrogeological conditions of the basin deposition system of Serres.

In the Quaternary deposits and especially in the chondrocytes of the alluvial ridges of the plains of the lowland area, the main aquifers in the area develop. These deposits in the northern part of the basin of considerable thickness

In general, the aquifer of the basin of Serres, according to the management plans of the Ministry of Environment and Waters, is: *The underground water system of Serres*. It is an alluvial aquifer located in the drainage basin of the River Strymon. It has an area of 2253.46 km², a maximum length of 100 km, a maximum width of 35 km and a thickness ranging from 10 to 120 m. Surface water is associated with the River Strymon, River Agitis and Lake Kerkini.

2.8 Borehole Network

Water level measurements

The sampling points of the underground aquifers in the Serres basin were selected based on the type of aquifers (alluvial, neogeneous, etc.), the degree of their influence on the surface waterways (filtrates) and the lateral transfusions from the mountain mass. Consequently, the largest number of sampling points is close to the surface flow axes and in areas where the underground aquifers receive intense lateral water supply. In the central part of the basin, which includes Stymon's old meandrisms and various drainage canals, the underground waters are mainly discharged to the river and drainage network. In basin nine (9) suitable locations (Figure 5) for the composition of the substation fluctuation monitoring network, the spatial distribution of which is considered sufficient to answer the questions concerning the underground supply, have been identified in the basin of Serres.

The group of boreholes 94, 95, 96 is located to the east in the neogeneous deposits, water supply by lateral transfusions of the karstic system of mount Menikio. They are characterized by average depth and the level variation is 3.0 m – 4.25 m (Table 1), depending on its position with respect to the underground selective feed water supply, thus indicating the relative rapid refueling of the these underground transfusions (Figure 5).

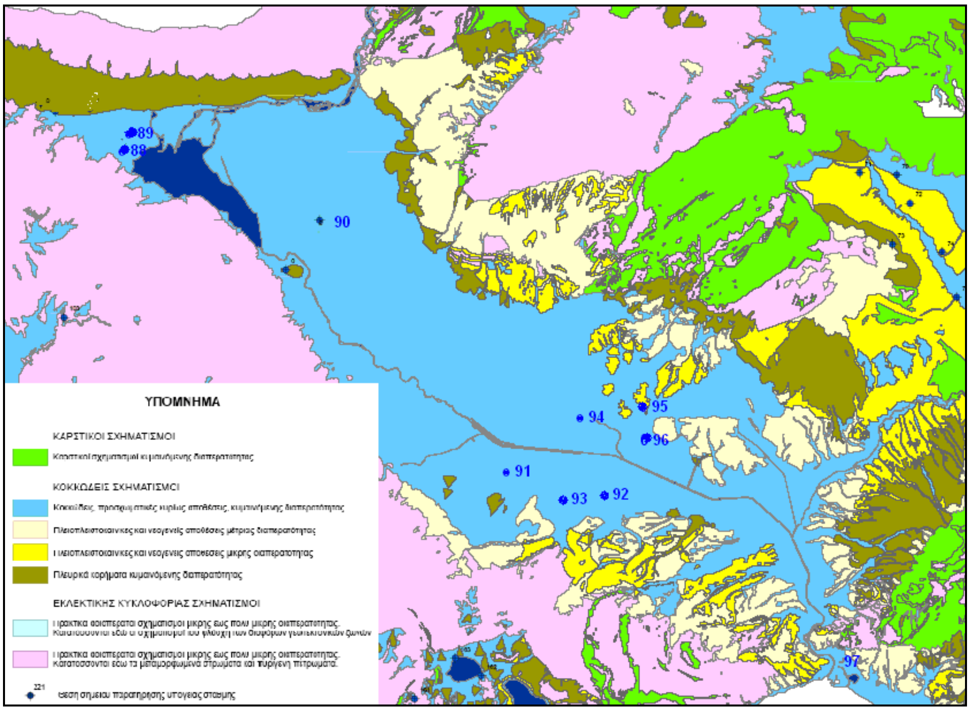

Figure 5. Hydrogeological map of Water Body no11 - Strymonas basin with the points of measurement of the level (from data of this study in combination with data from the Managing Studies of Ministry of Environmental and Energy).

The boreholes 91, 92 and 93 have been drilled in the southern deposits of south Strymonas, which are made up of classical sedimentary formations (loose conglomerates, alluvial ripples, alternating with layers of clay). The formulations have varying permeability depending on the development of the active porosity in combination with the presence of aluminate horizons. Boreholes no91 and no92, showing a relatively low level drop, up to 3.0m, between the two high-low level measurement periods (high-low - Table 1), water supply by aquifers with increased relative permeability, in related to water supply of borehole no93. Borehole no93 has been drilled into the same above-mentioned stratified sedimentary rocks, at a higher altitude with reduced permeability, relative to water supply of boreholes no91 and no92, resulting in low water table level with level between the two periods of around 8.16m. This suggests a generally weak side feed from the rocks of the area. Borehole no90 is located east of the southern part of Lake Kerkini, almost at the central point of the sediment of the plain. The lack of surface drainage in the area and hence continuous water supply, is shown by the great difference in level between the two periods. Finally, the drilling 97 is located in the last part of the basin, just before the exit to the Strymonikos bay, characterized by the direct feeding of the Strymonian waters due to its high level and very small variation.

Table 1. Water level of observations boreholes (combine with Figure 5)

Borehole number	Elevation (m)	Water level (m)	
		5th 2011	5th 2012
88	81	6.35	6.12
89	162	61.38	67.32
90	33	1.9	1.85
91	24	13.25	12.47
92	41	4.09	5.36
93	81	43.52	49.12
94	13	20.86	24.4
95	75	14.39	13.21
96	40	15.65	13.98
97	7	0.43	0.42

During the winter period, many of the abandoned drains of the hydrographic system drain the high-level water wells by transferring water to the settled ditches in the lower areas they have been cut off.

It appears that surface run-offs (rivers, streams) continuously feed the underground aquifer. Exceptions include some low southern regions, at the time of the high groundwater level, where groundwater is discharged into the settled ditches through the old cut-off riverbeds.

3. Characteristics of the selected area

3.1 Location of TEICM campus (Serres)

The city of Serres is located almost at equal distance from Thessaloniki, Kavala and Petrich (Greece-Bulgaria borders) as presented in Figure 6. The selected site of TEICM campus is located at the southern part of the city of Serres, next to the city Ring Road (Figure 7). The selection of the site is convenient since it fulfils the selection criteria presented in the first section of Deliverable 4.3.1 and, at the same time, is the base of one of the GREEN PUMP project beneficiaries (TEICM).

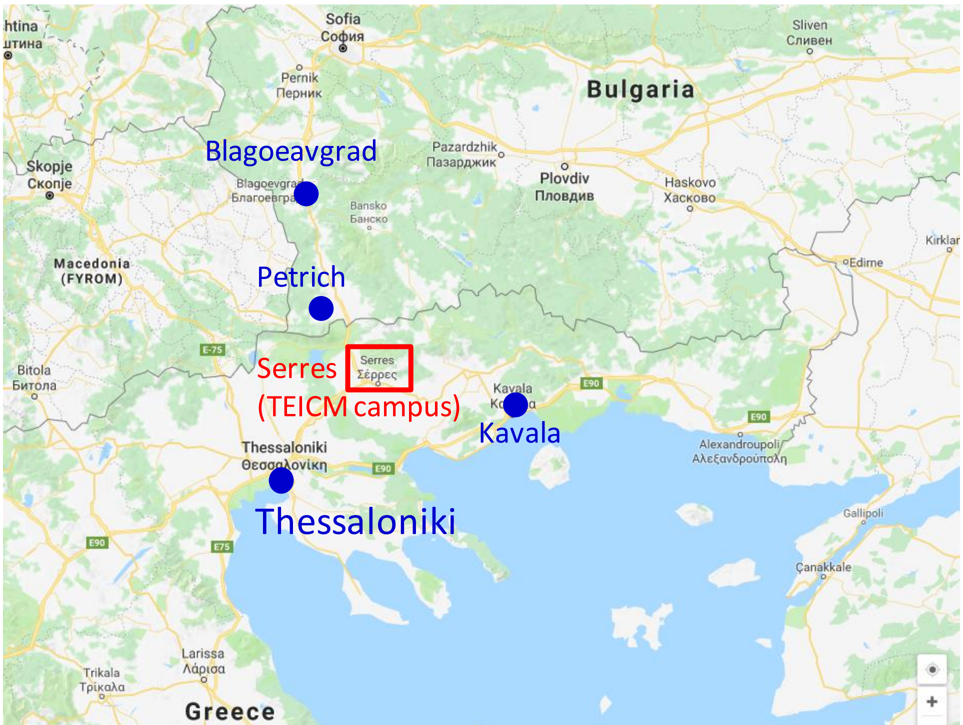

Figure 6. Location on map of the selected study area in Serres (TEICM contribution). Cities of the other project beneficiaries are highlighted as well.

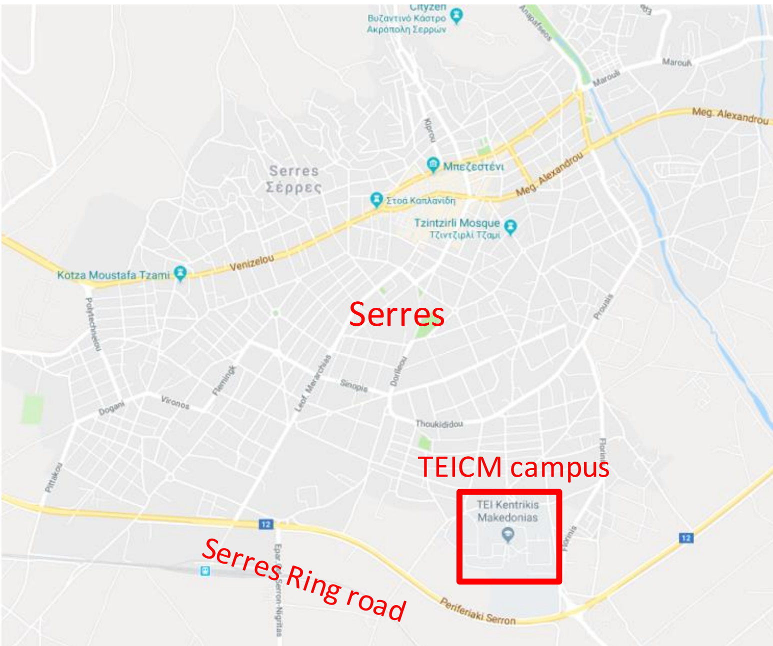

Figure 7. Location on map of TEICM campus, at the southern part of Serres city near the Ring Road.

3.2 Existing water table level data in the broader area

One of the basic criteria for the site selection is the shallow depth of the aquifer. Existing measurements near TEICM site verify that the water table depth is located at shallow depth in the broader area of the northern part of the city of Serres.

More specifically, water table depth monitoring from Egnatia Odos SA, during the preliminary stage of the study concerning the upgrade of Serres Ring Road, involved boreholes located very close to TEICM premises (from N17 to N22 in Figure 8). A synopsis of the measurements is presented in Table 2. A first evaluation of Table 2 values reveal a shallow water table depth in the broader area. This data is confirmed by specific observations in the basements of TEICM campus as will be presented in the next paragraphs.

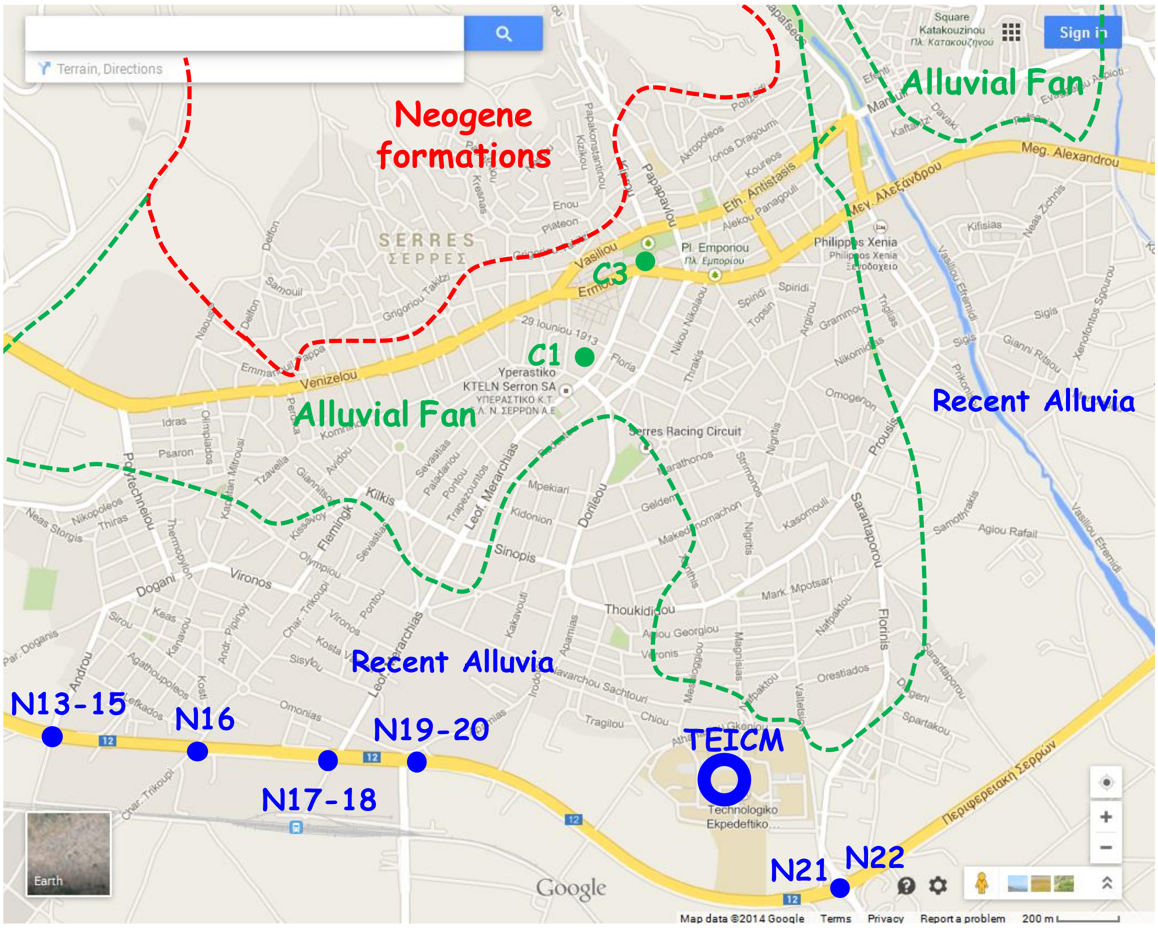

Figure 8. Position of existing geotechnical data (modified after Kirtas et al, 2016).

Table 2. Water table level from measurements in Egnatia Odos SA boreholes (combine with Figure 8) (data retrieved from GEOT.ER. 2013)

Borehole number	Borehole depth (m)	Water level monitoring (m)	
		Min	Max
N17	39.95	1.50	2.50
N18	40.05	1.50	2.50
N19	40.25	0.70	3.91
N20	45.35	1.55	5.80
N21	40.25	2.13	3.67
N22	45.25	0.62	5.10

4. Underground water in TEICM campus

As the aforementioned measurement data concerning the shallow depth of the aquifer suggest, underground water has made its presence felt in the campus buildings of TEICM, as presented in the following paragraphs.

4.1 Flooding events in the buildings of TEICM campus

Flooding incidents are quite often at the basements of several buildings in TEICM campus. Taking into consideration that the basement level is approximately 3m below the soil surface, recorded data of water table depth in the broader area (Table 2) suggest that underground water could be above the basement level at several occasions.

Indeed, photos of the discolored basement floor indicate the previous presence of stagnant water as can be easily observed in Figure 9. Moreover, in several parts of the basements, a thick layer of dirt/soil is visible near objects that were not moved after the last flooding events (Figure 10).

Even during the last few months, after the GREEN PUMP project has started, flooding of basements with teaching rooms, laboratory facilities and storage of expensive equipment has taken place (Figure 11 and Figure 12). It is quite obvious that these situations may disrupt the educational procedure and endanger expensive property of the institution.

Figure 9. Discolored floor slab indicates the previous presence of stagnant water.

Figure 10. A thick layer of dirt/soil is visible near objects that were not moved after flooding events.

Figure 11. Flooding of teaching rooms or laboratories may disrupt educational procedure and endanger expensive equipment.

Figure 12. Flooding at basement level (hallway of building).

4.2 Existing pumps in TEICM campus

The common approach to prevent flooding events from shallow water table is to use water pumps permanently installed below the basement level and operating, if required, at 24 hour basis. A built-in mechanism detects abnormal depth of the underground water and triggers the pump to remove excessive water quantities (details and operation status measurements are presented in Deliverable 4.3.2).

The extent of the underground water problems in the campus of TEICM required a large number of installed water pumps, more than 40, at the basements of the various buildings and other installations (Figure 13). It should be mentioned that in some installations of Figure 13 it was not possible to visualize the location of all existing pumps, e.g. in the Ceremony Hall (no. 12) a total number of 12 pumps have been installed, scattered at suitable positions in the large basement of the building.

In most cases the pumps are installed in properly constructed manhole size wells, near power supply to facilitate the pump operation (Figure 14). A protective cover is placed on the top of the installation construction to prevent accidents as well as garbage or small animals entering the well and disrupting the pump operation. The underground water level is only a few centimeters below the basement level, as can be clearly observed in Figure 15 and Figure 16.

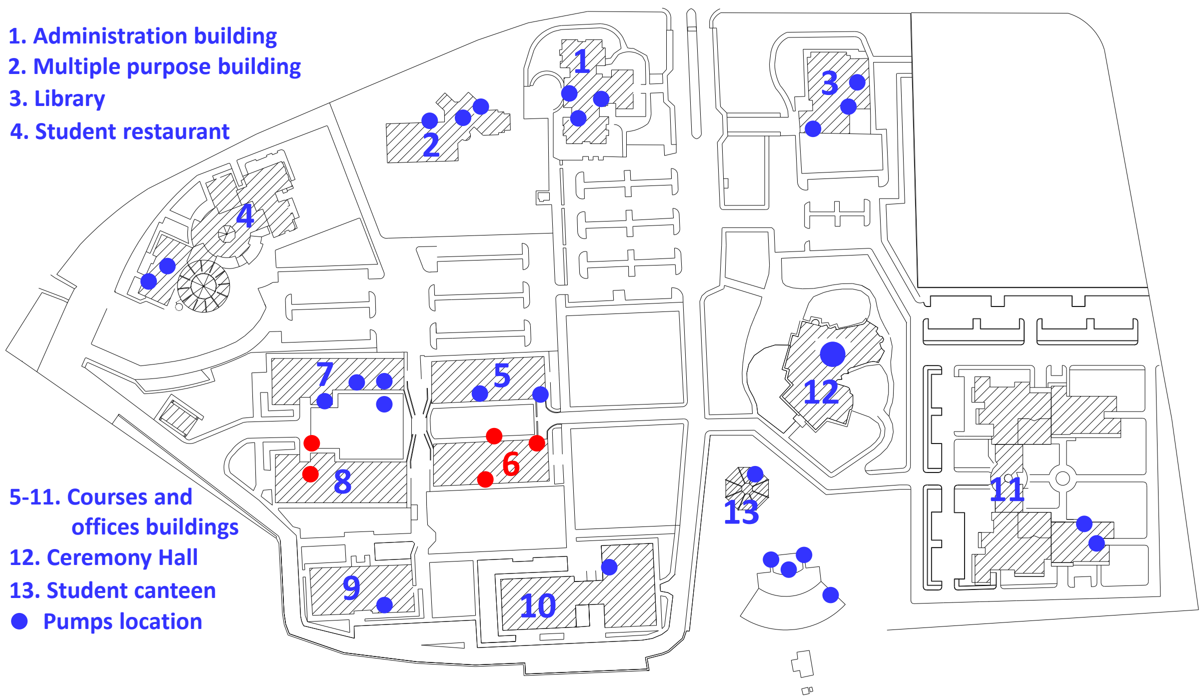

Figure 13. Location of existing water pumps in TEICM campus (monitored pumps in the framework of GREEN PUMP project are highlighted in red color).

Figure 14. Water pumps are located inside manhole size wells, near power supply, at basement level (Building B - number 6 of Figure 13).

Figure 15. Water table level depth is only a few centimeters below the basement level (Building B - number 6 of Figure 13).

Figure 16. Water table level depth is only a few centimeters below the basement level (Ceremony Hall basement - building number 12 of Figure 13).

5. Selection of specific building for the studies

5.1 Selection based on proposed criteria (related also to Deliverable 4.3.3)

The main criterion for selecting a specific building in TEICM campus for the studies was to present a continuous operation from a large number of students, which would be representative of other University buildings and demanding in terms of heat and water requirements. Buildings such as the Ceremony Hall do not comply with those conditions since they only present an occasional use on specific events. On the other hand, buildings that host teaching rooms and laboratories are ideal since a large number of students and teaching staff is present for many hours during the day.

Based on the above, the Building B is selected for the studies of the present project (Figure 17, Figure 18 and Figure 19). As presented in detail in Deliverable 4.3.3, this building has 3 stories and a basement and contains in total 21 classrooms, 4 of which amphitheatrical (e.g. Figure 20), serving each day several hundreds of students. Additional teaching rooms, nowadays used mainly as storage and student recreation areas, are also present in the basement of the building. Approximate dimensions of the building in plan are 55m length and 20m width.

With respect to the given selection criteria, Building B has faced several problems in the past due to the shallow water table. Three water pumps installed at the basement level (red dots of Building number 6 in Figure 6) reduce significantly any flooding risk, unless random malfunction of one of pumps leads to surface appearance of ground water locally. Indicative photos of the Building B pumps have been presented in Figure 14 and Figure 15, whereas the position of each pump in the plan view of the basement is given in Figure 21.

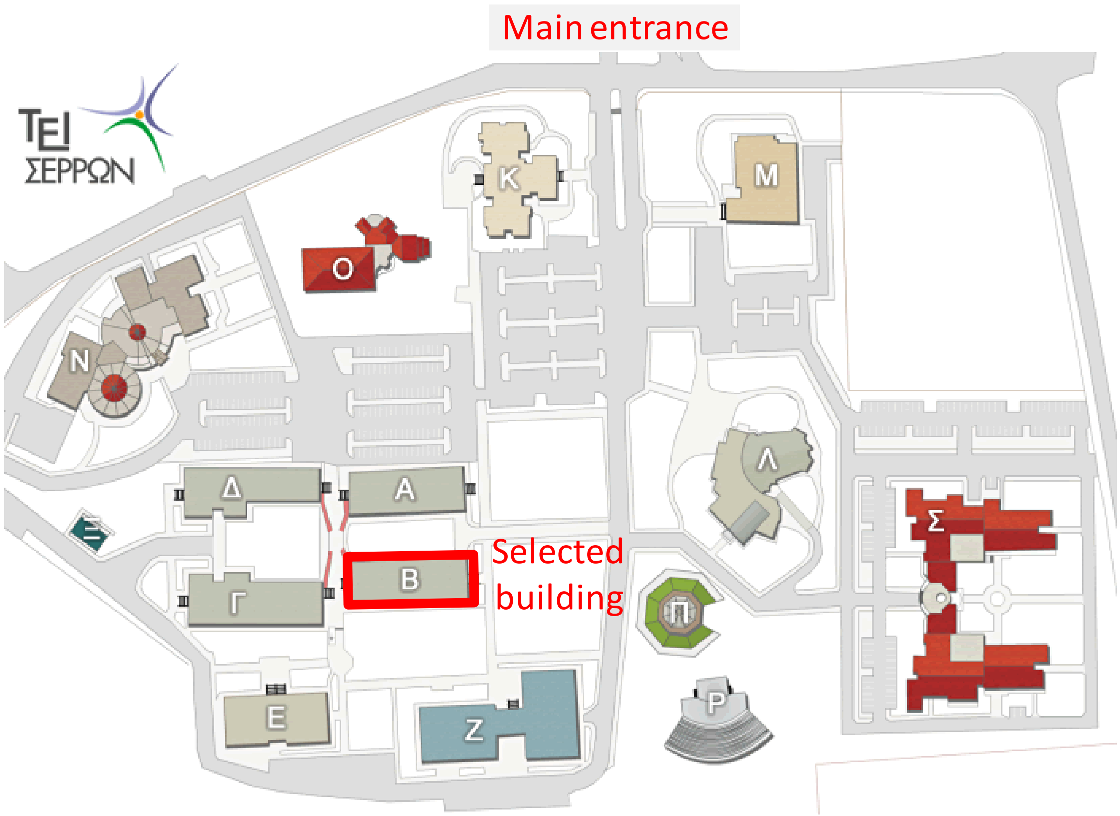

Figure 17. Building B is selected for the studies in GREEN PUMP project.

Figure 18. Front and north side view of selected Building B for the studies.

Figure 19. Rear and south side view of selected Building B for the studies.

Figure 20. Teaching room (amphitheatrical) on the 3rd floor of Building B.

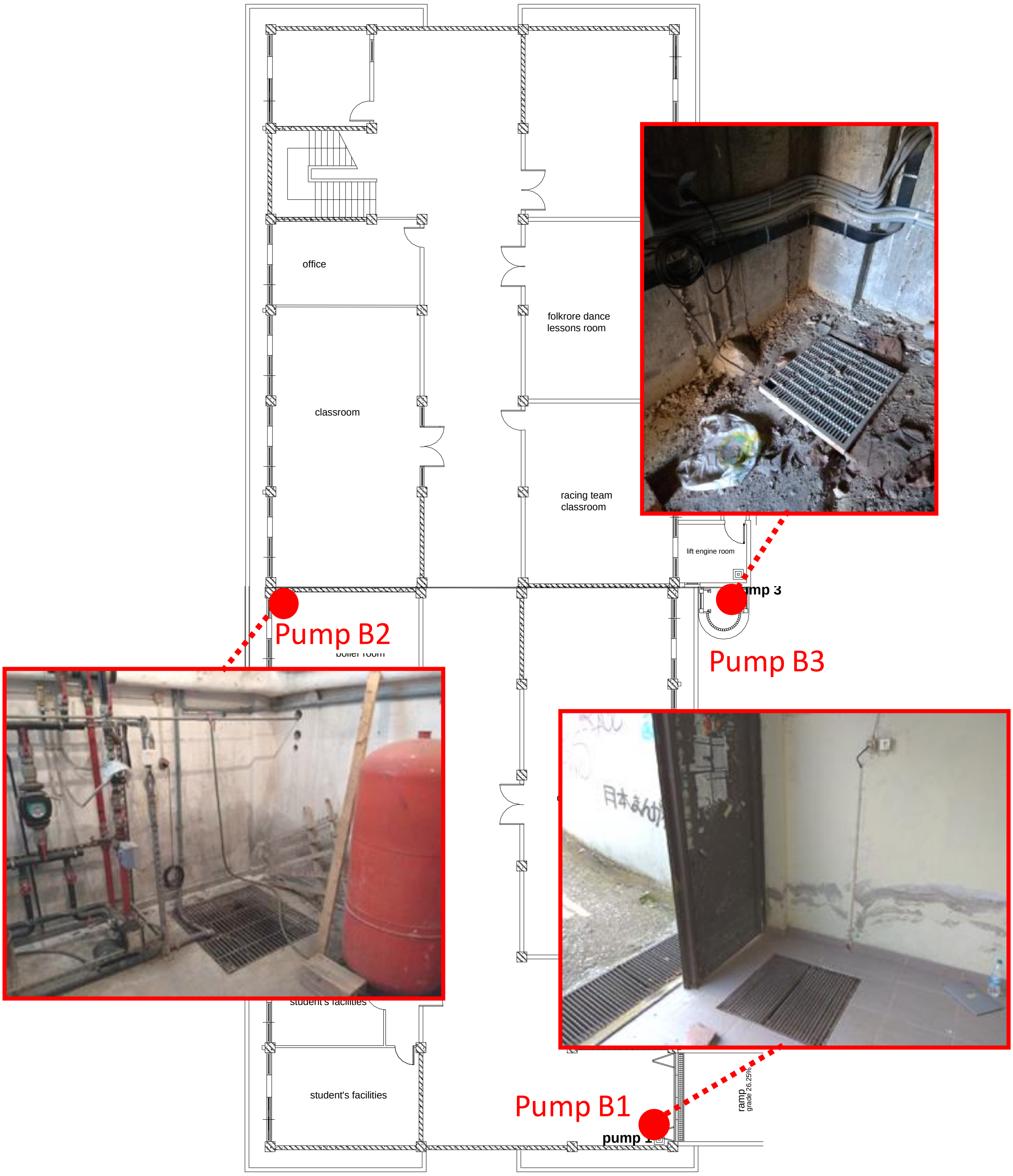

Figure 21. Position of existing water pumps at the basement level of Building B (Pump B1 near the ramp entrance, Pump B2 inside the boiler room and Pump B3 under the elevator).

The toilets of the building are concentrated to the two edges of each floor (except the basement) at the corners of the building (top left and bottom right corners of the plan view). Heating of Building B is currently based on a central heating system with an oil boiler and an oil storage tank placed at the basement of the building. Piping from the oil boiler to the radiators in each classroom is visible (Figure 22) and installed in a way that does not allow separate heating of selected building areas.

The last 3rd floor of the building was built in a different construction period, several years after the first two stories, using different materials. Thus, the heating system of the 3rd floor does not contain radiators but it uses a central air distribution system for heating of the classrooms (Figure 23) and fan coils for the offices (Figure 24). Yet, this system is also based on the oil boiler.

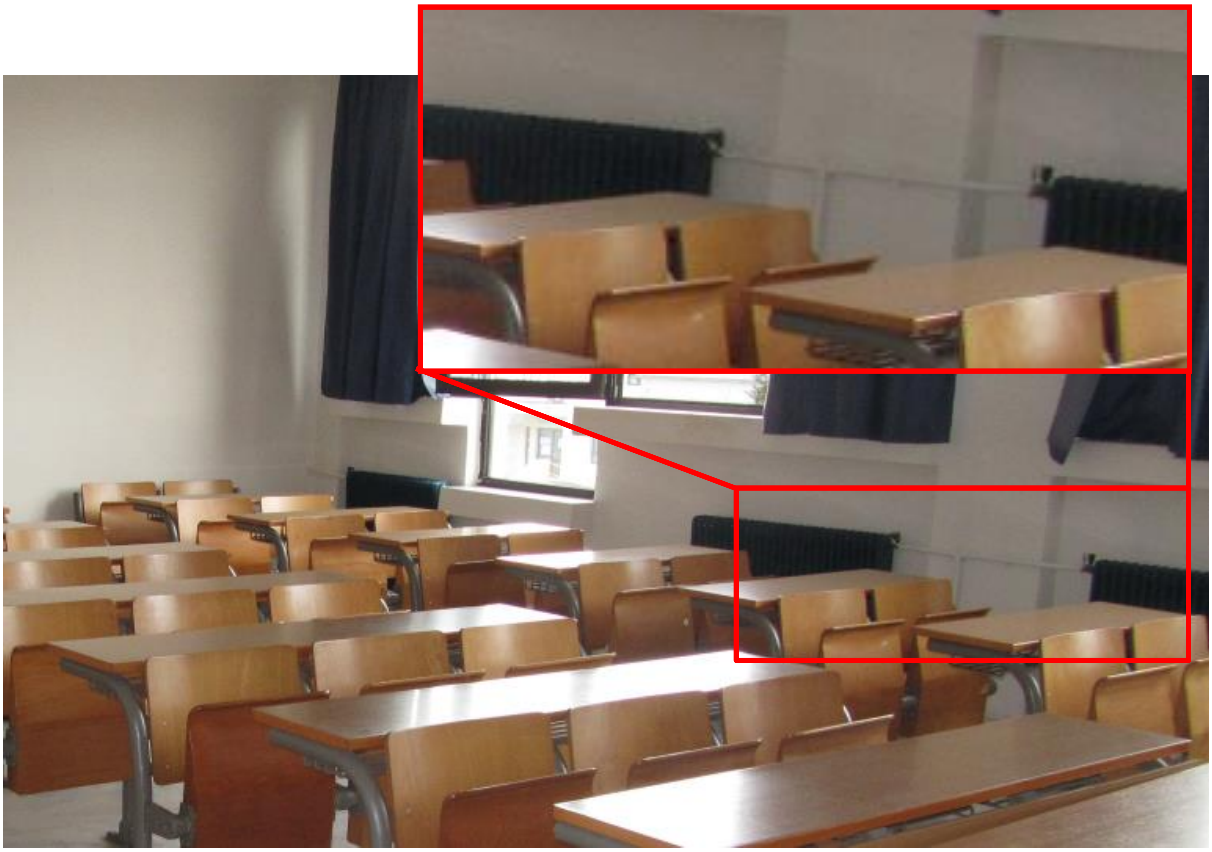

Figure 22. Radiators as part of the central heating system of Building B (piping is visible).

Figure 23. Central air distribution system for classrooms of the 3rd floor.

Figure 24. Fan coil units for heating of the 3rd floor offices.

The selected Building B is identical to Building A of the TEICM campus (number 5 in Figure 13 or Building A in Figure 17). This can be easily observed from the aerial view of Figure 25 and Figure 26 and is verified by the technical services of the Institution. Therefore, not only the building is representative of the characteristics of similar buildings in other Institutions, but any study concerning it is actually directly applicable to another building of the same campus.

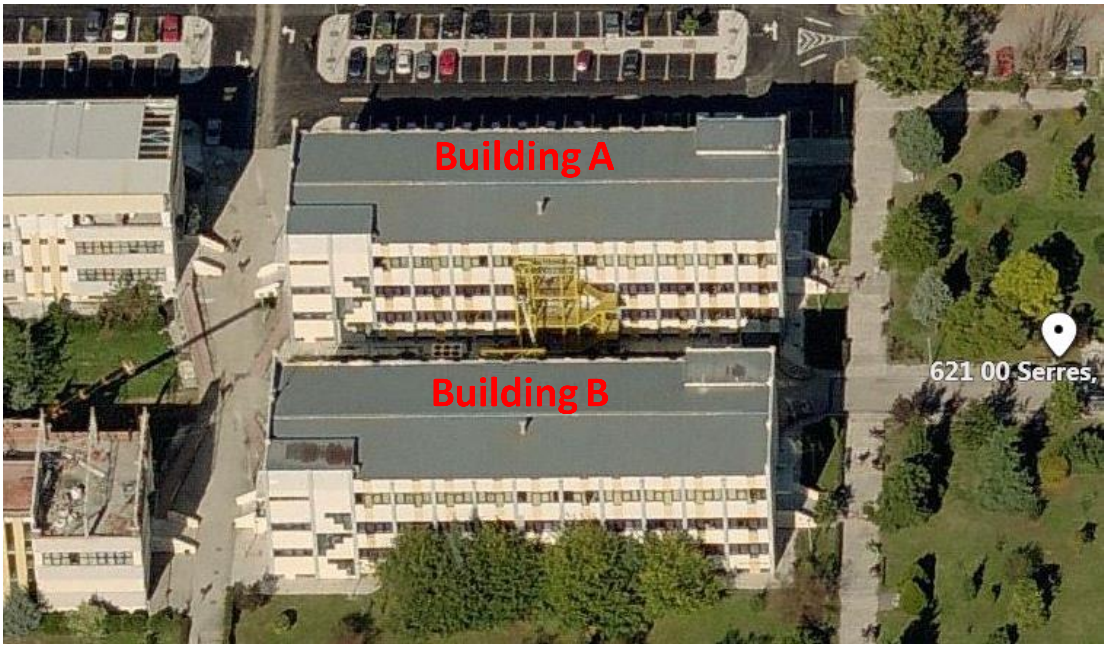

Figure 25. Aerial view of Building B and identical Building A (from South) (www.bing.com/maps).

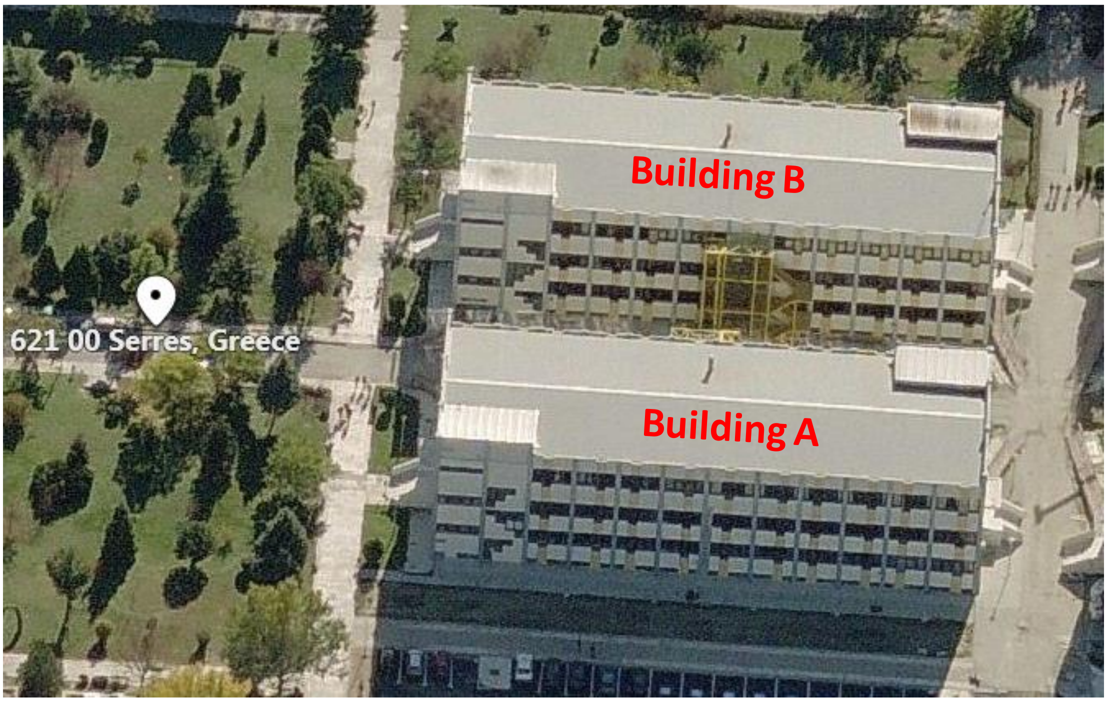

Figure 26. Aerial view of Building B and identical Building A (from North) (www.bing.com/maps).

6. Estimation of water demands for the examined Building B

The water demand for toilet flushing in Building B does not follow the usual calculation assumptions of residential buildings, due to several peculiarities when considering a building that hosts educational activities for higher education level. Therefore, in the following paragraphs, a procedure is described based on simplified assumptions to estimate the required water quantity.

6.1 Approximation of serviced people

The number of people using the toilet facilities will be estimated considering a time period during the semester with full educational activities. Building B is used for lessons of 3 different Departments, whereas, some of the available classrooms are also used from time to time by other Departments as well. However, it should be noted that several more buildings are also used for some courses or other educational activities of these Departments, therefore Building B does not bear the full burden of hosting the courses for all involved students at the same time.

Classrooms at each floor can facilitate attendance of approximately 400 students. Observation of classrooms utilization and students attendance during the last few years yields the following approximation of students presence in Building B:

- Mean values: Approximately 30% of the classrooms are used simultaneously, with a mean occupancy rate of 60%. It should be mentioned that the mean number considers also hours where minimum use of the classrooms takes place during the day, e.g. near lunch hours or late at the afternoon.
- Peak values: 80% of the classrooms are used simultaneously, with a mean occupancy rate of 50%. Although this estimation may not describe the absolute maximum floor occupancy, one should consider that it refers to all 3 floors of the building simultaneously.

Based on the aforementioned observations, the mean number of people being simultaneously present in each floor can be approximated to 80 students, considering that this is valid for 10 hours per day. On the other hand, the peak value at a specific floor can reach up to 160 students present for specific time intervals.

6.2 Technical data concerning the water demand

In order to approximate the water demand for toilet flushing, an estimation of the water quantity required per flushing should be made, based on available data of the existing flushing mechanisms as well as available market options in case of mechanism replacement in the future .

The present state of the toilets in Building B comprises of simple, single type, flushing mechanisms (Figure 27 on the left). On the other hand, when replacement takes place in the future, more advanced options using a dual (2 compartments) flushing mechanism could be selected, to conserve water when excess water amount is not required (right side of Figure 27).

Figure 27. Flushing mechanisms with single water compartment (left) and dual mechanism – dual button (right).

The water amount used for simple, single-type mechanisms is usually between 6 to 9 liters. The water quantity can be reduced to desired limits using some simple everyday techniques (e.g. insert another object inside the water compartment).

On the other hand, when dual mechanisms are used, typical water amount values are 4.5lt/9lt, 3lt/6lt, or 3lt/9lt.

6.3 Water demand calculation

In order to calculate the water demand for toilet flushing, several scenarios should be considered. In this section, two cases will be examined:

- Mean water demand calculation, based on mean people number at the building.
- Peak water demand calculation at specific short time intervals (e.g. during classroom break).

Mean water demand calculation per day

Considering the mean number of 80 students per floor for 10 hours every day, a simplified estimation could be based on the following assumptions:

- Each student will be present at the specific building for 3 to 4 hours per day. Therefore, a number of 240 different students will be present at each floor on a daily basis.
- Each student will need to use once the toilet facilities during his/hers 3-4 hour stay in the building (this estimation is rather on the conservative side since only a few students will go twice to the toilet but many others may not use it at all).
- A mean water quantity of 4 liters is considered per use.
- Educational activities take place on all three (3) floors of the building.

Based on those assumptions, a simplified calculation can lead to the following mean water demand per day:

$$V_w = Floors \cdot Students \cdot No.\ flushes \cdot Water\ per.flush$$
$$V_w = 3 \cdot 240 \cdot 1 \cdot 4lt = 2880lt \quad \textbf{Eq. 1}$$

Considering the approximately 10 hours of building utilization during the day, the calculations yield a demand of 288lt/hour for toilet flushing for the whole building. Of course, if the number of estimated mean toilet visits per student is considered e.g. 0.5, since many people tend to avoid public toilets for hygiene reasons, the aforementioned amount drops to 1440lt per day or 144lt/hour.

Peak water demand calculation per day

Considering the peak number of 160 students per floor for specific time intervals, a simplified estimation could be based on the following assumptions:

- An approximate 20% percentage of those students would like to use the toilet during one lesson break.

- A mean water quantity of 4 liters is considered per use.
- Educational activities take place on all three (3) floors of the building.

Based on those assumptions, a simplified calculation can lead to the following peak water demand at some specific time intervals during the day:

$$V_w = Floors \cdot Students\ using\ toilet \cdot Water\ per.flush$$
$$V_w = 3 \cdot (20\% \cdot 160) \cdot 4lt = 384lt \qquad \textbf{Eq. 2}$$

The calculated water demand of 384lt during a 15 minute break should be considered as an absolute peak. It should also be mentioned, that one toilet (per gender) using the conventional water distribution network will still exist on each floor for security reasons, to cover excessive demand and function as a failsafe in case of power disruption or other reasons that may cause failure to the secondary water distribution system. Therefore, the secondary water system is not necessarily required to be designed in a way that covers the peak water demand calculated above.

Water demand calculation conclusions

The proposed design that will be described in Deliverable 4.7.3 (former 4.3.3), includes a water tank at the basement level to supply the secondary water network. Based on the water demand calculations in the previous sections, a maximum amount of 2880lt will be required per day. The tank capacity will be selected after careful review of those calculations, to ensure that tank reserves will be sufficient.

7. Estimation of energy demand (heating) for the examined Building

The estimation of the energy demand for the heating requirements of Building B is presented in detail in Deliverable 7.3.3 (former 4.3.3), as part of the pilot study of heating system based on shallow geothermal energy. The following sections present a summary of the data related to the estimation of the aforementioned energy demand.

7.1 Determination of serviced areas

In order to estimate the energy demands for heating of the examined Building B, it is necessary to determine the properties of the building rooms that affect the heating requirements, such as the area and volume of each room as well as the respective heat loss features (exterior walls, structural elements, doors and windows, roof etc).

To this end, design plans of the structural floors were created and/or updated, whereas detailed recording of the various structural and non-structural elements of the building also took place. The plan view of the 3rd floor of Building B is indicatively presented in Figure 28, whereas drawings of all building floors are presented in the respective Deliverable 7.3.3 (former 4.3.3). In the same trend, both the dimensions and the heat transfer properties of all exterior opening (doors, windows) and exterior structural elements (concrete, brick walls, roof panels etc) have been determined based on in-situ measurements and/or typical values of the examined categories from the literature (Figure 29). Additional details, measurements etc, can be found in the respective Deliverable.

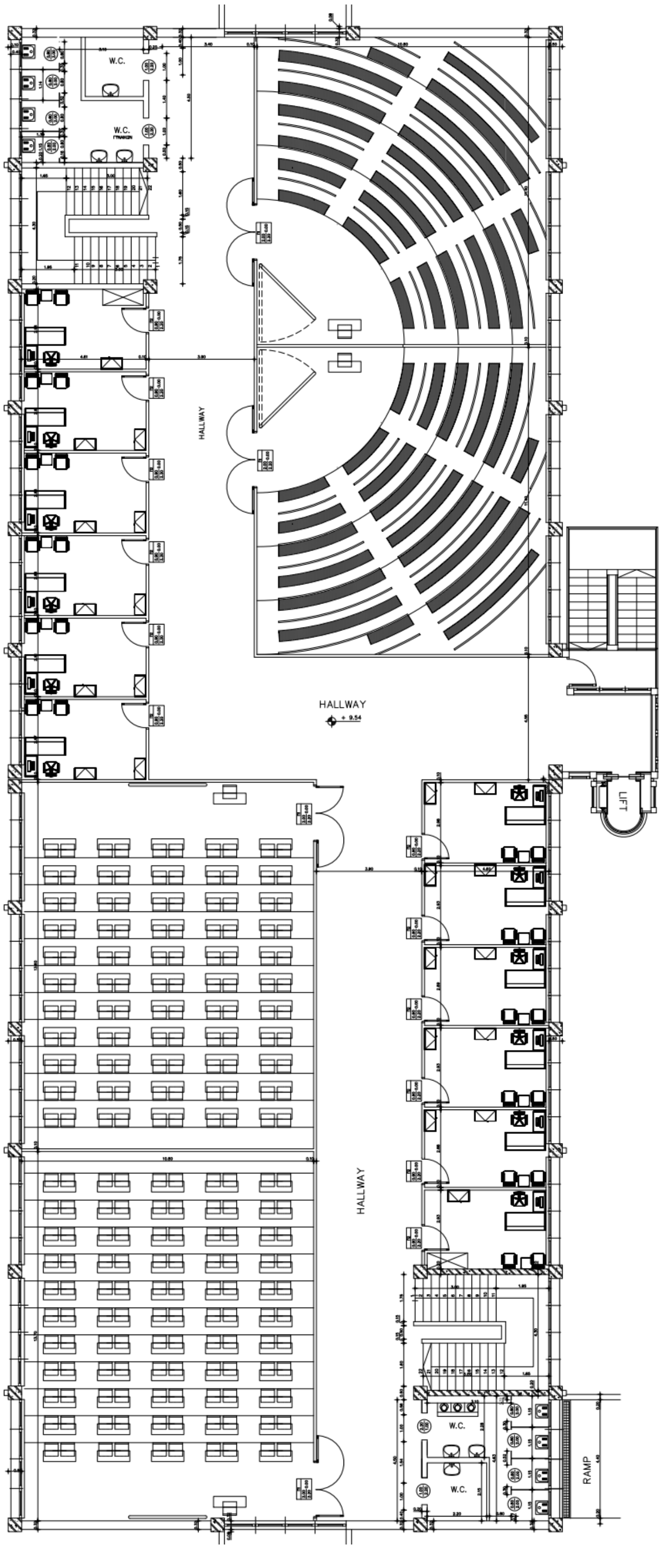

Figure 28. 3rd floor of Building B (detailed plan of all building floors are included in the respective Deliverable).

Figure 29. The dimensions and heat transfer properties of all opening (doors, windows) have been determined.

7.2 Estimation of heat losses/energy demand

The combination of the heat transfer properties and the area of each individual element (wall, window etc) allows for the calculation of the heat losses in each examined room, as indicatively presented for one of the teaching rooms in Table 3 (also presented in Deliverable 7.3.3 – former 4.3.3). The estimation of the total heat losses at building level allows the approximation of the heating demand based on specific assumptions. The detailed presentation of the aforementioned measurements and calculations for all the areas of Building B is given in the Annex of Deliverable 7.3.3 – former 4.3.3 (in Greek).

Table 3. Indicative calculation example of heat losses (Teaching Room 1 – 3rd building floor) (Check respective Deliverable 7.3.3 (former 4.3.3) for symbols/notation)

Area type	Orientation	Subtracted	Thickness	Length (m)	Height or Width (m)	Area (m²)	Area No.	Total area (m²)	Subtracted area	Calc. area (m²)	Coef. k (Watt/m²K)	Temp. difference (°C)	Net Losses (Watt)
T2	N			14.00	3.40	47.60	1	47.60	31.30	16.30	1.1	24.00	430.3
A8	N	A		1.00	1.90	1.90	1	1.90		1.90	3.368	24.00	153.6
A7	N	A		1.00	2.40	2.40	1	2.40		2.40	3.367	24.00	193.9
A6	N	A		2.00	1.90	3.80	1	3.80		3.80	3.350	24.00	305.5
A8	N	A		1.00	1.90	1.90	1	1.90		1.90	3.368	24.00	153.6
A7	N	A		1.00	2.40	2.40	1	2.40		2.40	3.367	24.00	193.9
A6	N	A		2.00	1.90	3.80	1	3.80		3.80	3.350	24.00	305.5
A8	N	A		1.00	1.90	1.90	1	1.90		1.90	3.368	24.00	153.6
A7	N	A		1.00	2.40	2.40	1	2.40		2.40	3.367	24.00	193.9
A6	N	A		2.00	1.90	3.80	1	3.80		3.80	3.350	24.00	305.5
T7	N	A		14.00	0.50	7.00	1	7.00		7.00	1.1	24.00	184.8
T2	A			11.20	3.40	38.08	1	38.08	7.50	30.58	1.1	24.00	807.3
A8	A	A		1.00	1.90	1.90	1	1.90		1.90	3.368	24.00	153.6
T7	A	A		11.20	0.50	5.60	1	5.60		5.60	1.1	24.00	147.8
O1				1	156.5	156.5	1	156.5		156.5	0.9	24.00	3380
Net heat losses value Q_o													**7063**
Heat losses increase due to orientation effects (Z_D)											-5%		
Heat losses increase due to non-continuous operation (Z_H) (since D=7063/(1384*24)=0.21)											20%		
Total heat losses increase (Z_D+Z_H)												15%	**1059**
Heat losses due to air flow through cracks (considering H=0.84, R=0.9 and Z_r=1) Q_L													**1464**
Heat losses due to air ventilation (air exchange) Q_L													**8614**
Total Heat Losses Q_{tot}													**18200**

After measuring the building areas and volumes, the total heat losses of Building B can be estimated as presented in Table 4.

Detailed presentation of the theoretical calculation approach and explanation of the employed symbols is given in Deliverable 7.3.3 (former 4.3.3).

Table 4. Total heat losses of Building B

Level	Heat losses (Watt)
Basement	77447
1st floor (Ground Floor)	68039
2nd Floor	90206
3rd Floor	117456
Total Building Losses	**353148**

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9. References

Altigos N. (1965), "Prefecture of Serres – Hydrology", Ministry of public works

Antonaropoulos, P. (2017) "Review of River Basin Management Plan of Water District of Eastern Macedonia (EL11)’, (in Greek).

Egnatia Odos S.A., http://www.egnatia.eu

Exarchou, Nikolopoulos, Bensasson L., Kourkoulis I., Enviroplan SA, Baltogianni etc (2012), "Development of River Basin Management Plans of the Water Districts of Central and Western Macedonia, according to the requirements of Directive 2000/60 / EC, pursuant to Law 3199/2003 & Presidential Decree 51/2007"

Filippakis N. (1988), "Geological study of strymonas river cachment", Athens

Giannakopoulou E. (2005), "Water balance of the hydrological basin of Strymon (within Greek territory). Comparison of Thorntwait - Mather and Turc Evaporation Method", Dissertation, AUTh

GEOT.ER. Didaskalou S.P. (2013), "Factual Report: Geotechnical investigation on Serres Ring Road", Thessaloniki

Kirtas E., Koliopoulos P.K., Panagopoulos G.K., Mouratidis E.K., Sous I., Kappos A., Theodoulidis N., Savvaidis A., Margaris B., Rovithis E. (2016), "Identification of earthquake ground motion using site effects analysis in the case of Serres city, Greece", International Journal of Civil Engineering and Architecture, vol. 2, no. 1, pp. 20-27

Klithakis M.,Petri E., Lazaridou M. (1988), "Water quality research in Strymonas basin", IGME

Orfanidou E. (2008), "Management of strymonas river cachment", Phd thesis AUTh.

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