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GIS Based Technology Applications and Assessments Related to Geothermal Energy Sites

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Supervisors:
Prof. Paolo Dabove

Prof. Glenda Taddia

Candidate:
Nubar Guney
S274144

TABLE OF CONTENTS

TABLE OF FIGURES

ACRONYMS

GIS: Geographic Information System

QGIS: Geographic Information System Software

GCP: Ground Control Point

GSHP: Ground Source Heat Pumps

℃: Degree Celsius

EU: European Union

CO_2: Carbon Dioxide

H: Thickness

K: Permeability

N/G: Net to Gross

KM: Kilometer

MCDA: Multi Criteria Decision Analysis

P: Pressure

T: Temperature

pH: It Is a Measure How Liquid Is Acidic or Basic

GSHP: Ground Source Heat Pump

GPS: Global Position System

WofE: Weight of Evidence Technique

WGS: World Geodetic System

Ma: Mega Annum / Millions of Years

GCS: Geographic Coordinate System

PCS: Projected Coordinate System

CRS: Coordinate Reference System

2D/3D: 2 Dimensional /3 Dimensional

RES: Renewable Energy Sources

ABSTRACT

Renewable energy is a fundamental measure to change climate reduction. In last decades, Geothermal energy is more preferred than fossil fuels across the world. With this conversion most of countries has planned to ensure their energy needs from renewable resources to enable reduce the negative impacts of nonrenewable fuel source. The objective of this study is to utilize GIS tools to assess, store, visualize and take advantage of the present thermal plants from the point of environmental matters, geologic conditions. Because of complexity and difficulties of spatial relationship, Geographical Information System (GIS) was preferred to perform on installed Geothermal power plants of Turin city of Piedmont region. GIS based on a vast scale use of graphics and provide service to users to display spatial data and understand the spatial samples and relationships between different datasets. The aim of paper was to use GIS system as a planning and monitoring tool for geothermal plants in urban areas, to find out the geological interaction around, to display, to assess, to explore more information about thermal springs, query and provide analysis convenience of study area. Those works were performed with the help of georeferencing and digitizing processes in QGIS software that utilized the datasets belong to 2020 year.

ACKNOWLEDGEMENTS

It was a pleasant and extraordinary journey in my life. I feel happy, fulfilled, and proud of myself.
It is an honor for me to express my gratitude and esteem to my supervisors Professor Paolo Dabove and Professor Glenda Taddia. They were pretty supportive and helpful during my entire work. I would also like to thank to Piedmont institution as called Citta Metropolitana di Torino for sharing datasets with me. Sharing was significant to proceed on my way.

CHAPTER 1

1. INTRODUCTION

Energy is one of the most important factors and pillars in the development of any country in modern ages [5]. It is known that growing human population leads to the increase of energy consuming day by day. Governments, academics have been faced to advance in pursuance of effective, ecofriendly renewable energy consuming instead of fossil fuels which have substantial effects on anthropogenic climate change. Nowadays, a broad range of environmentally friendly energies are available as solar energy, wind power, hydroelectric power, geothermal energy, tidal power, biofuels.

According to Muffler and Cataldi in 1978 Geothermal energy could be extracted at future at lower cost compared to commonly used but limited energy forms as oil, natural gas, coal, and hydropower. And this source could be provided modern society's energy needs unless difficult assessment. [1] EU commission embarked on reducing of the gas emissions 40% by 2030 and 60 % by 2050 compared to 1990 grades.[3] Therefore, a kind of renewable geothermal source or linked resources utilization can make explicit contribution for reaching the lower fuel consumption. Geothermal energy has a variety of using areas in electric generation, heating, cooling, bathing etc. [1]

Geothermal energy is counted an effective mechanism in terms of clean energy supply by qualified hereinbefore. It is also inexpensive and can be utilized in various forms. For this reason, it is essential to explore sources, exploit productively geothermal plants, investigate environmental obstacles or interactions around plants, assessment of data that picked from reserve regions. In order to get over all those listed affairs, GIS technology is a supportive and functional system which is usually preferred and has the growing interest in numerous fields. The implementation of GIS to the present database set gives opportunity to evaluation, exploration, and environmental management. Italy is known as having widely geothermal spring country and in Turin city there are geothermal plants. It is therefore this thesis intention to apply GIS technology on installed thermal plants to enable planning, monitoring estimation and development of present energy service plants in Turin.
Another important aspect of this exploratory it accelerates the survey and ensures wide ranges of look with representing the location of geographic features on the landscape. Additionally, this work is a preliminary to WebGIS in regard of any database presence thus far. There are GIS based techniques in Geothermal sites but mostly that are progressed in order to support decision making relevant geographic data as decision multi criteria analysis.

The advantages of this system; involves the accessing to many users even without the need for software.

Moreover, GIS has a broad range area of utilization in academic study such as in agriculture in hydrologic modelling in archeology in tourism in public health in renewable energy in emergency management in oil spill prevention and in many other fields a variety of samples are available.

This paper aims a study on applying GIS technology to assess existing Geothermal power plants to explore different attributes, physical information. Regarding datasets which belong low enthalpy geothermal plants in Turin were provided by Piedmont institution.

The low enthalpy geothermal systems are the major applications in cooling and heating of the buildings in urban life. These systems, are based on discharge of water from well to injection well or river, is exploited in shallow sites which have heat potential. In this way it develops thermal plume also known as geothermal source [2]

In the initial step data was performed the georeferencing of dataset in QGIS. Then generated maps were investigated to detect interactions, determination of necessity plants in location. Representing of the integration of dataset and geological maps was done with the results obtained.

Renewable power production has negative effect on environment and society, and it brings to financial problems for energy industry. [25]

Therefore, it is important to investigate potential negative impacts around plants with this work. It was searched an answer to some questions as specified What are the main resources? What are the development and considerations for spatial geothermal features? What would be well problems in terms of location? Is there any interaction around plants? Does location convenient to set another plant? What geothermal evidence features are closest the area of each potential well? What is the restrictions place on development? All those queries were searched for an answer by means of GIS technology. This study is preliminary in GIS application for thermal sources with this aspect.

CHAPTER 2

2. GEOLOGY

This chapter begins with the definition of essential knowledge used in evaluation of energy sites. Italy has a form one of the active deforming regions in worldwide with the history of earthquakes which are related to hot spring sites. Therefore, it is fundamental to have a brief information about the geology of power regions.

2.1. Geological Background

Earth structure has a shape kind of covered with layers therefore sphere consists of 3 main zone that are called crust, mantle, core. Radius of terra is around 6370 km. The most outer part is crust has average 7 km thickness on ocean basins and 20-65 km under continents. Oceanic part and continents consist of different type of rock as basalt and granite respectively. Second part is mantle which extends about 2900 km and is assumed compose of ultrabasic rock rich in Fe and Mg. Last part core prolongs from 2900 to 6730 km. The temperature in there is extremely high around 4000 C⁰ and pressure at the center 3.6 million bar. This heat is released from interior towards surface through a unit area. This heat flow is generated from Earth's formation that is based on decay of radioactive isotopes. Heat flow varies from continental crust to oceanic crust as 57 mw/m² and 99 mw/m² respectively. It is also known heat flow is highest in the recently magmatic and metamorphic areas. It decreases and is more constant with the increasing age of crust. [4]

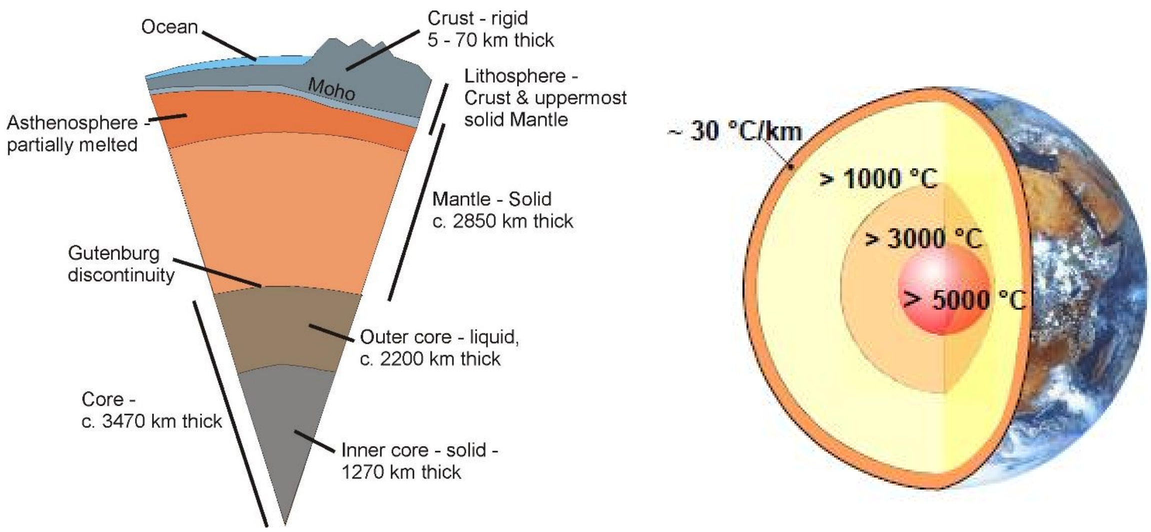


Figure 1 The Scheme of Earth's Structure [6],[12]

2.2. Geothermal Aspect from the Point of Geology

In order to understand the geothermal source, it is important to get with the subsurface mechanism of Earth.

Terrestrial globe has a heat transfer mechanism that depends on conductive and convection heat flow that is generation of geothermal gradient and thermal conductivity of rocks. Geothermal is specified as accumulated heat energy which is the beneath solid crust surface because of earth geological period releases steady heat. It would be compensated essential drive if energy would not have been dispersed substantially. Heat flows from interior to the Earth surface and dissipates. Temperatures of rocks decreases while heat moves upward which is called geothermal gradient. Average value is 30Cº/km of depth. Heat flow mechanisms are conduction and convection respectively. Conduction works with the casual kinetic energy collision between molecules thus it gives rise to transfer. Penetration of rainwater into subsurface and interaction with temperature and pressure generate a geothermal source in the aquifer reservoirs. Geothermal sources consist of a continuous heat flow system circulation therefore it is approved as a renewable energy. Convection is based on movement of hot fluid, more effective than conduction which transport of kinetic energy between molecules without transfer of material.[7] Mostly conduction is used for solids convection is used for fluid or gases. As seen in the figure 1 rainwater also known thermal waters infiltrate into recharge area and keep going on to depth and it uprises the temperature

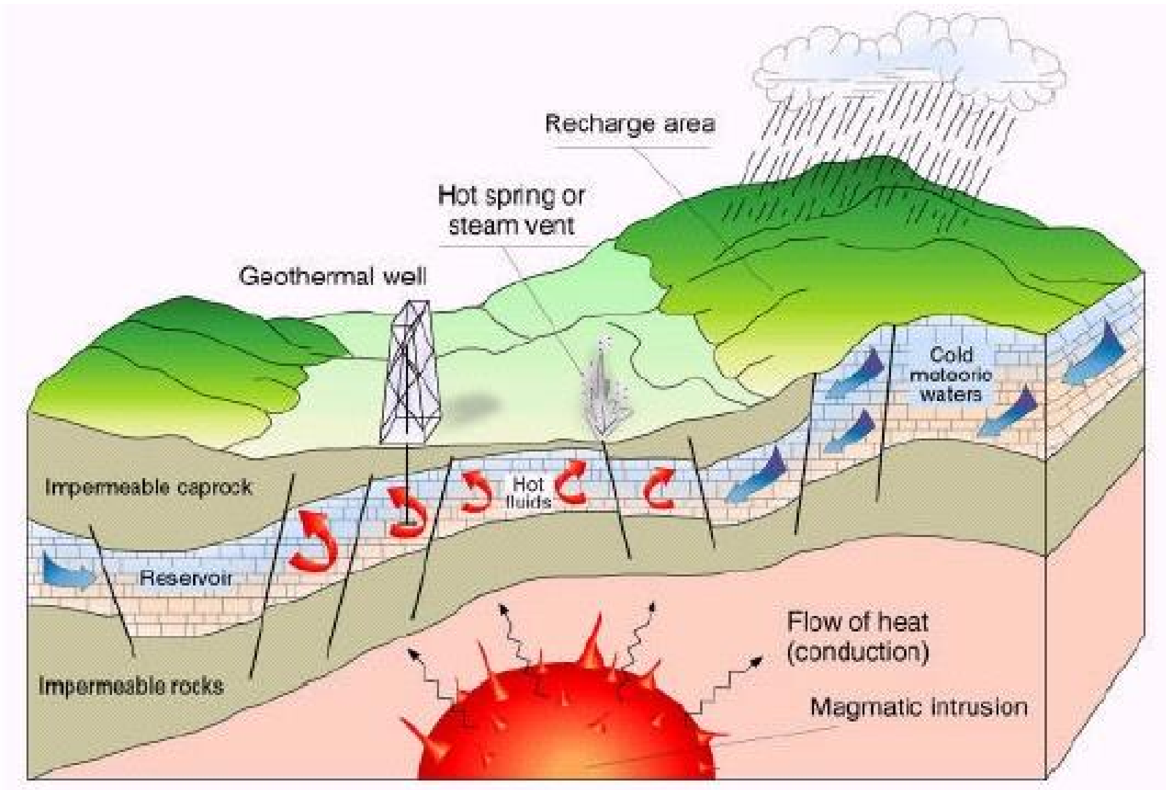


Figure 2 Geothermal Heat Flow System Scheme [7]

Heat flow generally are higher at geothermal resources. To generate efficient geothermal resource, it needs some anomalies such as thermal anomaly, reservoir filled with fluids (water and steam) inside the permeable rocks. It is known as convection mechanism due to density variation of temperature that causes to moving of heat from lower side to upper side. 4 types of geothermal systems are pointed out namely hydrothermal, hot dry rocks, geopressured and magmatic. In our present time hydrothermal is only used as industrially and it is classified as water dominated and vapor dominated. Hot water fields and wet steam fields. [1] Thermal behavior is determined by the variation of temperature with depth during its geological time. Geothermal sites arise from tectonic active regions which have several natural open fractures. Fumaroles, active volcanoes, hot springs, steam vents, geysers are accepted as geothermal activities which have potential energy. Warmer surface indicates the geothermal activity areas. [7]

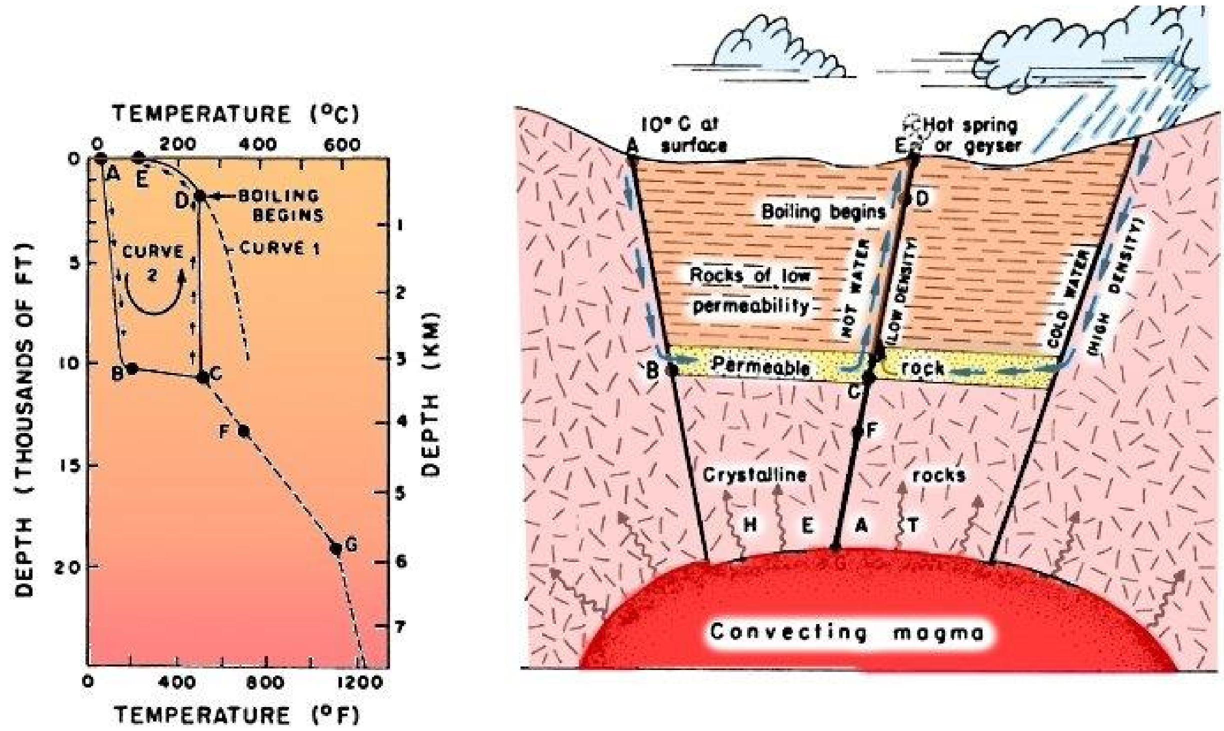


Figure 3 Geothermal System Representation Curve 1 Is the Reference Curve for The Boiling Point of Pure Water. Curve 2 Shows the Temperature Profile [7]

The term geothermal refers to the thermal energy stored beneath the surface of the solid Earth. This energy is huge and derives principally from planetary and geological process. Our planet has been slowly cooling since its formation and this primordial heat moves from Earth's interior towards surface where it dissipates.[12]

2.3. Geothermal Energy

Geothermal is the energy as described stored power beneath the subsurface. It is a mass energy that is formed by geological process.[12] Structures produced by tectonic activities like graben formation, rift valleys, block faulting generally manifests around geothermal sites.[18] Geothermal energy is accumulated in rocks and trapped vapor such as water or brines.[1] It is required a carrier transfer to exploit this mass trapped energy and is done by convection and conduction because of thermal fluid carrier properties.[7] And heat, fractures and fluids are accepted as essential agents of the convective geothermal sources. Fractures make connection for fluid transportation in the reservoir however, it will cause circulation loss in case of absence fracture.[19] That mechanism plus thermal gradient are based on heat flow from interior to towards surface as aforementioned in the geothermal aspect part. Highest thermal values are determined near volcanics or in the thin and hot crust areas.[12] Active spring sites show natural indications at ground surface especially hot springs, mut pots, hydrothermal alterations are accepted main indicators in terms of determination of the energy.[18]

Figure 4 Geothermal Power Station in Iceland [20]

Geothermal fluids contain gas, nitrogen, CO_2, small amount of ammonia, mercury, radon, and boron. Chemicals are collected in wastewater by routinely reinjection therefore it does not give a harm in terms of environment.

Even in Iceland, that is known as a rich country with thermal sources, has reduced CO_2 1.9 tons/a with clean thermal using compared to fossil fuels.

In which ways geothermal energies are used? We could answer 2 ways as direct and indirect. Direct use of geothermal energy consists of a whole range area of utilization as heating, cooling, industry, greenhouses, fish farming, health spas. Hot springs have exploited for bathing washing of clothes etc. by people from the early time of civilization times.[16] Traces regarding direct use of geothermal were founded it could say it used a variety of countries such as Japanese, Greeks, Indians, Chinese, Mexicans, Romans.[7]

Besides, direct use could be possible after extraction by the direct circulation of heating system with the help of heat exchangers. 3 basic power plants are used namely steam, high temperature water (above 200°C) and binary. Thus, hydrothermal fluids could be converted to electricity.

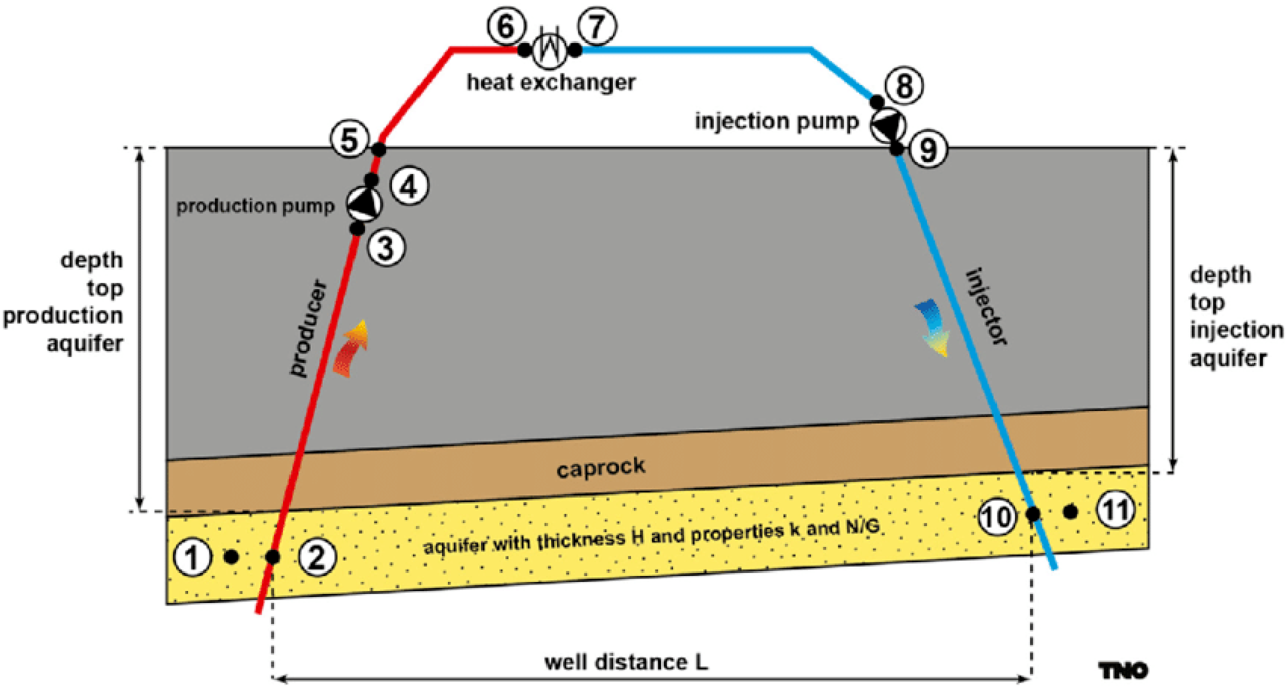
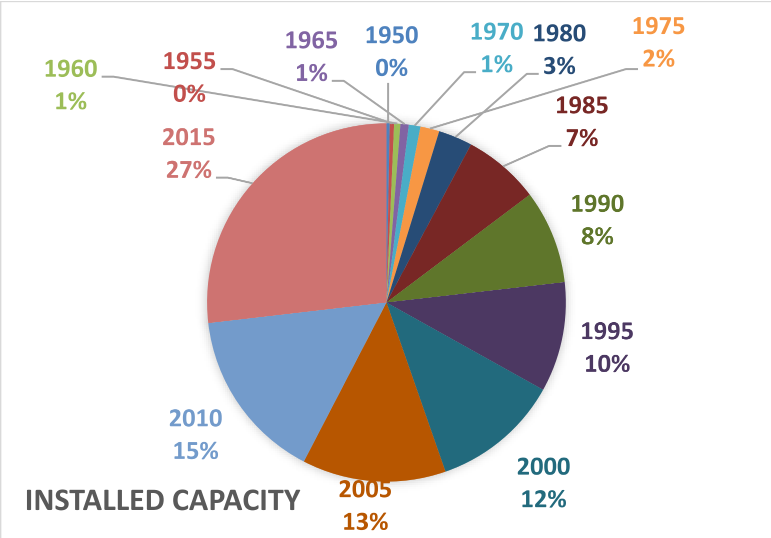


Figure 5 Schematic of A Doublet Geothermal System. 1 And 11. The Aquifer and Geothermal Source; 2. Mid-Aquifer in The Production Well; 3. Inlet Production Pump; 4. Outlet Production Pump; 5. Top Production Well; 6. Inlet Heat Exchanger; 7. Outlet Heat Exchanger; 8. Inlet Injection Pump; 9. Outlet Injection Pump; 10. Mid-Aquifer in The Injection Well. [21]

Geothermal energy has been produced for electricity generation for 109 years ago, however Prince Piero Ginori Conti started electric power generation with geothermal steam at Tuscany (Italy) 9 years ago.[16] It is observed an increasing on installation of geothermal plant all around the world. [23] Especially after 2010 there is explicit rising as it is seen from the figure 6. Using area of thermal systems are changing according to its temperature but higher than 120 °C are mostly use in electric generation. It is possible take advantage of shallow underground heat stability by means of shallow geothermal technologies. Water is used as carrier to extract the heat from deep to surface.[12]



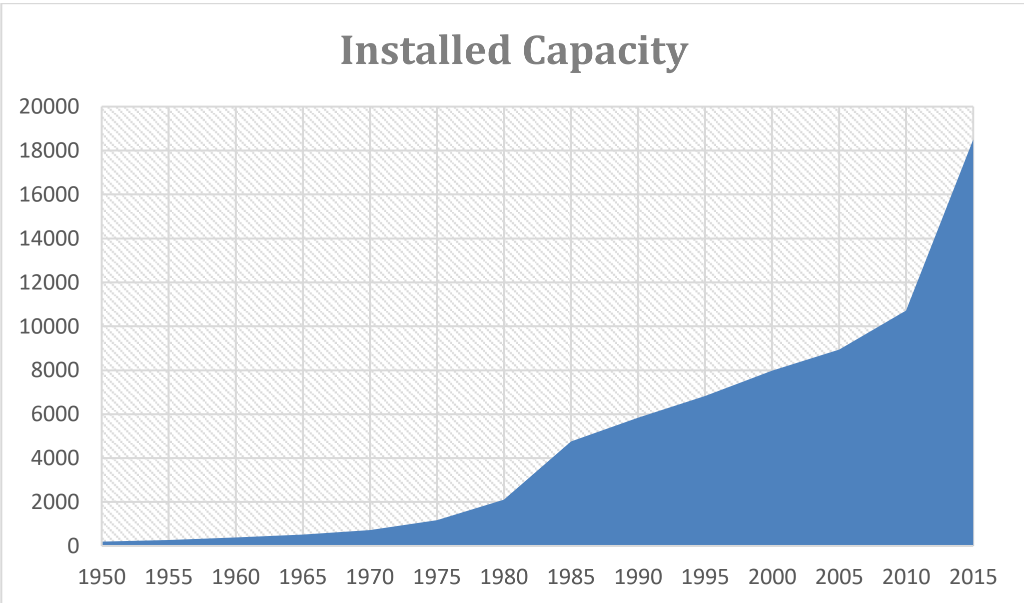


Figure 6 World Geothermal Power Plant Graph (Data Retrieved,[24])

Until this part, technical information was given about geothermal, and it was said that it is used to meet human energy supply and now the question, is geothermal a renewable source? Generally, it has often said to be a renewable energy resource. But from the point of Barbier it is not on the time scale, if strictly speaking. And he adds it is accepted as the renewable energy solely in case of heat does not go over the limit of reservoir recharge rate.

On the other hand, Cataldi specifies that Thermal energy could be extracted at a lower cost compared to fuel energy sources therefore accepted as a good option renewable and clean energy source in the future.[1]

Geothermal energy has a restriction to extract from less than 5 km depth due to modern day technology. It is accepted that to evaluate temperature, reservoir volume, permeability also to predict about production type (steam or hot water) of reservoir. Invention of surface manifestation, geological and hydrogeological surveys, geochemical and geophysical parameters, and exploratory wells are techniques for the exploration.[7]

Resource assessment is done during exploration and development process. As more data enables more accurate evaluation in terms of the source evaluation. A productive source is described as a

- High T,
- Large amount of stored heat,
- A low-rate liquid production,
- Lower reinjection wells,
- Produced fluids with neutral pH,
- Sufficient permeability,
- Low elevation and easy terrain for access roads,
- Lower tendency for scaling pipelines,
- Low risk of volcanic and hydrothermal eruptions,
- Closeness to electrical load and transmissions lines

2.3.1. Thermal Energy Supply in Turin and Italy

Absence of fossil energy leads the country to external supply therefore decrease of fossil consumption and to limit the external dependency consistent usage of renewable energy will increase the efficiency. There is not use and production of coal and peat in Turin.

Regarding energy sector, Turin is the cleanest province in Italy for high number for RES plants and one of the largest remote heating regions.[57] As renewable energy there is rising production and consuming of hydropower, geothermal energy of low enthalpy, solar energy, wind power, biomass in various forms of wood, biogas, biofuel.

Geothermal energy is proper to generate power as renewable source, numerous countries are thriving usage and progress of its. In Italy there are ample thermal resources, ranging from resources for heat pump applications to high temperature system (>150°C) Electricity is generated from thermal power in Italy, usage of thermal energy is prevalent in national scale with heating system, direct uses, and ground source heat pumps.[60]

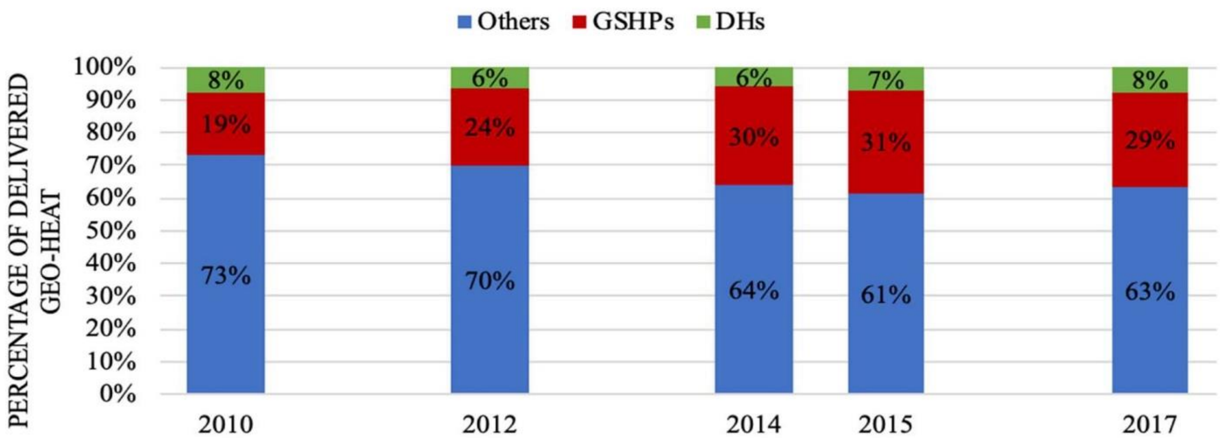


Figure 7 Development of Geothermal Direct Heat and GSHP in Italy [60]

Terrain of Turin has may installations of medium and large size groundwater heat pump have been performed and still keep growing [61]

2.4. Brief Information of Study Area

In this study, the used dataset gathered from Turin city center north-west part of Italy, and it was shared by Citta Metropolitana. Turin is the capital city of Piedmont in northern Italy. It is bordered to the west by France to the north Valle d'Aosta Region, to the east with the Province of Biella, Asti, Vercelli and Alessandria and to the south the province of Cuneo. Points belong to energy plants are more often located in the center part of the province. 12 installed thermal plants are present in study location. As seen in the below map, there is an apparent concentration of plants in certain location.

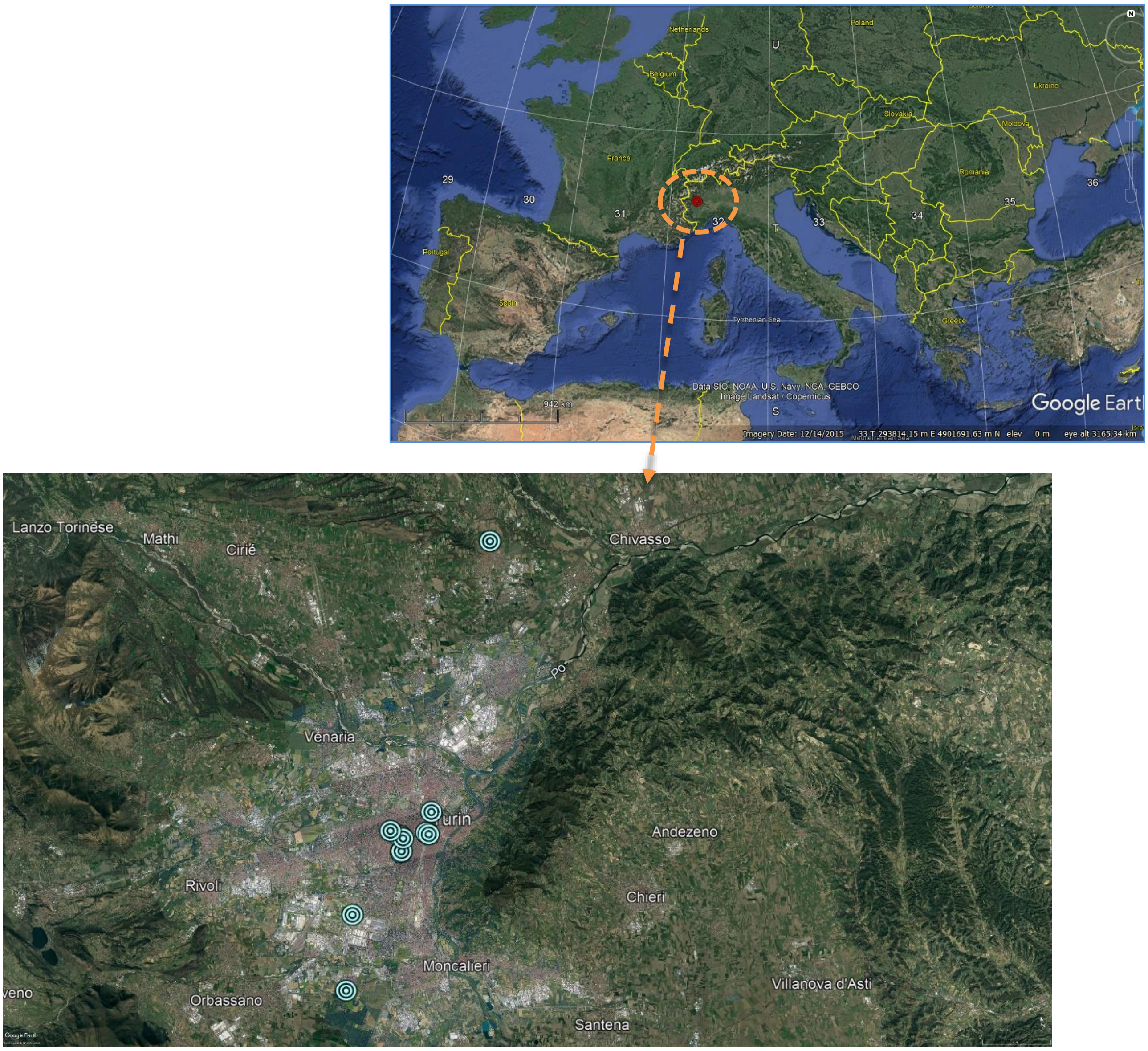


Figure 8 Satellite Image of Study Area (Provided from Google Earth)

City is mostly flat that was developed on glacial wash with fans that connected to Susa glacier. The area of Turin mostly has a plain land with the surrounded rivers as Dora Riparia, Po, Stura di Lanzo, Sangone as seen in Figure 8.[13] Mainly coarse gravel and sandy sediments are set which derived from alluvial fans by Alpine rivers

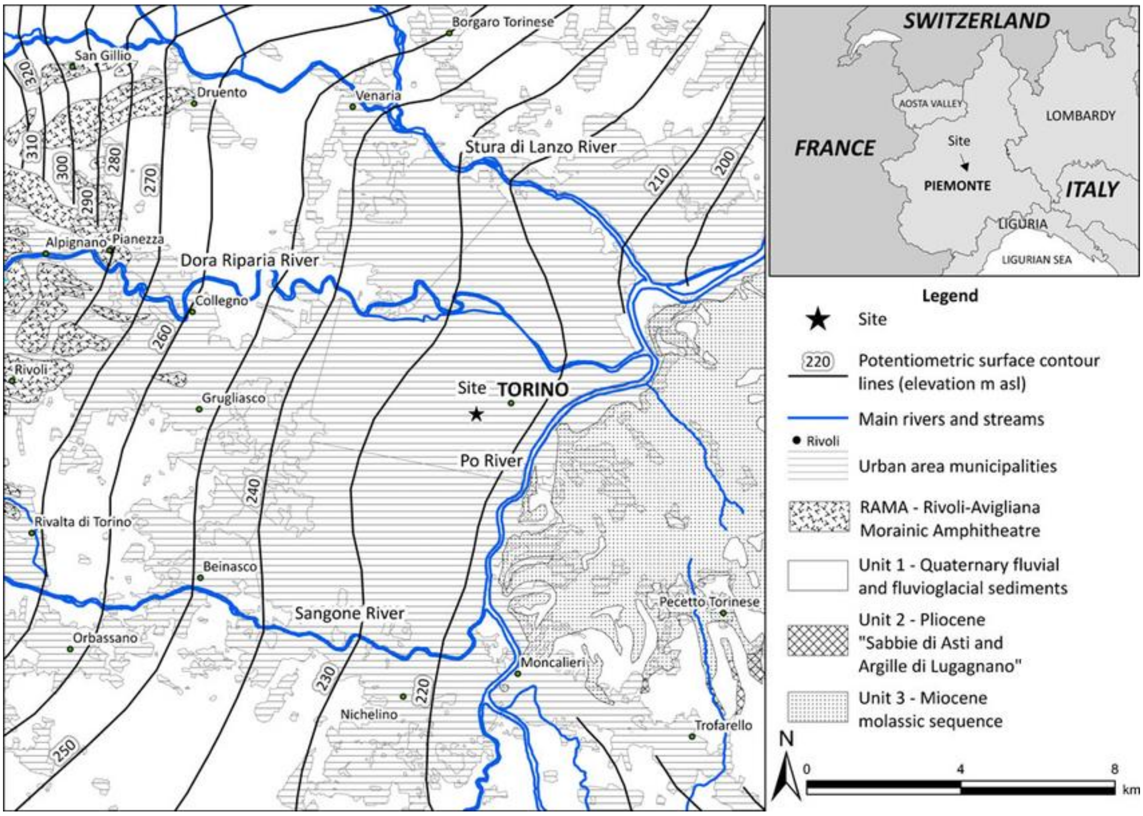


Figure 9 Hydrogeological Map of The Turin Area and Study Region [26]

In the map main rivers are depicted by blue lines and urban area municipalities with black point mark. There are 2 lithologic zones which are Unit 1. and Unit 2 with explicit hydraulic properties. Unit 1 is the base as erosional surface inclines toward to northwest the city. Unit 2 is formed mostly sandy marine layers, fine gravel, and sands. An unconfined aquifer that widens around all area, because of shallow depth and inclusive connection with the drainage network area it is open to pollution.[26]

2.4.1 Geological Setting of Piedmont Region

Turin city stays on in western region of Po plain which is settled among the Western Alps (Alp mountains) and the Turin hill. Torino downtown mostly is on the plain which is the end of hill surrounded of city. Over the morphologic character, it is presumed its geological setting structure that represents extensively elevations between 230 m and 270 m relatively flat morphology admittible.[49]

Piedmont area is qualified numerous features as The Alps, Langhe and Alto Monferrato, The large end moraine systems, fluvio-glacial, alluvial fans of major alpine, glacial lakes in the northern side and a range of alluvial plains of Po River.[50]

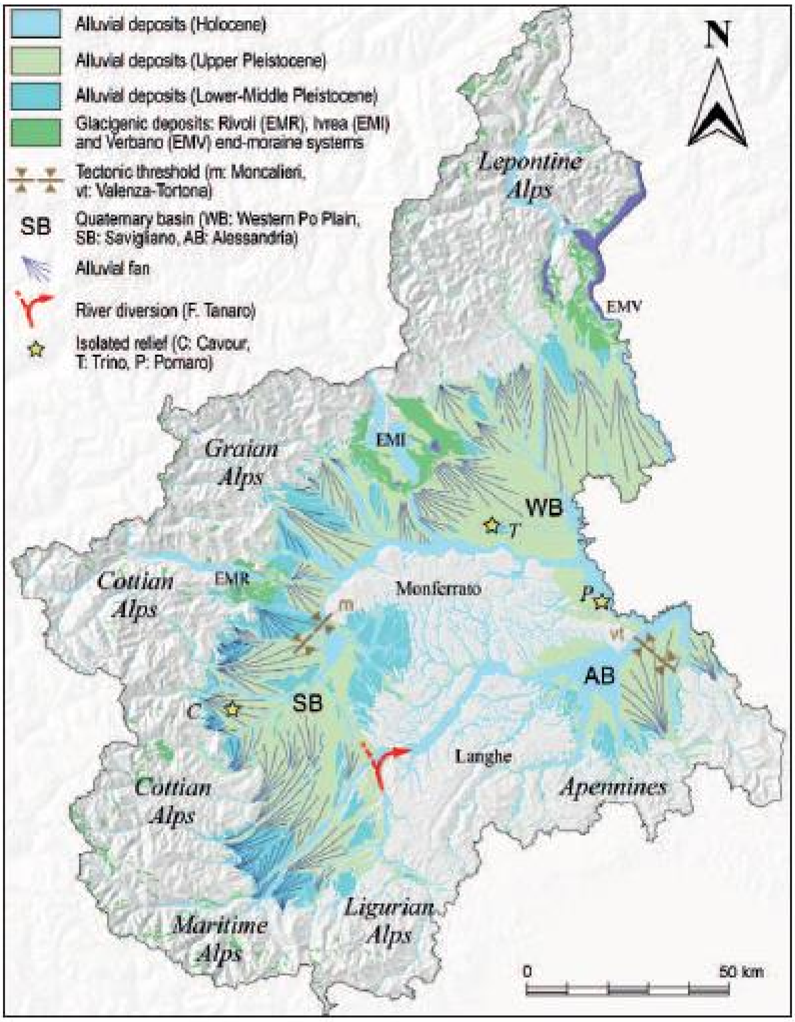


Figure 10 Piedmont Site Orographic Features

Because of complex geology and tectonic evaluation, a various of geomorphological structures are observed. Different lithologic fragments such as deep mantle rocks, oceanic basalts, sedimentary covers, plutonic and volcanic continental rocks, siliciclastic sedimentary covers, and many kinds of metamorphic rocks which are generated under high P and T conditions. However, it is identified sedimentary rocks which indicate to a permanent range of magmatic, metamorphic, and sedimentary events.

Turin is located on Early Pleistocene (2.5-0.7 Ma) outwash (materials formed of glaciofluvial) sediments forming the fans. Fans are bonded to Alpine streams of Po River. Turin hill ranges proceed in subsoil of Turin buried by Quaternary (2.6 Ma to present) deposits. [49]

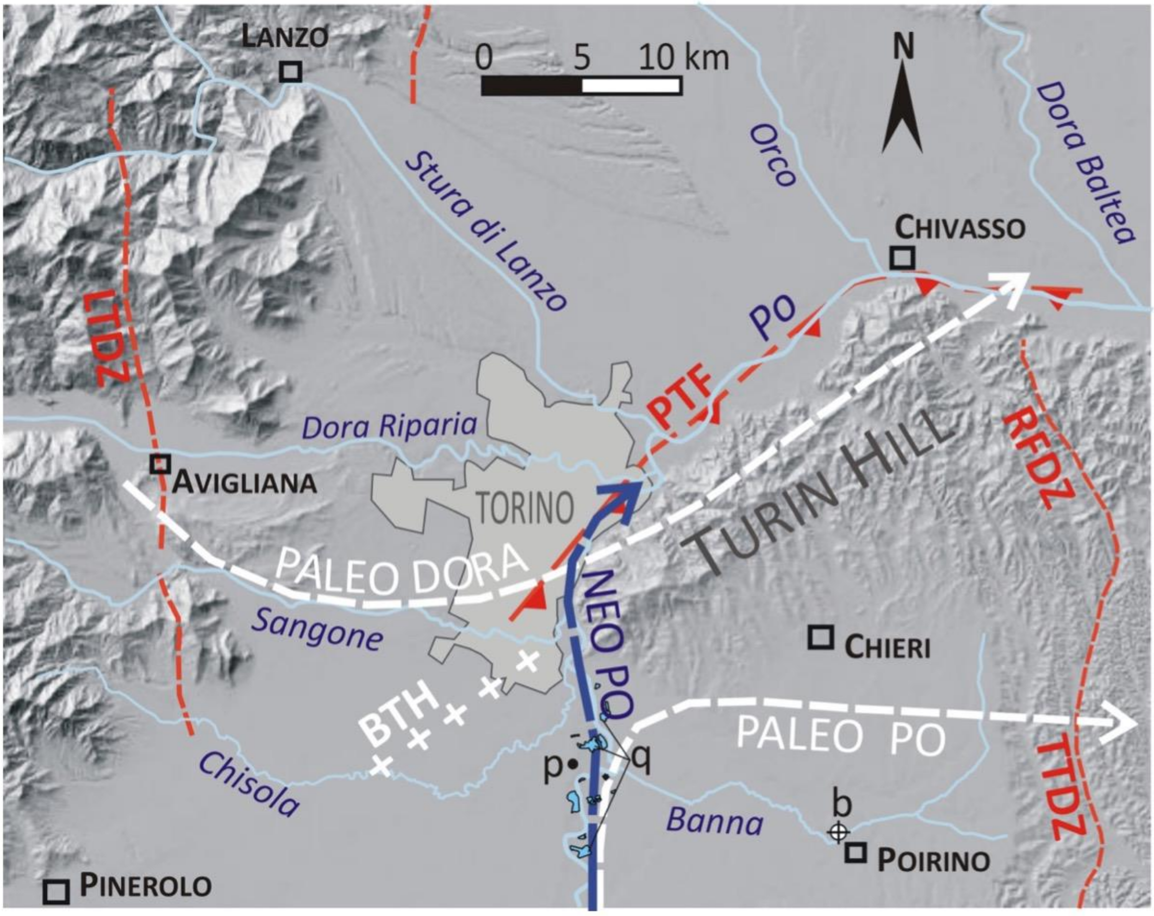


Figure 11 Fluvial Successions Map [49]

Turin hill is proof for that the hydrographic traces in the Early Pleistocene were formed Dora River. As indicated in the map (figure 10), Neo Po River flows towards North and Paleo PO River flows towards East from southern part. Flat surfaces crop out Northwest and West side of Turin hill. RFDZ: Rio Freddo Deformation Zone, TTDZ: T. Traversola Deformation Zone PTF: Padan Thrust Front

Even if Torino is not the preliminary seismic active area, it will be useful to give some information about seismic activity of the study location.

Turin is the 4th seismic zone in Italy as known less seismic region compared to other geography. Potential of this province is associated 2 fundamentals seismic zone namely Borbera Grue and Northern Cottian Alps. Annual hundreds of seismic tremors epicenter is in the Piedmont regions; Susa Valley, Lanzo Valley and Langhe. Generally estimated magnitude of earthquakes are between 4.5 and 6.

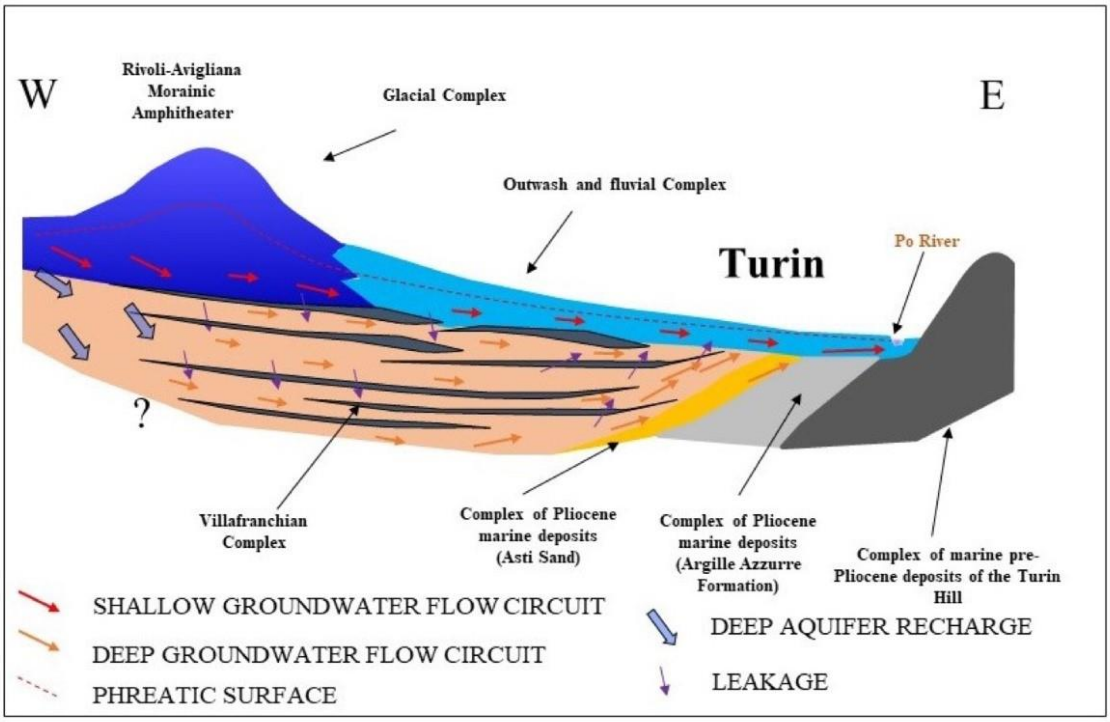


Figure 12 Hydrogeological Model of the Turin Area [49]

Hydrogeological complexes are seen on the figure 11. Stratigraphy of the city is affected by its hydrogeology. Marine deposits complex consists of permeable silt and clay meanwhile Asti sands provide productive aquifers, but fine matrix can limit productivity. Villafranchian complex has sandy gravel and silty clay and peaty silt. The alternating coarse permeable deposits generate multi aquifer system which are mostly groundwater system in Turin both human needs and industry intentional. Th Glacial complex has sediments that are grain size which permits developing of small water table aquifers that occurs near the ground surface. Base of hydrogeological complex is higher at west side and lower slope in eastern. Even some depressions are present among Rivoli, Alpignano, Orbassano. This morphology effects groundwater flow that is directed towards to current Po River.[49]

CHAPTER 3

3. GEOGRAPHIC INFORMATION SYSTEMS

3.1. GIS Definitions and Basic Concept

The purpose of the thesis is digitizing and analysis of thermal plume database that were monitored and gathered in Torino throughout 2020 year. A large set of incommensurate evaluation criteria are the typical spatial problem. Interactive maps based on Google maps and institutions local website have been generated by countries at the present time, nevertheless those maps may not meet in all aspects of evaluations. [9] This process was done with help of geographic information systems. For that reason, in this chapter it will be helpful to give some basic information, descriptions, literature review about GIS technology and its application areas. There are several different definitions of GIS that defined by academics, and it is an uprising-discussed topic. The identified definition varies and updates over the years with the investigation and progress of GIS utilization. Moreover 'Geo base information systems', 'Spatial information systems', 'Geo data systems', Natural resource information systems' are alternative terminology of GIS.

According to Parker opinion GIS should not be perceived only as an integrated computer system, as a technology it can be operate spatial data processing with a diversity of software, hardware tools [29].

Clark definition in 1986 is 'Geographic information systems are computer-assisted systems for the capture, storage, retrieval, analysis and display of spatial data' And also emphasized about increasing application and demand of GIS in recent years [27]

Dueker defined as 'Special case of information systems where the database consists of observations on spatially distributed features, activities, or events which are definable in space as points, lines, or areas. A GIS manipulates data about these points, lines, and areas to retrieve data for queries and analysis' [28]

Further description was made by Buckley, and he describes like 'A geographic information system, commonly referred to as a GIS, is an integrated set of hardware and software tools used for the manipulation and management of digital spatial(geographic) and related attribute data.

In addition, categorized in 4 essential parts namely:

- Data input subsystem,
- Data storage and retrieval subsystem,
- Data manipulation and analysis subsystem
- Data output and display subsystem [9]

Data input permits to capture, pick up and convert geographic data into digital form. Data storage and retrieval promotes data forming to recover by user updates and maintain. Data manipulation and analysis supports the user to determine spatial process to product information from acquired one. Data output lets the user to visualize graphics, maps, and table reports from acquired information. GIS technology is based on 2 different data types about spatial and attribute that are used as input. Spatial data gives accurate location of geographic features, attribute data defines characteristics properties.

Physical components of GIS:

- Computer hardware
- Computer software
- Organizational context [9]

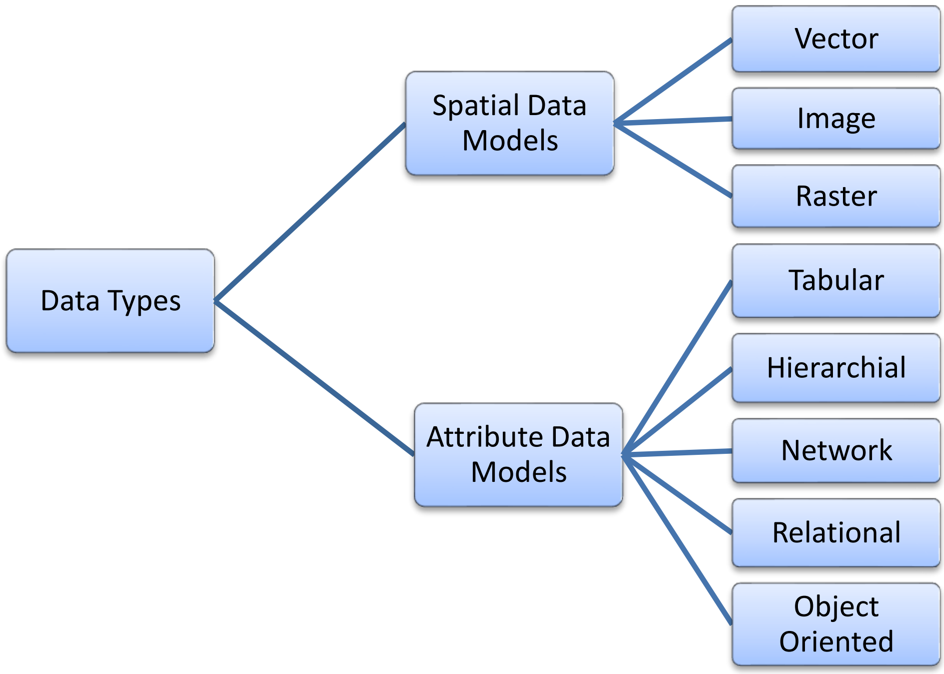


Figure 13 GIS Data Type Diagram

Different data models are present to storage and management of attribute data however spatial data has form of a map to do those processes.

Those 2 main data identify the sources. The input operation could be done both attribute and spatial. Both data models have an extensive source broadly we could state for spatial as

- Hard copy maps
- Aerial photographs
- Remotely sensed imagery
- Point data samples from survey
- Existing digital data files

About attribute it could remarks much more extensive sources like any type of textual or tabular. After having input data, the next step is determined by input techniques which are separated to 4 basic procedures

- Manual digitizing
- Automatic scanning
- Entry of coordinates
- Conversion of present digital data [9]

After that data editing is realized both for spatial and non-spatial data. Then data storage / retrieval and data analysis follow it. In this part basic explanations were done in term of GIS system.

3.2. Literature Review

Recent years, related studies were conducted in the worldwide. It showed that GIS has a wide array of application to manage, analyze the spatial problems especially in the Geothermal energy sites. Here it is, there are a few compilations literature search of related studies.

GIS is a significant decision support technology to determine the favorable areas for wind turbines. GIS analysis could serve to identify favorable locations and it leads a future development. MCA evaluate alternatives, based on multiple factors and restrictions where the agents are indicators of extent.[22]

MCDA is considered as an advantageous method in terms of evaluation of potential geothermal fields hereby it is possible to control and get more accurate results in consequence of narrowing target area. So that in this study potential geothermal sites were determined by means of GIS in Afyonkarahisar city of Turkey. However, Analytic Hierarchy Process was implemented as a supportive method in the decision-making stage. In conclusion, all present sources were determined as provided [30]

In this paper it is seen that GIS effect were investigated by the help of thematic coding to analyze study impacts. Awareness and sensitive working are required with increasing using of GIS. [31]

It is focused to determine geothermal resource areas with multi based criteria decision analysis. Temperature distribution to fault lines, distance to hot springs, distance to basalts and distance to grabens were used as criterion parameters. MCDA method has also been employed for geothermal favorable mapping; each digitized layer gives a different weight. This research combined 2 methods (EMW and Analysis Hierarchy Process) to prediction of geothermal favorable areas. It was expected to lead an early geothermal exploration the study area.[11]

In another study, with the urban development it is expected to increase of construction and demolition waste therefore paper represents an integration study with GIS and GPS technology to reduce the waste. According to results it is reached a satisfied outcome with the integrated implementation in the construction management. Integrated work purpose to carry real time location information to the site therefore it could be enabled to improve efficiency and profit under favor of visualization of architecture. [32]

GIS is a helpful application in terms of environmental evaluation of wind energy system as well. A decision support system could assist decreasing of environmental impact of renewable energy. With multi decision making method it was implemented in western Turkey. First criteria parameters (acceptable and safe terms) were determined. All those satisfaction actors obtained regarding to study area and created maps to identify potential and eco-friendly locations.

Except of developing proper maps according to result interpretation it is considered that other energy sources could be used too.[33]

Digital data layers were employed to select favorable areas for Geothermal sources in Egypt. With 6 thematic layers GIS based analysis was done. Comparison of wells and spring helped to perform suitable area determination. GIS based Geological, Geophysical and Geothermal data were utilized. Most promising zones were detected near to shore of Gulf of Suez.[34]

It is also feasible to implement GIS in regional mineral exploration programs, in this study Harris and friends run an exploration with the WofE analysis. According to deduction of paper that it is evaluated the situation as useful with regards to assess of geochemical maps. Further it could contrast the anomalies and know location. On the other side it is beneficial to provide measure between anomalies and prospects.[35]

There is another GIS application in different field is Geomorphology. Geomorphology is defined inseparable and connected with geospatial technology in this work. GIS also has uprising in this field. It is used to relieve spatial explorations. First step is digital elevation model attached with image data and remote sensing information from area. Application was done in numerous fields as hillslopes, gravitational processes, glacier environments, fluvial environments, sediment flux and erosion in mountain areas. Application GIS gives opportunity of visualization approach, classification. Hydrological analysis. process and modelling, detection of hazard zones. With the process lots of geomorphological indices were developed [38]

GIS is applied with decision sensing in exploration and environmental management. It is focused to determine proper location for drill sites and site selection for a geothermal power plant. Mapping, spatial visualization tools are as decision support system. In first step, geological suitable area and weighted geophysical and raster maps are overlain and then proper area is selected. Similar method is done for environmental suitability analysis again to be able to choose area. In final well site determination is selected with overlaying of exploration and environmental suitability map [14]

3.3. Geospatial Data

Geographic data, is also addressed spatial data, is one of the basic models of GIS and it implies directly or indirectly the coordinate system while provides information about a specific geographical location of sphere. Geospatial data is combination of location and attribute information which describes events, features near to surface of earth.

Geospatial data management solves big data applications such as earth observation, system information modelling integration, 3D/4D city planning. It has a connection role among data acquisition, data modelling, data displaying, data analysis [46].

At the present time, geospatial data handling is growing and an essential task to enable GIS modelling, planning, earth observation, visualization, data analysis. It is possible to query, understand geospatial relationship by way of maps which are created with geospatial data. Geographic base maps supply a reference to associate the sources with the surrounding landscape thus numerous beneficial information like area sizes, distance, directions are revealed. Geospatial analytics is employed to add timing and location to display. Geospatial data includes:

- Vectors and attributes
- Point clouds
- Raster and satellite images
- Census data
- Cell phone data
- Drawn images
- Social media data

A map consists of a variety of properties that depict by points, lines, areas, is an essence to identify and visualize the position of geographic attributes on terrestrial globe. Those properties are based on a reference system, which indicates position on Earth, and determines the attributes thus mapping is a common generic way to represent and storage of the geographic data. We could obtain location and feature, attributes of features, connection with other features from a map.[9]

Geospatial relation of subject is made observable by visualization. It is feasible to have many forms of those objects. We see signs in the figure 5 that signs are linked to objects and their relationship. It enables to transmit spatial relations between point, line, area to the map user. If solely one dimension is present about object, spatial data could be expressed from a point of origin. Two-dimensional imagery with dots, dashes, patches such as contour maps. 3D representation could be generated by cardboard.

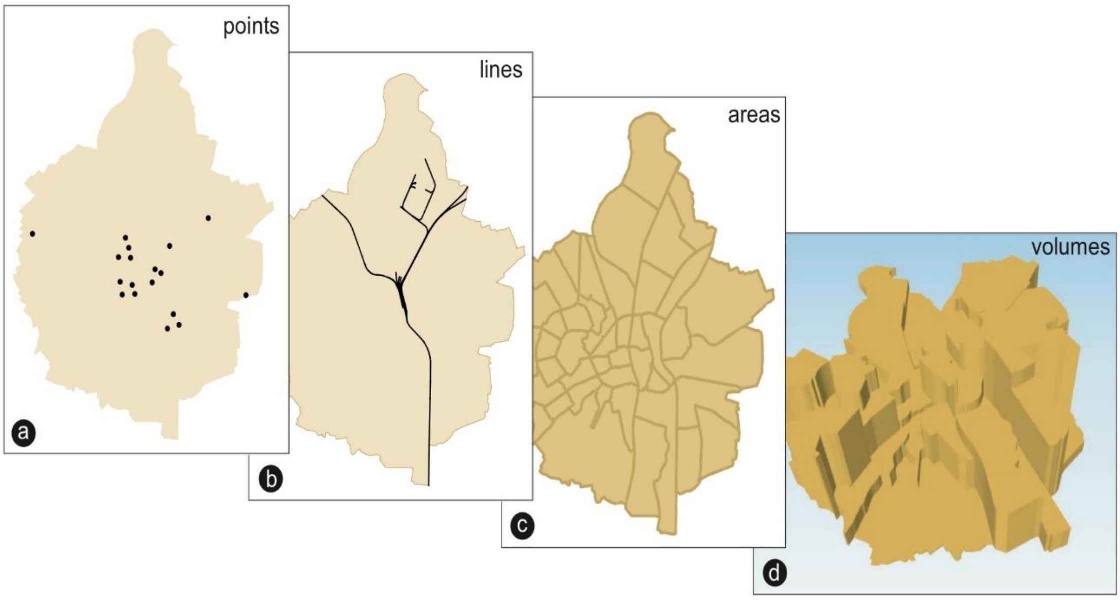


Figure 14 Digital Environment Representation of Geographical Objects [39]

Vector and raster are 2 different technically ways of representing spatial data in map. Vector consists of points and lines, raster is based on grid cell by points it describes single location information as oil wells, reservoirs by lines rivers, pipelines by grid cells areal indication is done. Satellite images, photographs, scanned images are samples of raster data. Roads, rivers, streams, villages, towns are examples of vector data.

Geographical information system enables to see the difference between spatial and attributes of topographical features. It is possible to represent to data at different scales from smaller to greater.[9]

Maps are more than final products geospatially holding, representing, and analyzing of data is significant benefit of maps. Maps support to visualize geospatial data.[39]

According to big data research, it is mentioned that spatial data opportunities and challenges that enable to innovate daily life and business by using location provided by spatial data.[41]

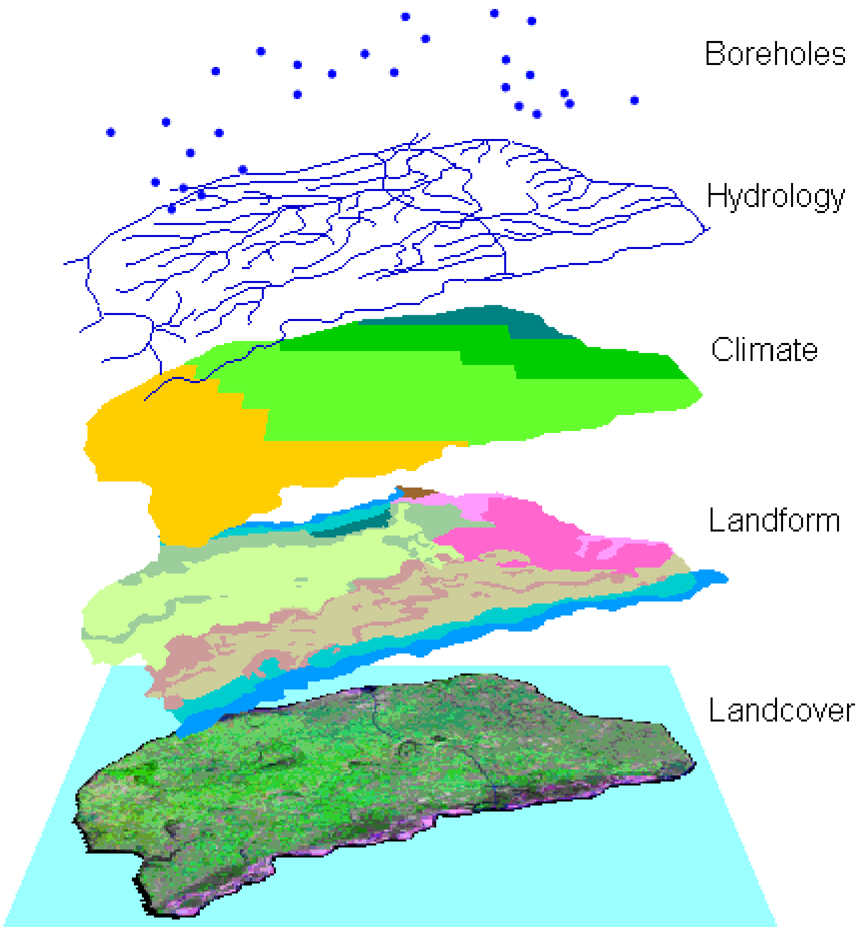


Figure 15 Representation of Different Types of Spatial Data [42]

3.4. GIS Methodologies in Geothermal System

GIS has opportunities such as management of mass data, mapping from low to large scale, supporting geographic behavior in big areas, especially Geothermal regions. According to this paper, the materials were done with the analysis of energy, economic and environmental in GIS technology subsequent site-specific conditions determination. Shallow geothermal and specific thermal energy rate maps provided such that it is big deal. Hydrogeological and Climatic module data debated. Hydrogeological comprises thermal conductivity, thermal capacity, undisturbed underground temperature, BHE properties. Climatic module involves heating and cooling degree days and operating hours. Identification of thermophysical properties were achieved, water saturation evaluated, thermal conductivity and thermal capacity estimated, shallow geothermal potential was calculated which is extremely helpful information in terms of renewable energy contribution. Energy needs and distribution and climatic needs characterization maps created in GIS environment. In conclusion, variation of parameters that impact to SGE productivity obtained and translated economic and environmental information.[15]

According to Ramachandra studies, GIS has an important and efficient role in evaluating of the potential renewable energies. Therefore, it could be accepted and used as a basic element to discover and improve probable shallow geothermal sites.[10]

Joseph Mutua and Ryan Ndombi published an article in the matter of Use of GIS in Geothermal resource database Management. It is essential challenge to face with approximation, storage, and management of digital information on geothermal exploration and development running. They targeted to simplify geothermal exploratory under favor of web-based GIS system. They benefited the function of system service known as browse map system mode, querying, navigation system, search region, map editing, visualization of spatial distribution, printing. Paper concludes and recommend promoting using web based which can inform and conduct development of regional energy.[45]

A geospatial assessment of the installation potential of shallow geothermal systems in graben basin study was done by Jin Lu and friends. In this work, Geological condition effects the GSHP system and to develop the resources they consider and assess the geospatial variations. It is addressed that a specific type of geological site extends similar setting geospatially. According to result alluvial area is more potential site for GSHP than other places. [51]

It is also possible to evaluate the GSHP with mapping. In this paper assessment of shallow geothermal potential in the city was done with different methods as open loop and closed loop systems. In order to identify the most proper sites aforementioned systems are essential.

In the conclusion part it is indicated that shallow potential maps are precious tools for the evaluation of viable closed and open loop systems. There is a distinctive feature for open loop and closed loop system, closed loop is suitable to install everywhere but open loop is needed a sufficiently productive aquifer.[52]

Different kind of maps were created over the analyzing of geological, geochemical, geophysical information in Kenya. Spatial analysis with the GIS functions is used to uncover associations between datasets. Data layers spatial relationships is exploited for prediction of suitable regions. For raster data a weighted overlay analysis was done while well sitting studies. GIS was used for pipe route determination. For the calculation of production efficiency data integration and displaying was used as a function of GIS. In the final part, it is emphasized integration datasets into a single layer is the main feature between the GIS functions. This enables creation of suitable model for potential well sites. And GIS is most popular and productive system to go by data handling especially for Geothermal systems which involve lots of data.[53]

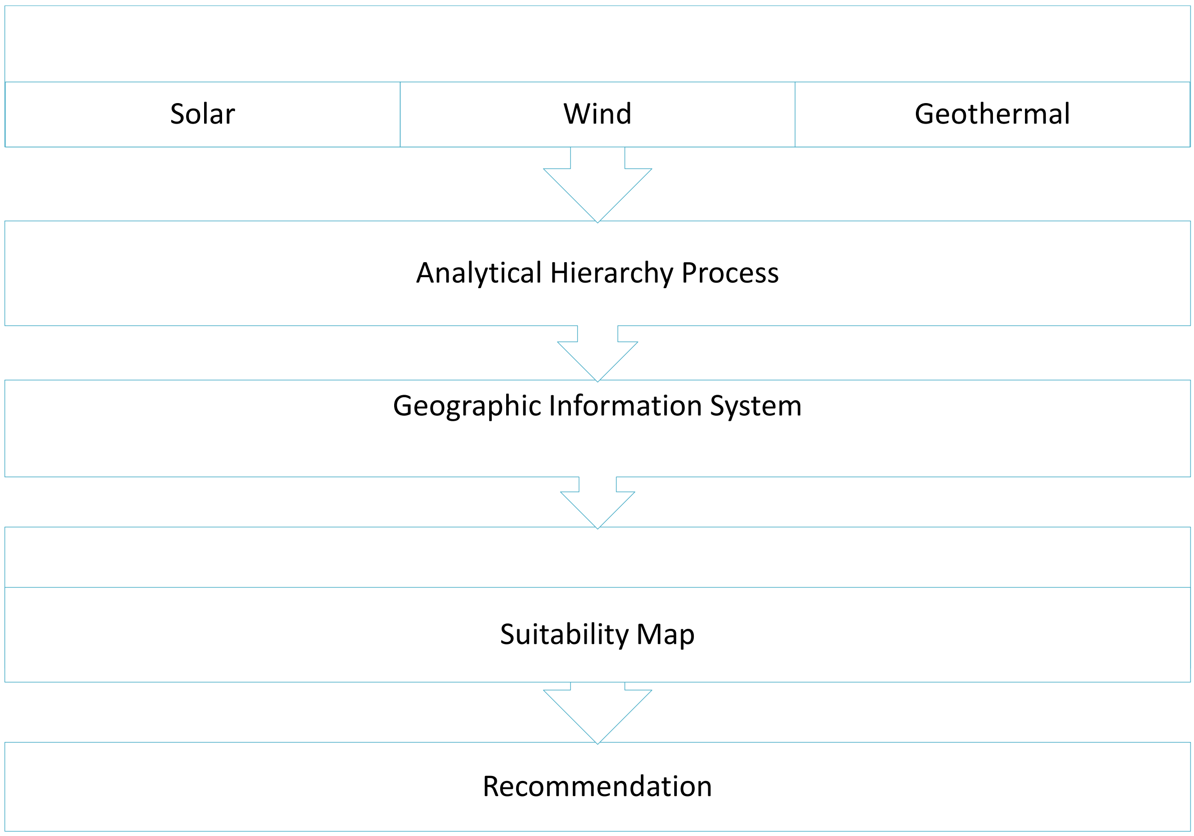


Figure 16 Schema of GIS Used Methodologies for Geothermal Sites in Literature Studies

CHAPTER 4

4. METHODOLOGY

In the following title, we are going to discuss our implemented method, used data that compiled from geothermal active fields and plants, and software for this research. As previously mentioned, the aim of study is to utilize spatial data regarding thermal plants and the assessment of relation between data and geothermal impacts in terms of environmentally, geologically. In the locating power plants all of analysis were conducted with using QGIS to perform georeferencing of present maps regarding geothermal effects such hydrogeological map, mining map, geology, and tectonic maps of the Turin city. However, we have strived to determine the non-suitable areas as urban development, water bodies like rivers, streams, lake, environmentally protected regions, mountains, and all other possible interaction that could be obstacle with the power plants. The last step is combining the georeferenced and digitized maps with shapefile that contains points which indicates the locations of existing plants. Thus, we could have a wide evaluation perspective with combining of different kind of descriptive data.

Structural, hydrogeological, thermal, geological data is essential for exploration and benefit of the thermal energy.[17]

Before starting subtopics of methodology, it will be useful to give some information about basic concepts of reference systems. Locations and areas on surface of terra is tagged. Generally, longitude (a series of vertical lines) and latitude (a series of horizontal lines) systems are used by Geographical coordinate system thus it enables to fit well to the spherical globe. Coordinate reference system (CRS) determines the object real settlement in space by using coordinate system which consist of X, Y, Z numbers. CRS is important while performing GIS or another program. In case of having datasets from the same location that are not stored in the same coordinate system, they will not align. While trying to create a map we need to choose coordinate system.

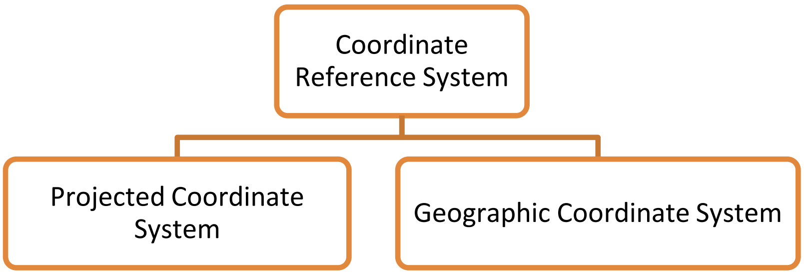


Figure 17 Two Main Types of Coordinate System

PCS is 2D reference system that give information to the data how to draw on a paper map or computer screen without deforming it. GCS determines where data is localized on earth surface.

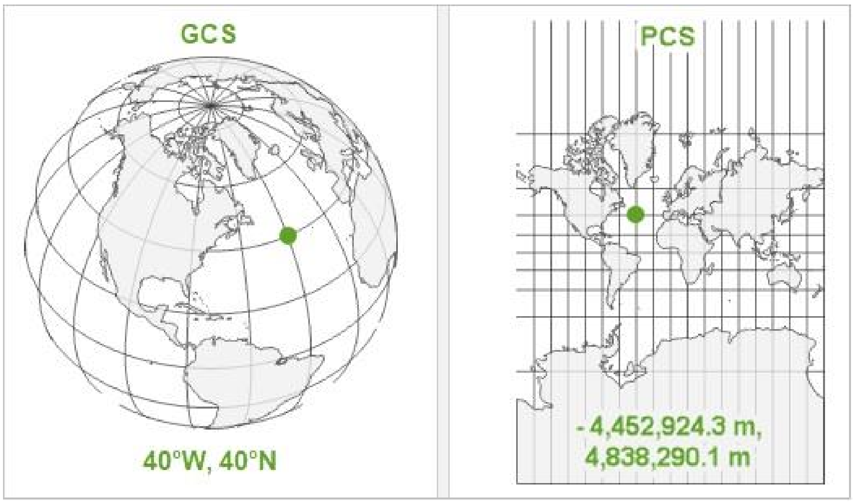


Figure 18 Utilization Difference Between GCS and PCS [55]

PCS is flat and records location as meters, GCS is round and not ideal for measuring distance only records location as degree. Because of that inability, PCS was developed. To generate a map, it is imperative to have a projected coordinate system. GCS involves entire world; PCS is localized to minimize visual distortion in particular area. Using of globes to represent the earths shape is not sufficient method because of problems may arise. As is known, globe preserves and depicts, majority of earth's shape but it is useful at extremely small scales as most of thematic maps. Thus, map projections were designed to eliminate that issue. Different kind of projections are present. There is not perfect projection due to moving from sphere onto flat area causes distortions that is inevitably.

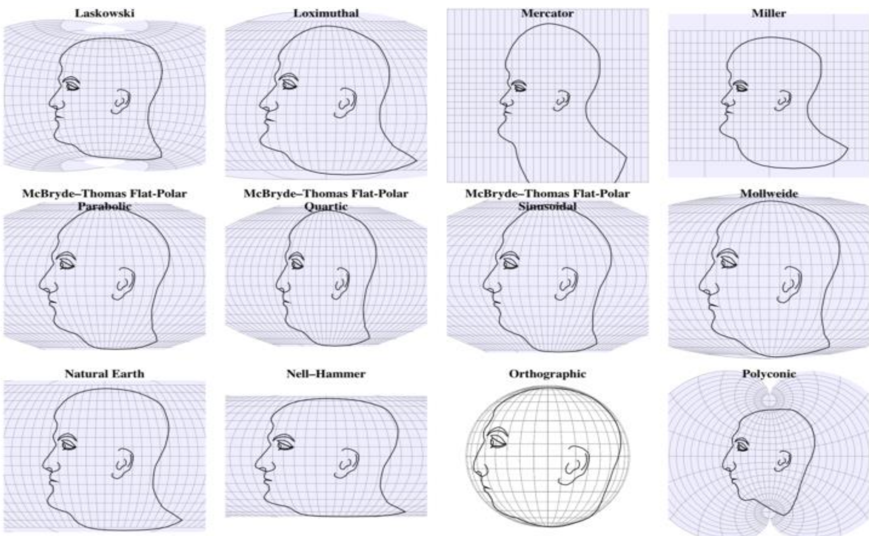


Figure 19 Map Projections with Face Shape [56]

4.1. Data Acquisition/ Sources

Collecting data about Geothermal sites was done to perform assessments of thermal energy. This report contains documentation of dataset and processed input with combining of particular GIS tools. Information in our GIS is a point location database of geothermal districts and points in Turin in northern Italy. Relevant data was shared by Piedmont institution named Citta Metropolitana di Torino. These records were overlayed with the georeferenced hydrogeological, geological, map images of Torino province and Piedmont region. Regarding maps were found out literature search (articles, books).

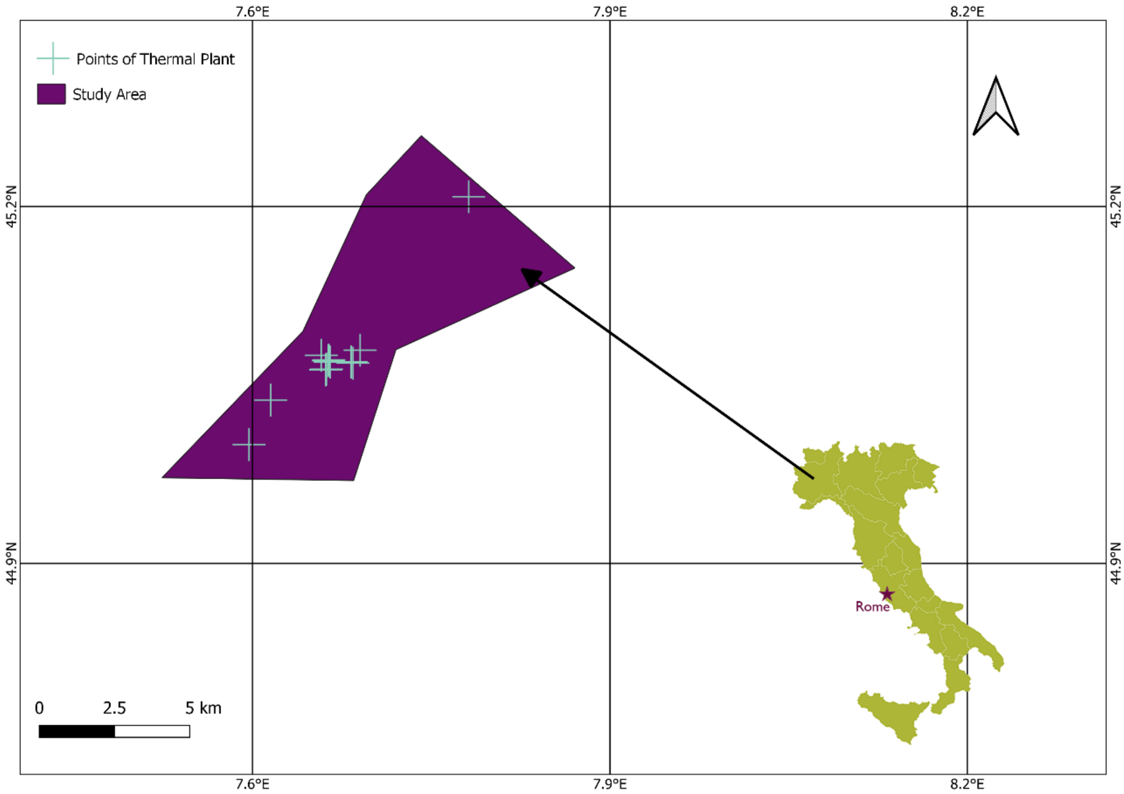


Figure 20 Location Map of Retrieved Data

Geographic coordinates for organizations were collected using Open Street Map Standard based on QGIS plugins. Besides manual search was performed in Google Earth in order to locate points plus create contour map of Turin province.

Google Earth’s high resolution satellite images helped during study for comparison. Certain images were collected by Google search. The data related to organizations was retrieved from the website of organizations.

Generated DEM (digital elevation model) on QGIS system, as it is seen Torino has mostly plain area at center of province and hills around as it illustrated more intense and darker blue contrary to light blue in plain sites.

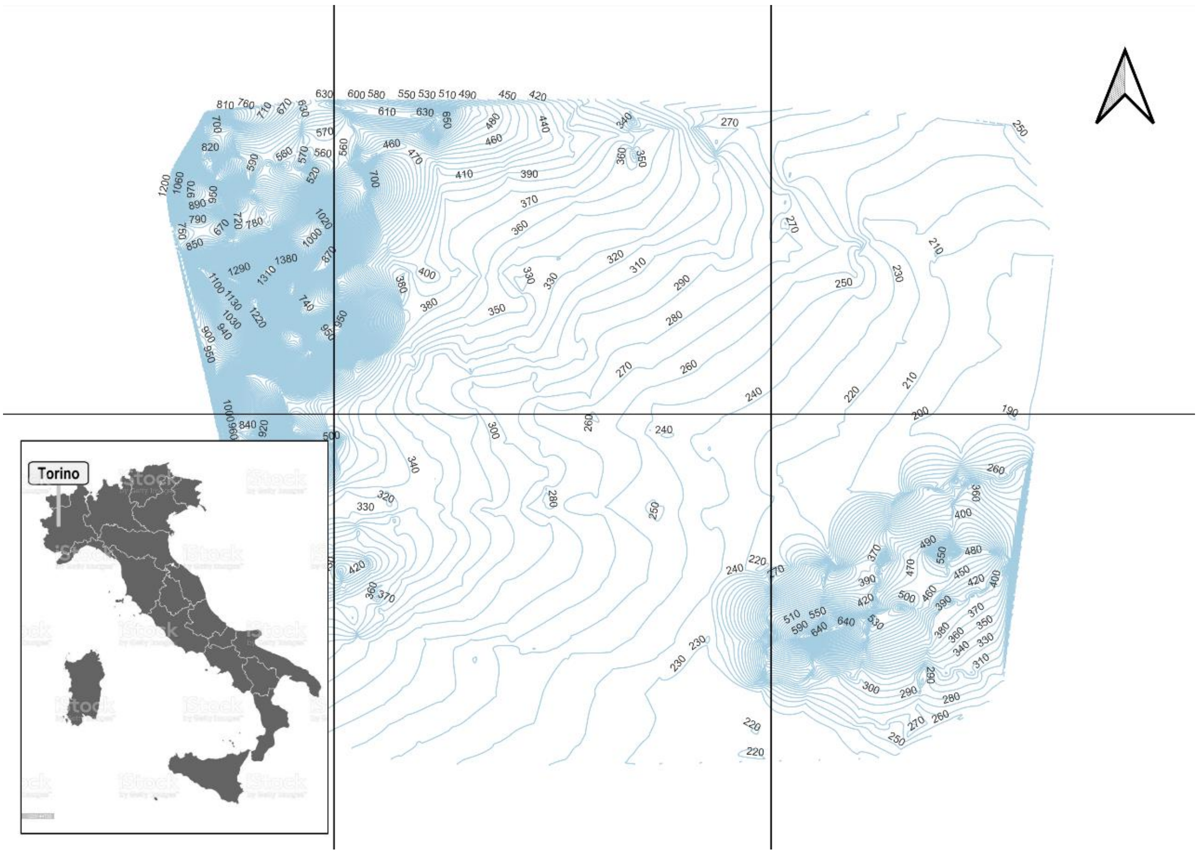


Figure 21 Contour Map of Turin City Center Created on QGIS

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4.2. Software Used

To implement the sample dataset was preferred one of the most used software QGIS 3.16.16 LTR that ensures comprehensive accessible information even for beginner in an easy way. It is free and open-source geographic information system plus compatible with Windows, Linux, Mac, BSD and mobile devices. Besides this study even would be done in ESRI’s ARCGIS which is even suitable for GIS application only with a license. Software gave an opportunity create, edit, visualize, analyze, and publish of geospatial information. Besides it supports plugins and numerous vectors, raster, database format. Vector data is stored as point, line, polygon features.

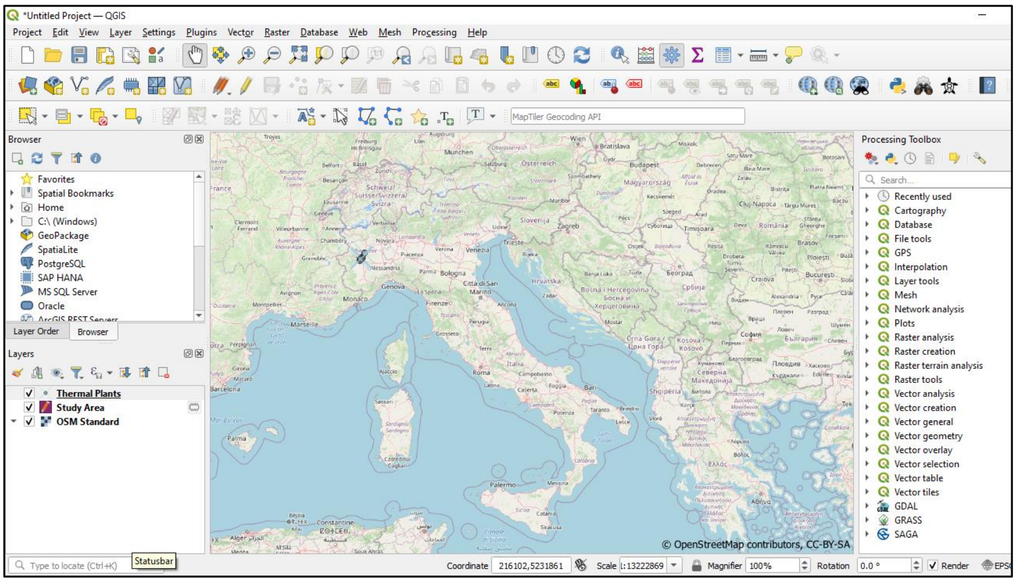


Figure 22 QGIS Software Vista

QGIS supports shapefiles, coverages, personal database, dxf, mapinfo and another format. Software has various plugins that support additional functionality to GIS application. A collection of plugins ready to be used that is available on software in this way could be downloaded. Visualizing of multiple layers containing different source is doable and preparing map to print is also possible with the help of layout function.

Standard vector file format is the ESRI shapefile which contains several files. 3 required files are shp, dbf,shx.

Shp: File contains feature geometries

Dbf: File contains the attributes in dBase format

Shx: It is index file

Prj: It is suffix and contains the projection information.

4.3. Georeferencing

Georeferencing is used as a term to organize spatial reference information to a dataset. It is also referred as geocoding and positioning. Georeferencing enables to allocate spatial reference information to dataset, superimpose and compare datasets from different periods. At the same time, it allows visualize, query, analyze of datasets. Process could be done any image, pdf file, scanned map, picture of map.

Georeferenced data implies to any data with geographic or projected coordinate system. Georeferencing gives opportunity to determine a relation between images and coordinate systems.[8] It is describing as a parasol term for the identification method of structures that related to geographic location with a spatial reference as roads, agricultural areas, buildings, bridges etc. [36] There are different definition regarding georeferencing.

According to Sommer and Wade it is defined as follows ‘aligning geographic data to a known coordinate system so it can be viewed, quired, and analyzed with other graphic data’ [37]

More surface views by Zheng, Zha and Chua that identification of geographical objects in general.

Georeferencing use a geodetic reference system that generally could be WGS-84.

Some basics will be need to georeferenced location data as addressed below:

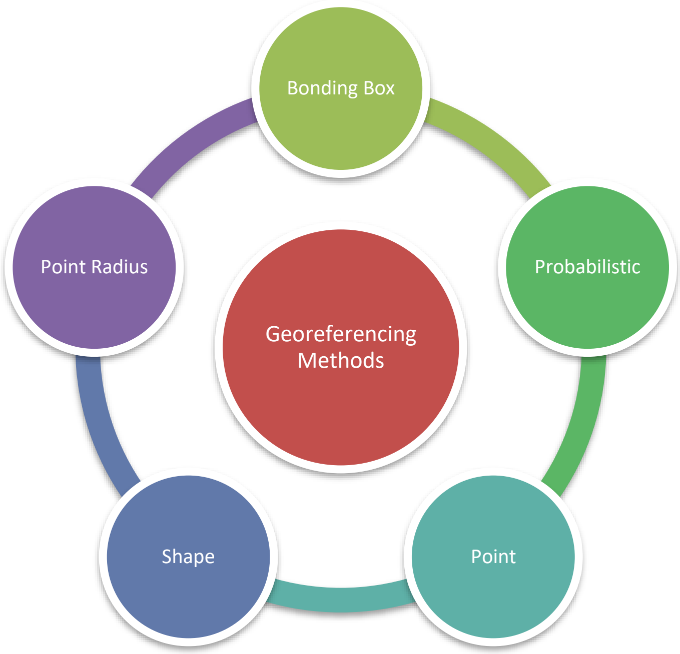
- Suitable computer to support relevant studies
- A database and database software
- Topographic or bathymetric maps, geologic maps
- Access to good gazetteers
- Internet access [40]

Determine a standard reference to data provide advantages in terms of processing and the analysis of data. Specialists could provide additional data sources by coupling references and controlling of relation between observations in space. Having said that this process contributes for a wide scale of different objects and applications as a useful tool [64].

4.3.1. Georeferencing Methods

Georeferenced data describes objects from the point of location in a determined known local or global reference system, attributes describe the characteristics of the object., spatial or descriptive relation between objects.

There are particular georeferencing methods as depicted below.



Within methods, the difference is the basic approach taken to obtain location of data.

Point method consists of coordinates or coordinates in coordinate reference system. It does not ensure scale of coordinates. It is not recommending as the end of a georeferencing workflow due to probable mistakes during scale.

Point radius method based on radius length; it should be large enough to be able to center the circle. Radius involves all of indefiniteness in the interpretation of position. The point circle radius also intersects with other spatially information to be reproduced a shape.

Bounding box method consists of 2 coordinates with their reference system. Those coordinates are for 2 corners of bounding box. Corners determine maximum and minimum values of coordinates. It resembles point radius method with simple representation of location.

Shape method is also simple and employs polygons, buffered points, buffered polylines to describe locality. It is possible to depict town, park, river, junction on a map. This method could generate specific digital spatial descriptions.

Probabilistic method is more difficult compared to other methods.[40]

4.3.2. Transformation Types

During georeferencing process we need to set up transformation parameters. There is different type of transformation:

- Linear
- Helmert
- Polynomial 1
- Polynomial 2.3
- Projective
- Thin plate spline

Linear is used to generate a world file. It does not transform raster pixels, only positioning the image but no rotation or other transformations are enabled. At least 2 GCPs are needed.

Helmert transformation distinctly ensures rotation. 2 GCPs should be at least, is proper for aerial image or a good quality local map.

Polynominal 1 preserves points, straight lines, planes as called affine transformation too. It is useful for cartogram which is a thematic map that geometry of regions is distorted to convey the information. 3 GCPs is necessary.

Polynomail 2,3 permit to account curvature of image. Angles and local scale are not retained. At least 6 GCPs are required.

Projective allow transformation the images and map canvas. Straight lines are preserved but not parallelism the image varies. It is not preferred for angled photographs. 4 or more points should be chosen.

Thin plate spline uses the local polynomials to match the GCPs. It is proper to employ with deformed, inaccurate images. 10 GCPS are required.[47] To increase the error more GCPs will be efficient.

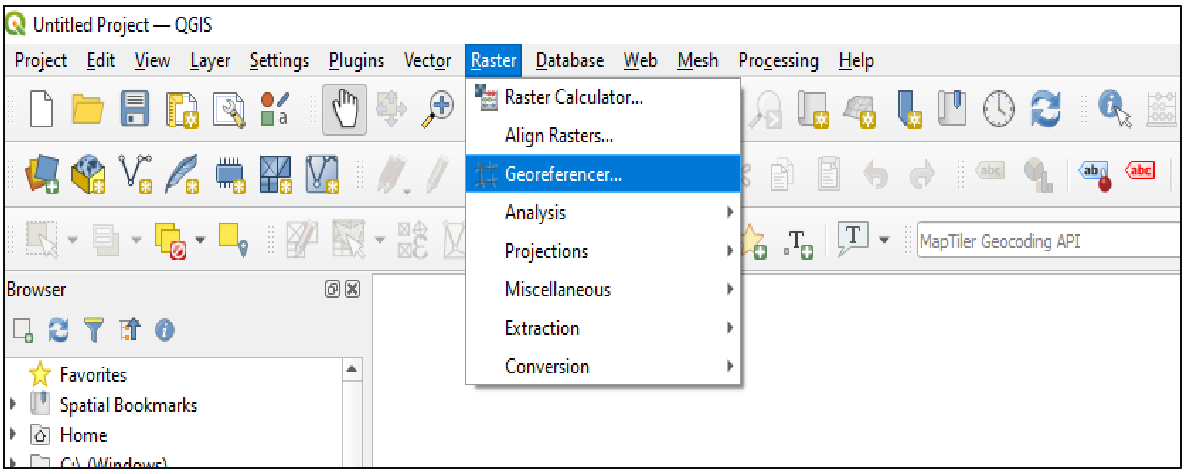
4.4. Data Processing

Dataset refers to 2020 year which involves shapefiles with indicated plant points. Plus, pdf files that contain measurements of thermal plumes basis on real input data of each plant during entire year with monthly recorded. Additionally, geological, and hydrogeological maps of the city were obtained from articles. Maps and pdf file images were executed by the basic georeferencing and digitizing processes in QGIS software. In this part, I will provide summary basic information about process steps both Georeferencing and Digitizing.

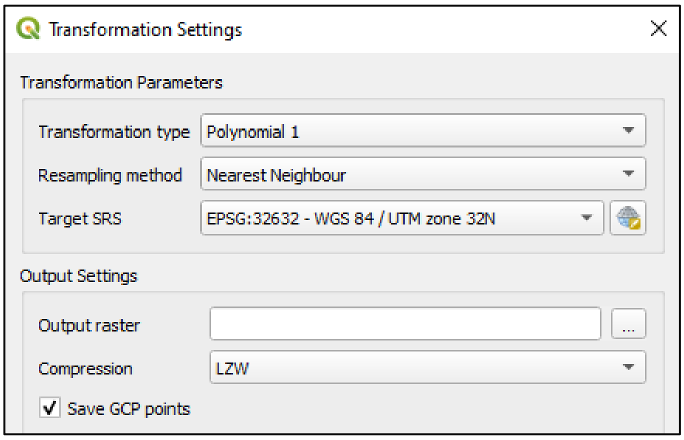
In the first step, it is important to choose proper CRS. Determining appropriate CRS will prevent our maps to look distorted and poorly reflect real world relative sizes and location features. By default, QGIS starts each project using a standard projection. This CRS is EPSG:4236 also known WGS84. It is global based reference system, and it was changed from settings as WGS84 EPSG:32632. Afterwards, georeferenced plugin enabled on operating system subsequently raster model uploaded. Associated with using of the Georeferencer tool, I desired to align with my projected data.

Georeferencing Procedure Steps:

1. A base map used from OpenStreetMap to capture the coordinates for georeferencing. The coordinate reference system of map is EPSG 3857 Pseudo Mercator which is seen in bottom corner. It is possible to change it from project tab
2. The image georeferencing is for Turin downtown so with the zoom in zoom out click it is possible to view location closer.
3. Launched to Georeferencer from Raster. Before GCP Transformation Settings should be defined.



4. Transformation type was chosen Polynomial 1. Checked the save GCP points to store as a separate file therefore the option clicked.



5. Clicked add button on toolbar and selected easily identifiable locations on the image especially corners, intersections were preferred.
6. After choosing from map canvas button, in the open street map layer I clicked on the exact position in the reference layer thus coordinates automatically replaced in chart.
7. More chosen points will give more accurate results more than 3 point is much more efficient. 4 different point was chosen. From GCP chart we could check dx, dy, residual error values.

GCP table

Enabled	ID	Source X	Source Y	Dest. X	Dest. Y	dX (pixels)	dY (pixels)	Residual (pixels)
√	0	479.609213	-249.722414	399493.53	4994348.41	0.024637	0.250542	0.251750
√	1	483.692712	-301.582855	399688.47	4992403.70	-0.033307	-0.338713	0.340347
√	2	377.055045	-468.272963	395506.38	4985806.13	0.020624	0.209735	0.210747
√	3	291.484901	-484.234722	392071.32	4985028.88	-0.011954	-0.121564	0.122150

8. After satisfied with the chosen point values on GCP chart, I proceed to starting of georeferencing. Once it finished its process, layer was seen loaded in QGIS
9. Then OpenStreetMap was removed thereafter data imported as shapefile that contains points of study location.

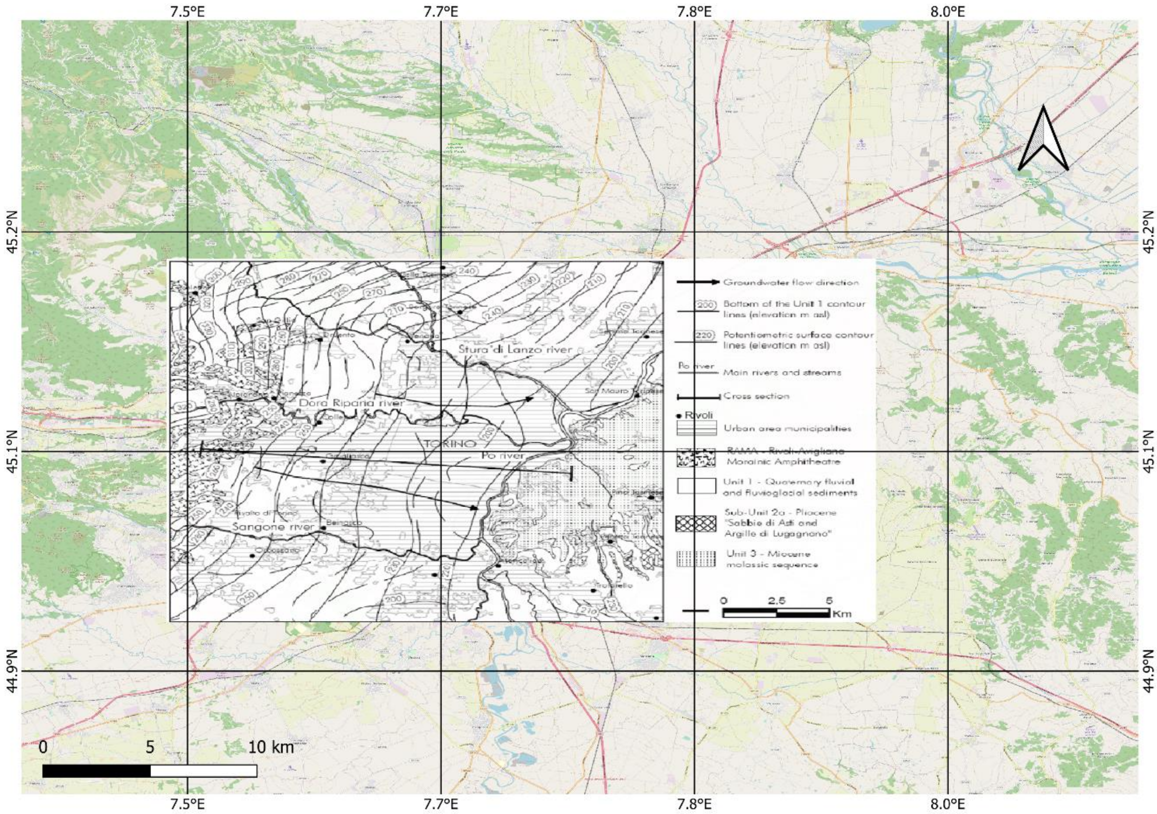


Figure 23 Displaying of Georeferenced Hydrogeological Map on QGIS

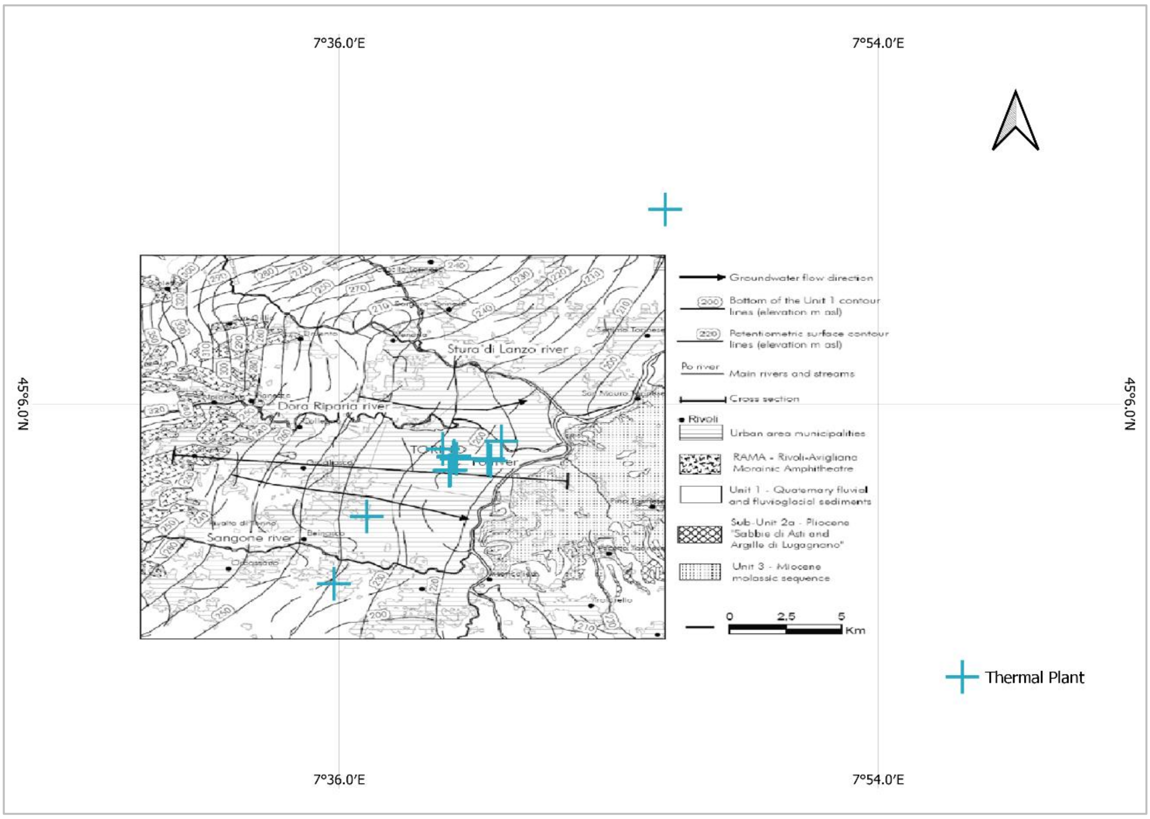
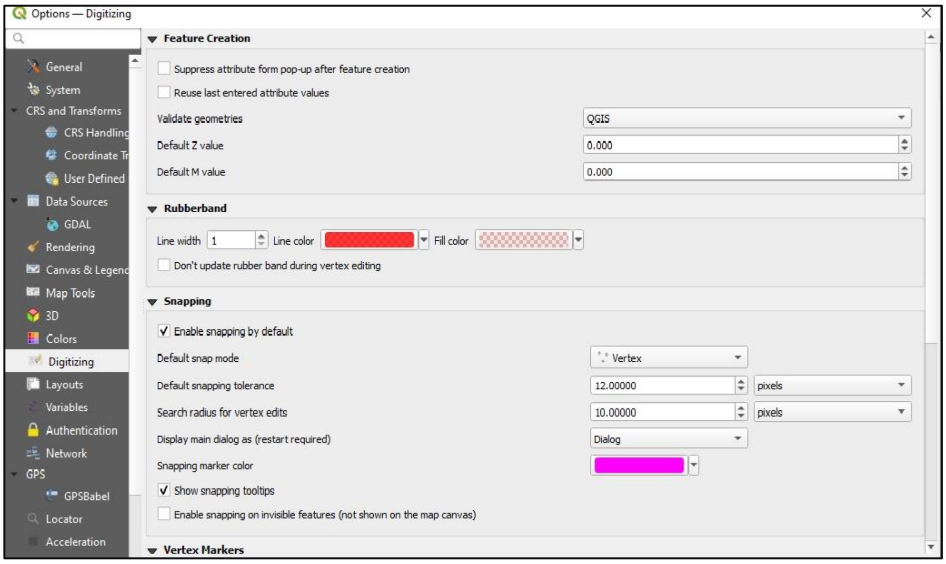


Figure 24 Georeferenced Hydrogeological Map of Turin and Points of Thermal Plants

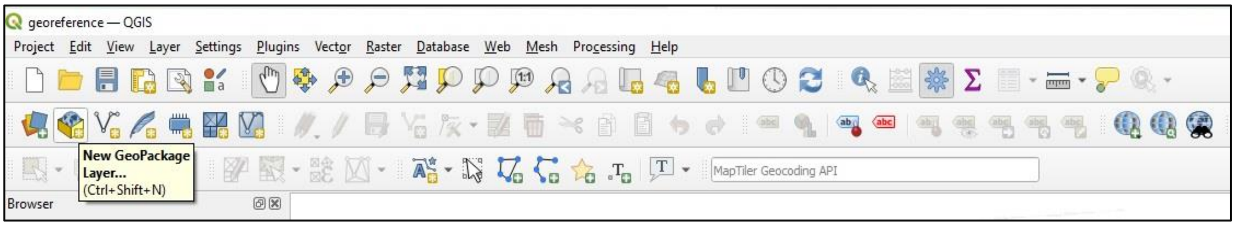
Digitizing is one of the most common tools that is used by GIS experts. In analysis digitizing takes a fair amount time to create vector layers from raster model. Main features were adopted by digitizing tool from georeferenced map to provide more efficient evaluation and information.

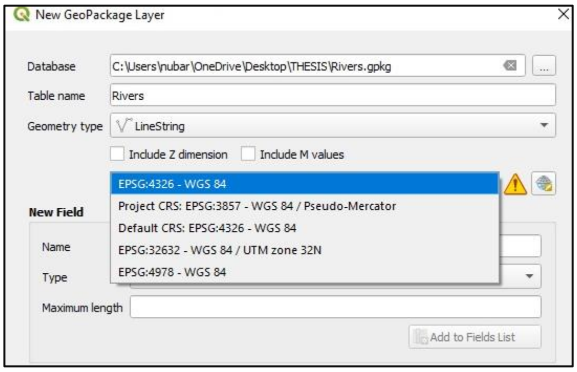
Digitizing Procedure Steps:

1. First from the layer → Add raster layer clicked
2. Then we need to set default Digitizing Options from settings → options→ digitizing

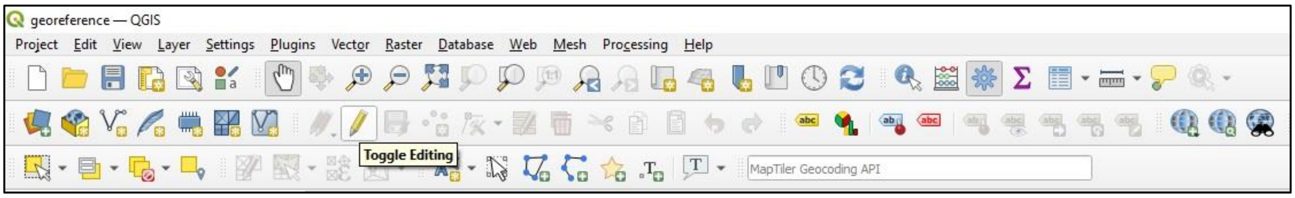


3. After arranging of the tool, it was started to digitize. First from New Geopackage tool a polygon layer was created to digitize rivers around the thermal plant's locations.





4. Following rivers layer was loaded, Toggle edition button activated to put the layer in editing mode.



5. Consecutive drawing rivers with right click feature ended and saved to layer. From properties, it is possible to change color, thickness of line.

Similar steps were implemented for another vector images as well. At the end of all processes, converted and transformed model were gathered with overlaying on GIS to check the conditions of plants and collect useful information from comparisons.

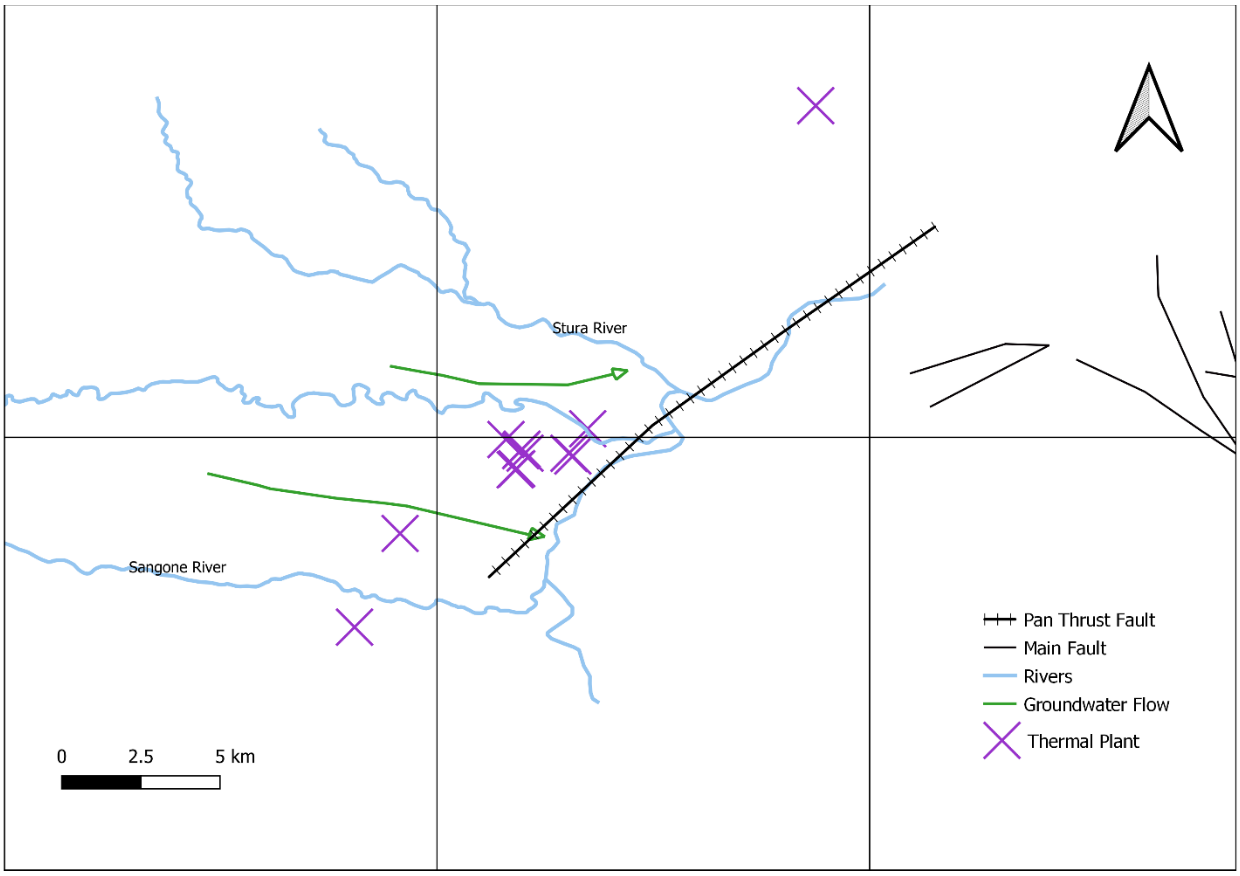


Figure 25 Ground Flow, Faults and Rivers Visualization

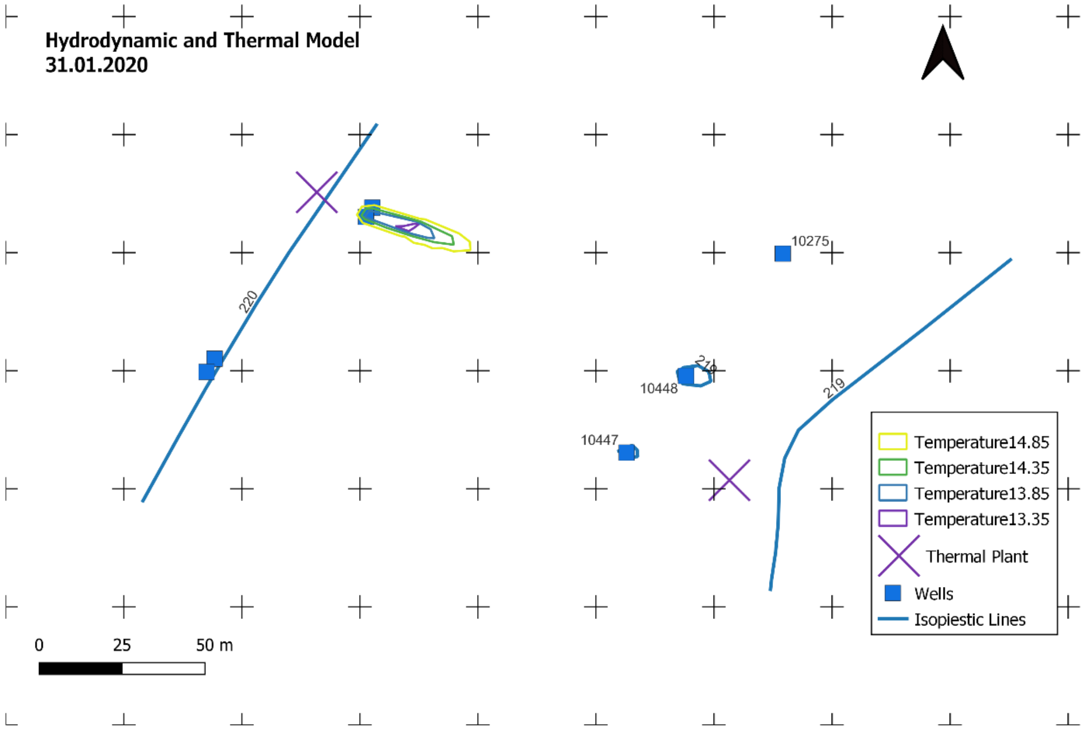


Figure 26 Georeferenced and Digitized Map of Thermal Plume Measurements (January)

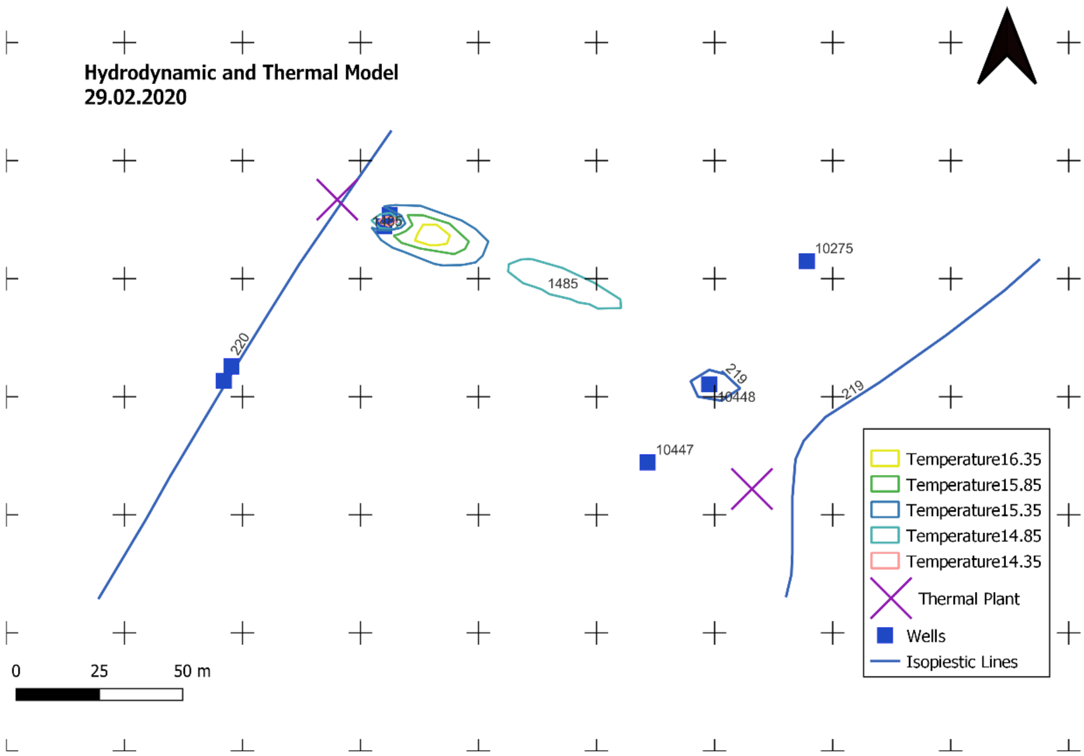


Figure 27 Georeferenced and Digitized Map of Thermal Plume Measurements (February)

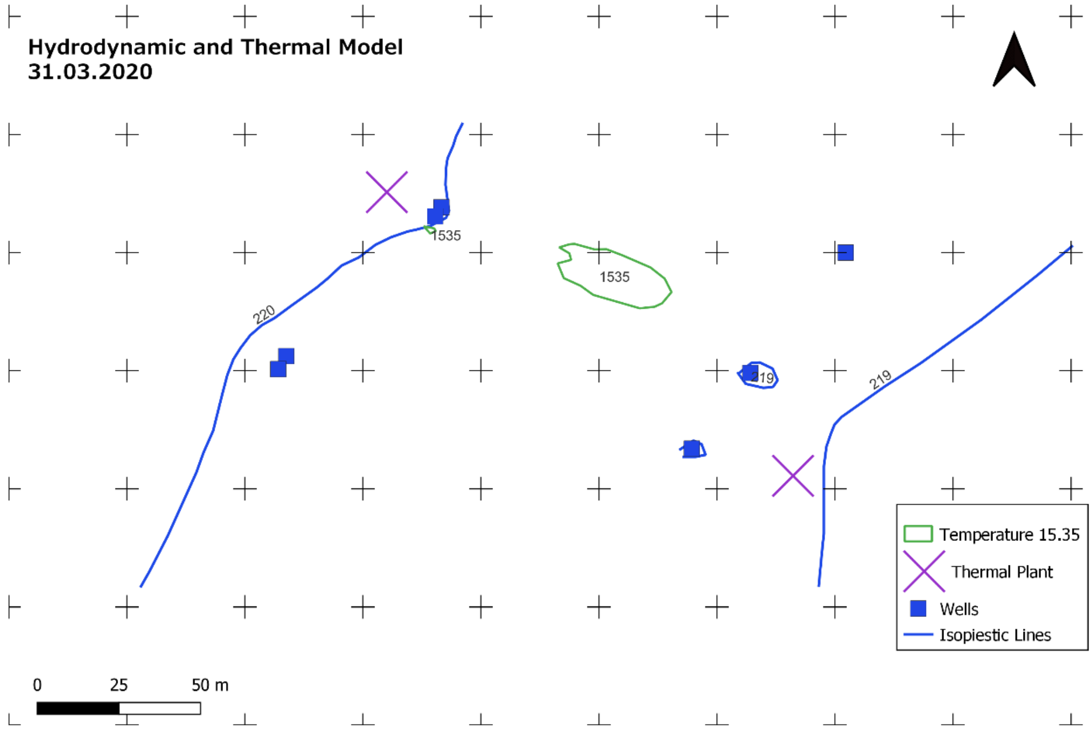


Figure 28 Georeferenced and Digitized Map of Thermal Plume Measurements (March)

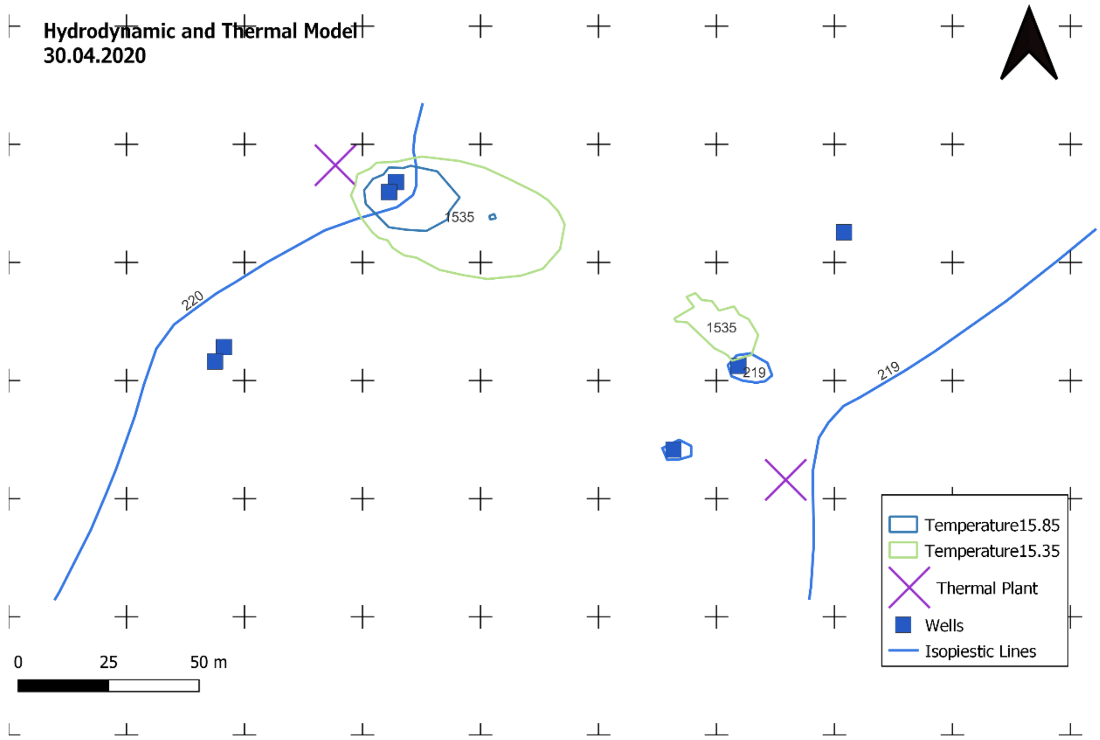


Figure 29 Georeferenced and Digitized Map of Thermal Plume Measurements (April)

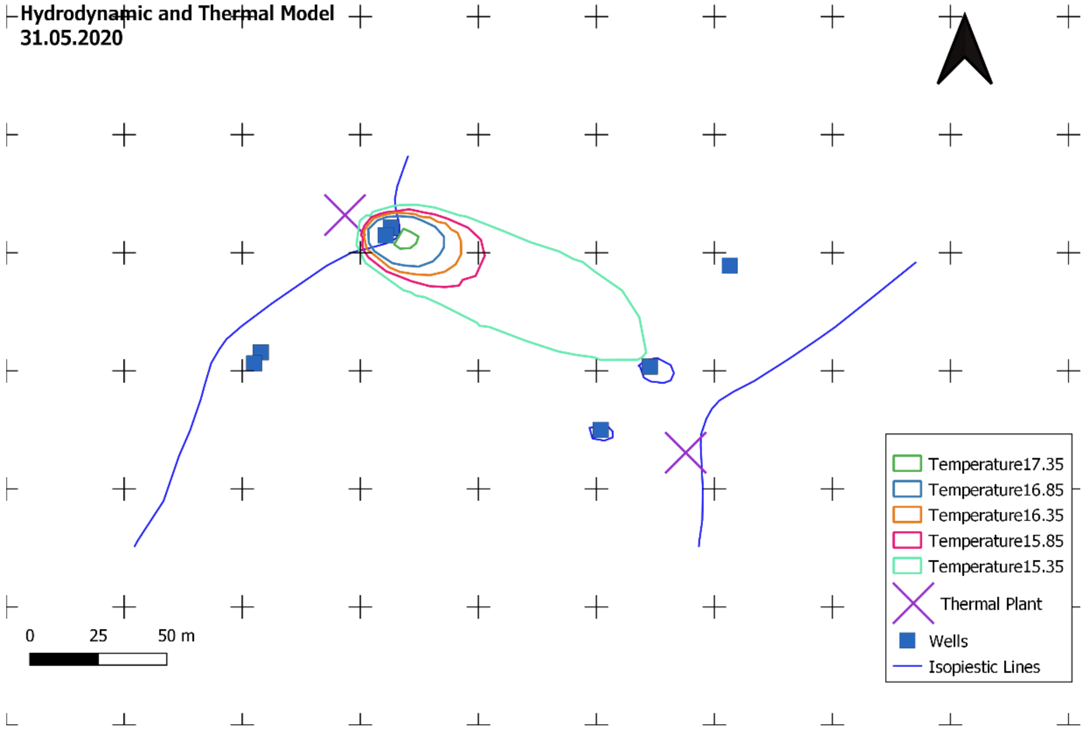


Figure 30 Georeferenced and Digitized Map of Thermal Plume Measurements (May)

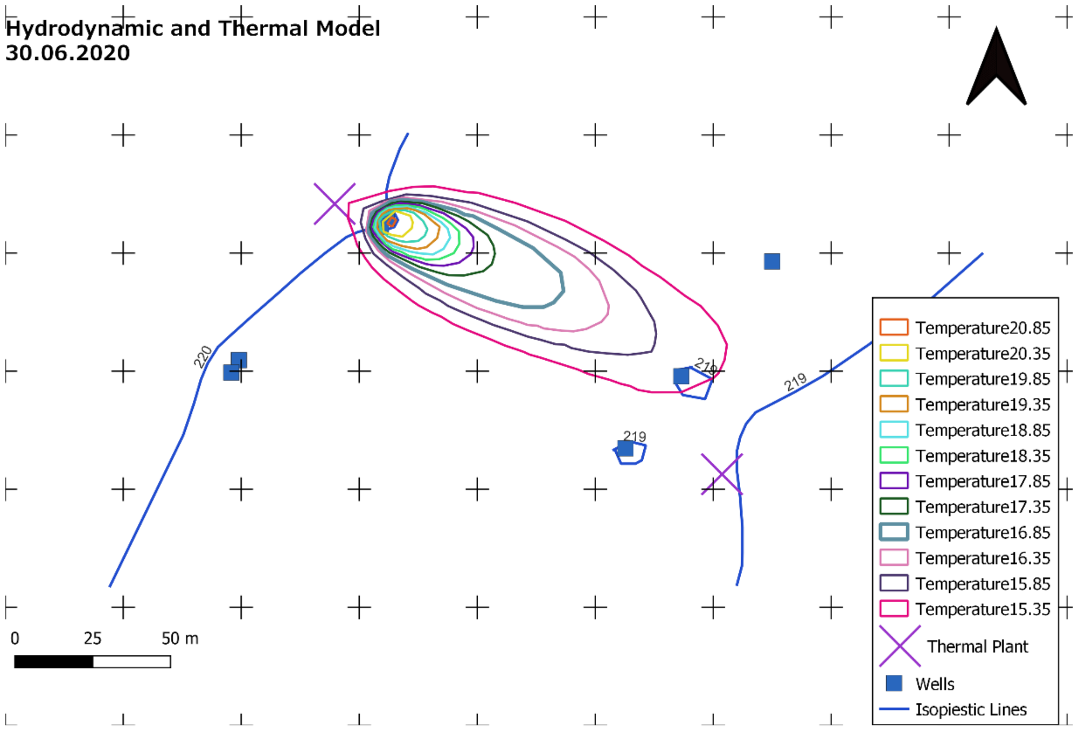


Figure 31 Georeferenced and Digitized Map of Thermal Plume Measurements (June)

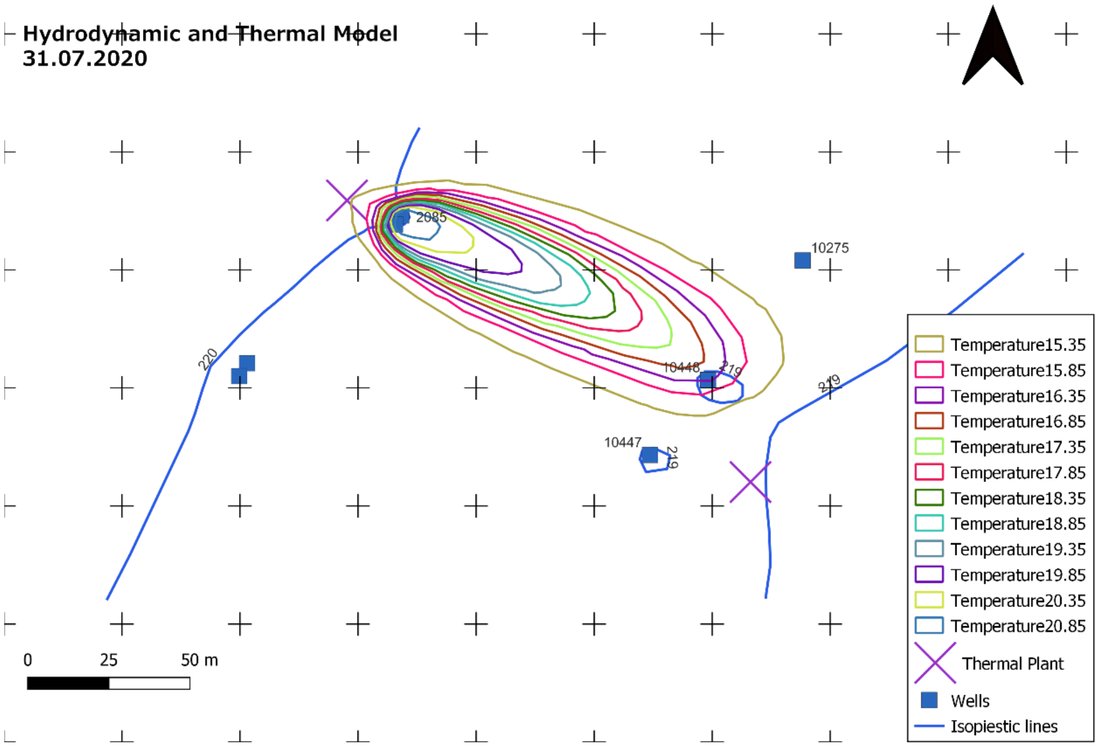


Figure 32 Georeferenced and Digitized Map of Thermal Plume Measurements (July)

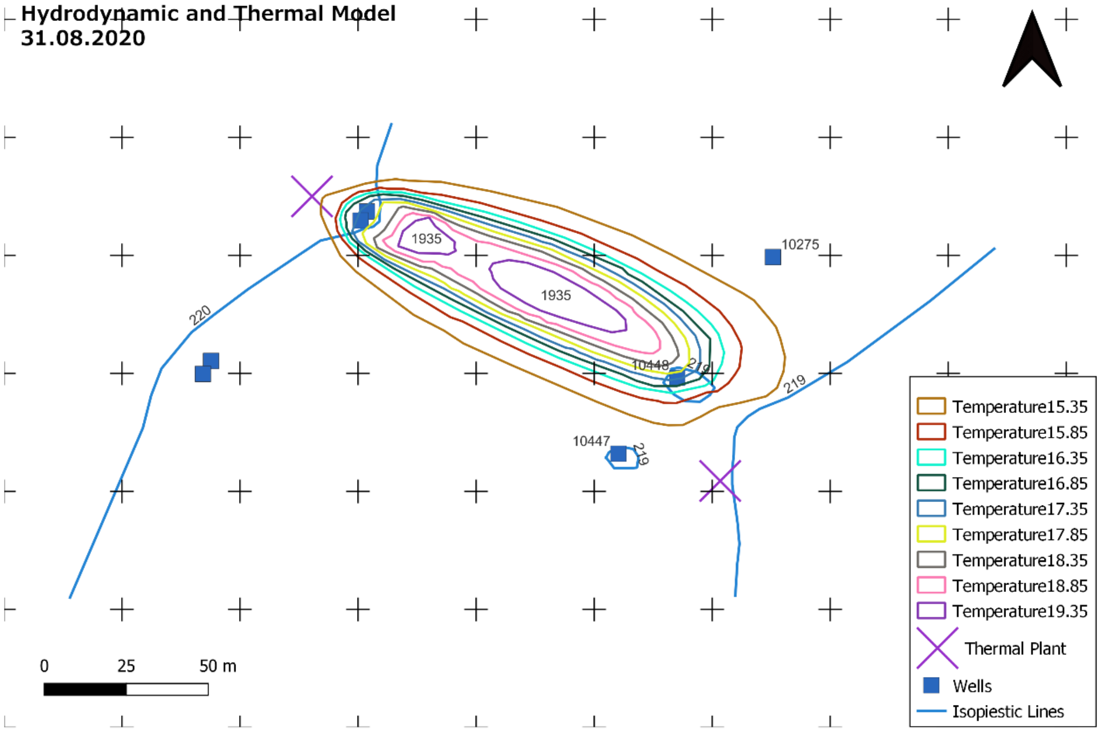


Figure 33 Georeferenced and Digitized Map of Thermal Plume Measurements (August)

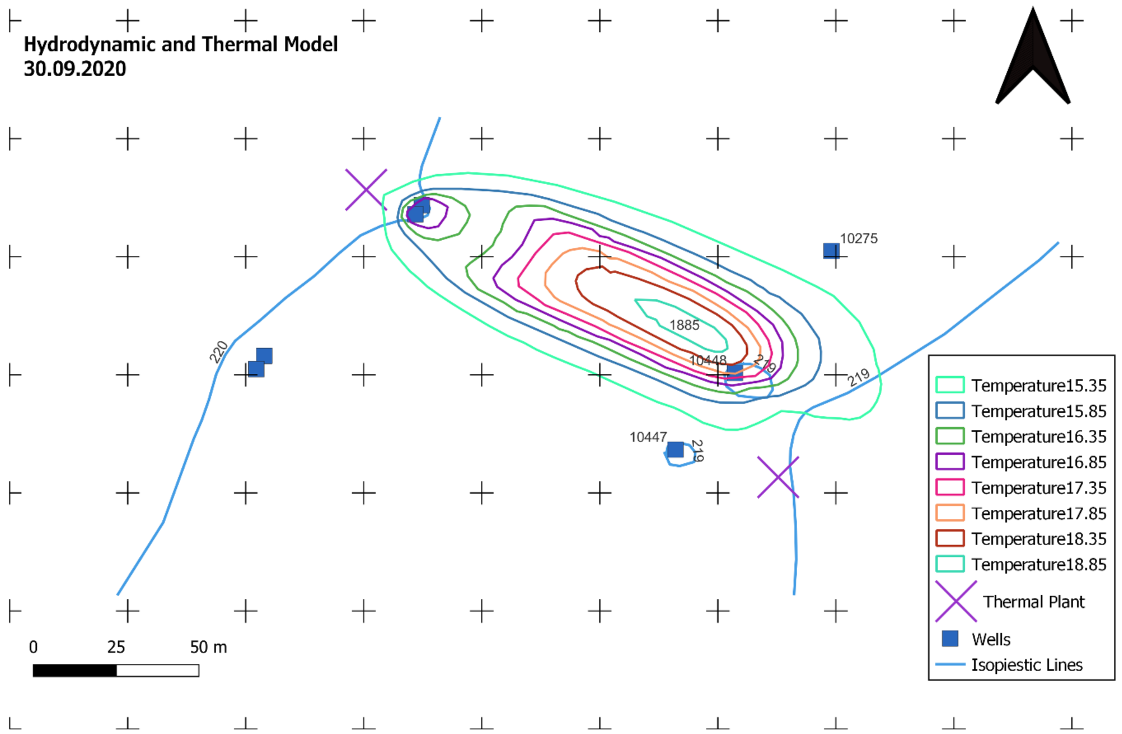


Figure 34 Georeferenced and Digitized Map of Thermal Plume Measurements (September)

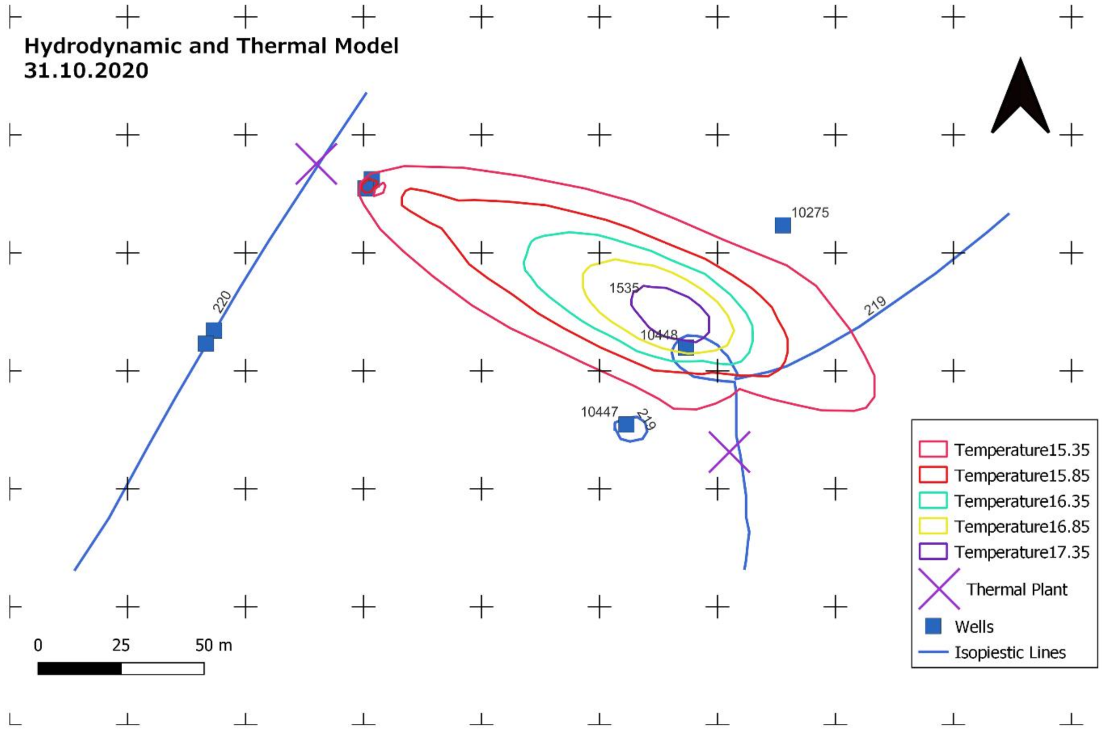


Figure 35 Georeferenced and Digitized Map of Thermal Plume Measurements (October)

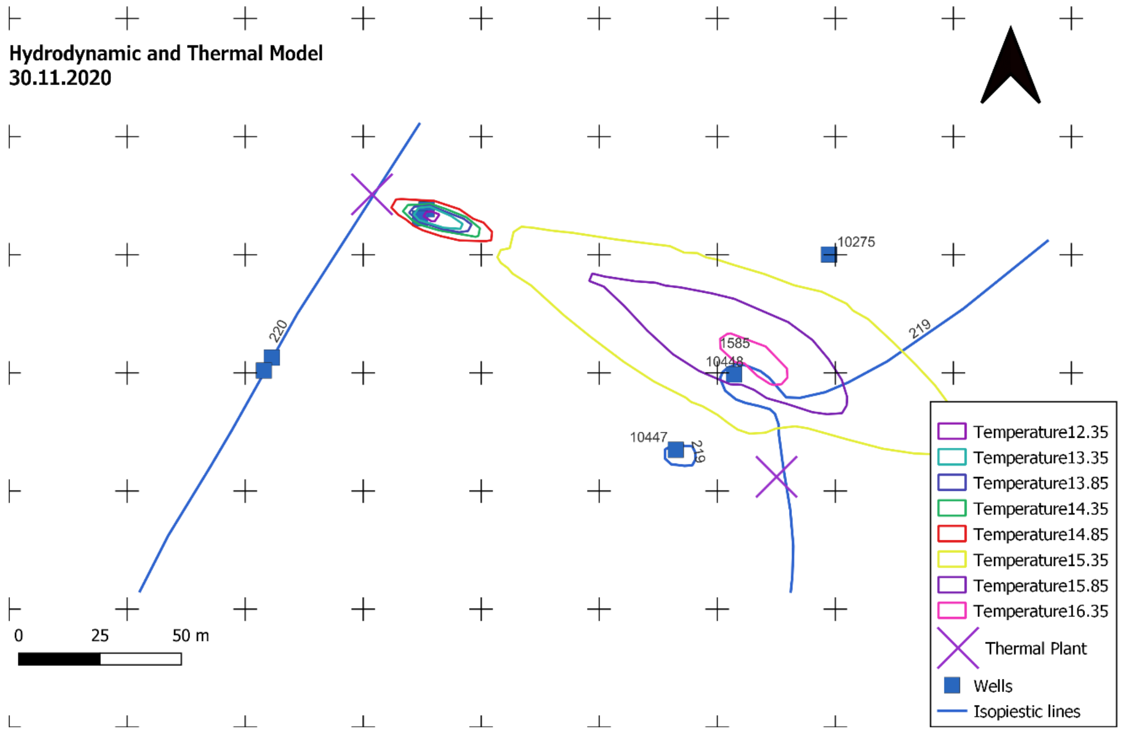
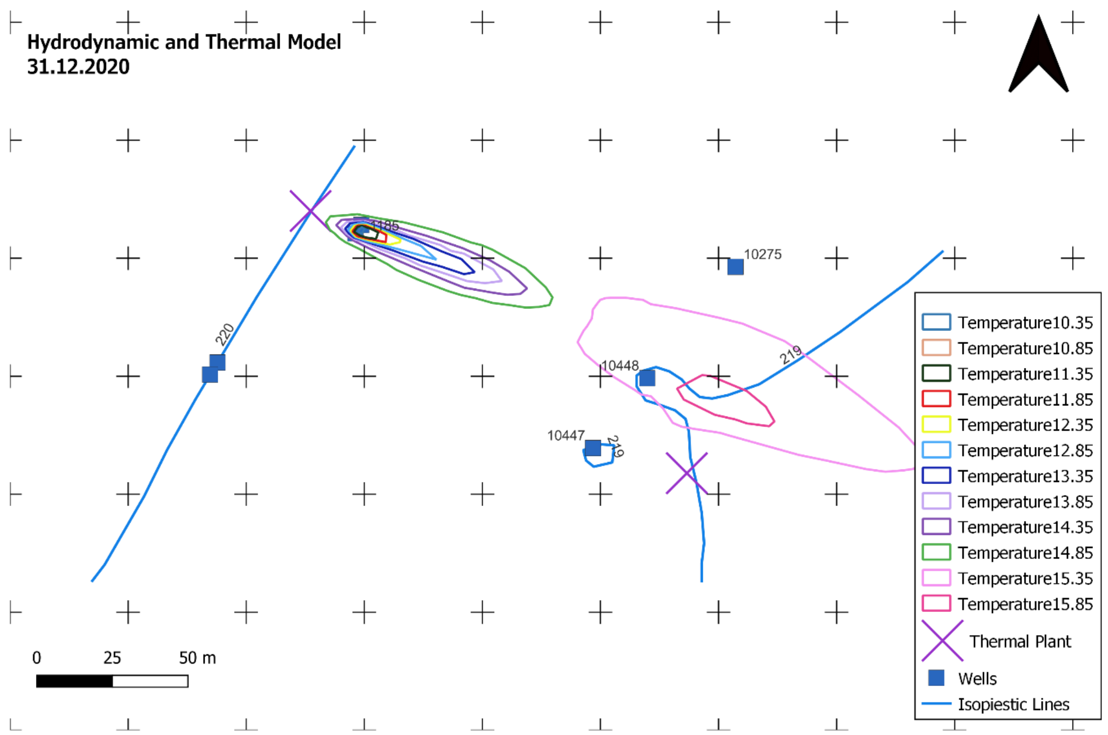


Figure 36 Georeferenced and Digitized Map of Thermal Plume Measurements (November)



3

Figure 37 Georeferenced and Digitized Map of Thermal Plume Measurements (December)

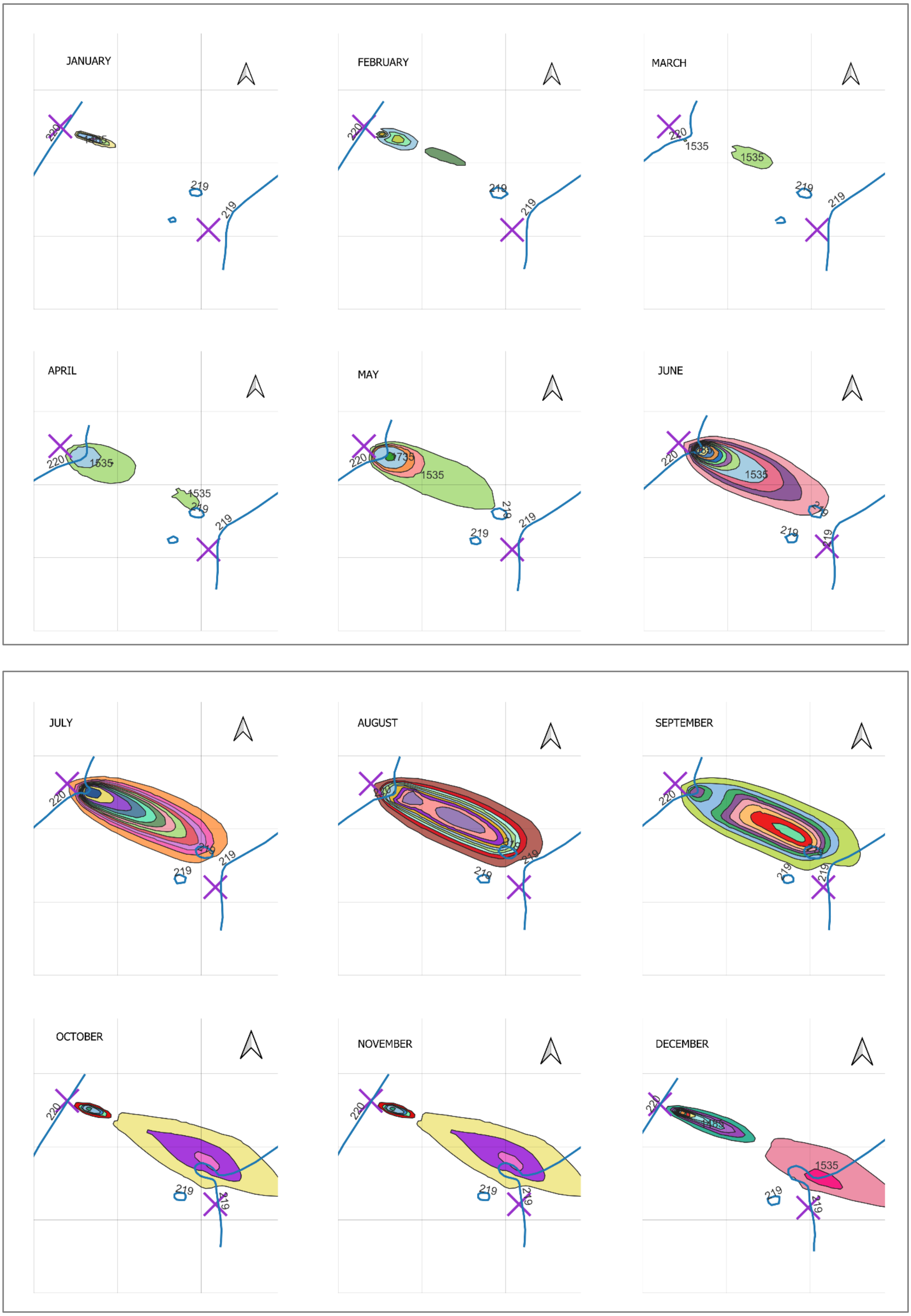


Figure 38 Thermal Plume Propagation Month by Month

CHAPTER 5

Various maps were georeferenced and visualized with datasets to understand the environmental, geological, human activities impacts around thermal plants. Besides the data collected concerned to thermal plume measurements from the 2020 year were digitized in previous step. In this chapter, there will be results plus comparisons and analyze in many aspects between georeferenced maps and deduced information from observations.

5. ANALYSIS

In advance of serving results of our examination, it will be productive to analysis to provide notable knowledge about shallow thermal systems in the urban. Geothermal installations and development of installed stations require the information of location properties as hydrogeology of terrain, thermal measurements, technical obstacles like landslides, polluted sites to analyze.

Existing critical situations regarding to the ground source heat pumps in terms of installation are artesian aquifers, swelling, landslide-prone area, soluble layers, mines, quarries, landfills, contaminated sites, low quality groundwater sites. On the other part, construction of GSHP could have impact related to thermal alteration. 2 systems are available to circulate fluids as open loop systems and closed loop systems.[43] Important parameters for the closed loop are thermal conductivity, ground temperature and for the open loop systems are aquifer thickness, gradient, transmissivity. [58]

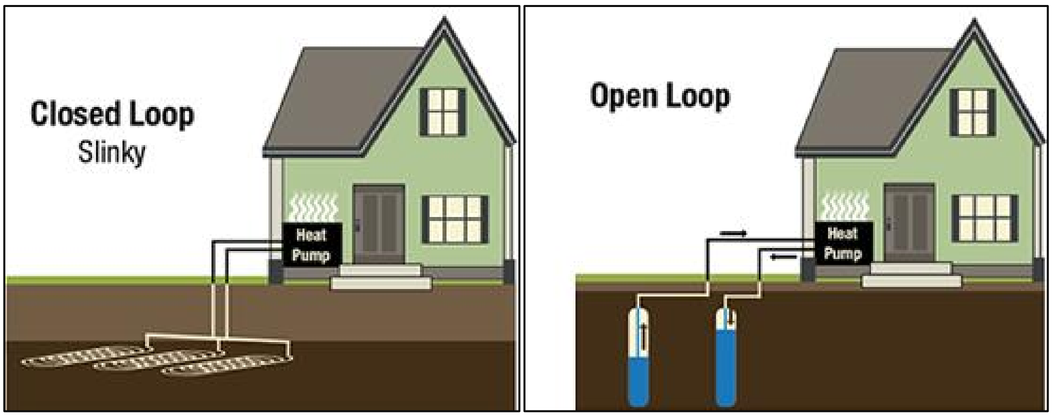


Figure 39 Geothermal Closed Loop System- Open Loop System [47]

Commercial geothermal power generation are drilled among reservoirs which have naturally convective systems. That does not mean naturally convective systems are always productive it also depends on fracture systems that allows fluid circulation in reservoirs. There are essential parameters affects convective sources namely heat, fractures and fluid. According to aforementioned information for geothermal development, fractures play important role, and its permeable structure contributes enable well production.[19]

Prediction of groundwater flow, heat flow is fundamental to assess the system performance broadly. [26]

Open loop systems are affected mainly by growing of Thermal Plume. Hydrogeological and subsurface characterizations are fundamental parameters that effects the thermal plume. In case of existence of thermal affected zones around the open-loop geothermal systems provide development of its. [61] Piezometric lines also called Isopiestic lines are a simple and quick way to define pore water pressures in a domain and promote hydrogeological and geological investigation.

Abu Nada specifies that it is not possible to manage completely the exploiting of groundwater in everywhere, its performance, efficiency depends considerably on prevalent hydrogeologic and geologic conditions. [62] It has various usage as heating or cooling therefore energy can be extracted or injected according to using mode. Thermal plumes develop due to discomforting of surrounded aquifer temperature. It is required to predict and assess the heat flow and groundwater to optimize the design and operation of GWHP systems. Normal temperature range disturbance of groundwater in case of GWHP system (7°C-10°C) availability lees than 2 %.[63] Bordering groundwater temperature of wells is related to aquifer properties.[26]

Geothermal heat pumps are charming systems for air conditionings of constructions that should be supported in smart city planning in order to improve clean air in urban environment.[58]

5.1. Environmental Impact Analysis of Thermal Plants

Environmental impact assessment takes notice during a project that could have the possible impacts on environment in respect to this, social and economic conditions and major decisions are taken accordingly. Whether proceeding of the project acts upon result of the impacts.
Thermal power plants are known as significant resource for electric production in the progressive countries. Thermal station based on stem driver works with heating water and triggers the movement of steam turbine. Therefore, heat is main task while design a thermal station. But this heat usage has impact on environment. There are different types of environmental issues subject to activities carried out. [44]

- Issues during construct phase regarding coal-based power
  Loss of biodiversity, dust pollution, noise pollution, erosion, loss of soil quality, huge diversion of land in case of power plant with captive mine

- Environmental impacts during operational stage
  Air pollution, waste generation, water consumption, emission of mercury, Greenhouse emission

- Impact of Thermal power on water source
  High impact on river & ground water,

  Apart from there are other issues due to thermal power plant.

- Air pollution due to plants
  Particulates matter, gaseous emission, Sulphur dioxide, oxides of nitrogen, carbon monoxide, hydrocarbon

- Air pollution from non-point source
  Indirect air pollution along transportation of coal about to using in thermal stations [44].

5.2. Results

Structural, hydrogeological, thermal, geological data is essential for exploration and benefit of the thermal energy.[17] Thermal installations are strongly influenced by the site-specific properties. For that reason, with the help of GIS applications knowledge of those properties were investigated and gathered in spatial environment. In this topic, relevant achievements and observations are explained. 2 considerations were discussed in this study. First consideration was realized in the first part of study which was performed with the help of georeferenced and digitized map of hydrogeological, geological of regions. Herewith, a general aspect gained via evaluation of the existing thermal plants in geography out of superimposed maps in GIS system. Thereby it enabled to deduce about interaction, evaluation of environmental impacts, determination of another plant needs in the area. 2 executed processes support to better analysis, management of dataset and easily identification of points on the integrated map. In the first process we presented the georeferenced style of several maps to catch a better results more than 3 ground control points employed during georeferencing. That operation provided us more superimposed map position.

From georeferenced hydrogeological map groundwater flow direction, streams, rivers information were achieved as transformed to vector data. Over transformed map following observation remarked namely, multi aquifer systems which are mostly groundwater system, are generated by coarse permeable deposits. Groundwater flowing towards Po River by means of morphology. And according to Cassasso and Sethi [58] investigation, it is known that a strong groundwater flow enhances the thermal transport Unconfined aquifer in entire city is hydraulically connected to drainage network for this reason, geothermal potential of low enthalpy heat pump systems is available either in local or region. Unconfined aquifer and plants are accommodated fluvioglacial sediments that is inclined the region to pollution in terms of aquifer. Besides 3 essential units were recognized around the present points of thermal plant, those are hydro stratigraphic units.[61] Intensively thermal installations are located between the Dora Riparia and Sangone rivers which are the Alpine rivers down streaming towards the east. One of the present plants has an interaction with river Dora Riparia.

Geological features such as faults, type of sediments, geological setting was acquired over georeferenced geology map and again those explicit saved as vector model.

It is observed from map that location consists of permeable silt and clay in Marine deposits of Hydrogeological complexes. Plus, there are productive aquifers. City center is mostly on Po plain which is consists of Pleistocene and Holocene sediments.

Glacial complex has sediments that are grain size which permits developing of small water table aquifers that occurs near the ground surface. [49] Padan frontal thrust fault is on Po River route Rio

Freddo Deformation zone fault is nearby the Po River region between Chieri and Chivasso. Other prevalent geological structures near Po plain are Tertiary Piedmont Basin and Alpine Alpennine Chain. Western part of plain is encircled with alluvial fans of fluvioglacial rivers.

Another determination regarding environmental condition of thermal plants is historical buildings. There is a pile of historic structures around installed power plants, but major constructions are Turin Cathedral, Mole Antonelliana, Porta Nuova, Royal Palace, Castle of Valentino, Medieval Castle.

In the second part of study once again similar proceedings were actualized as firstly georeferenced subsequently digitizing of remarkable features and survey results. Albeit, in this instance datasets are images concerned monthly thermal measurements and isopiestic lines (indicates piezometric surfaces). Dataset contains temperature measurement and monitoring of hydraulic levels by means of installed piezometers of the entire 2020 year. Measurements belong to 2 installed plants and monitored month by month during the entire year.

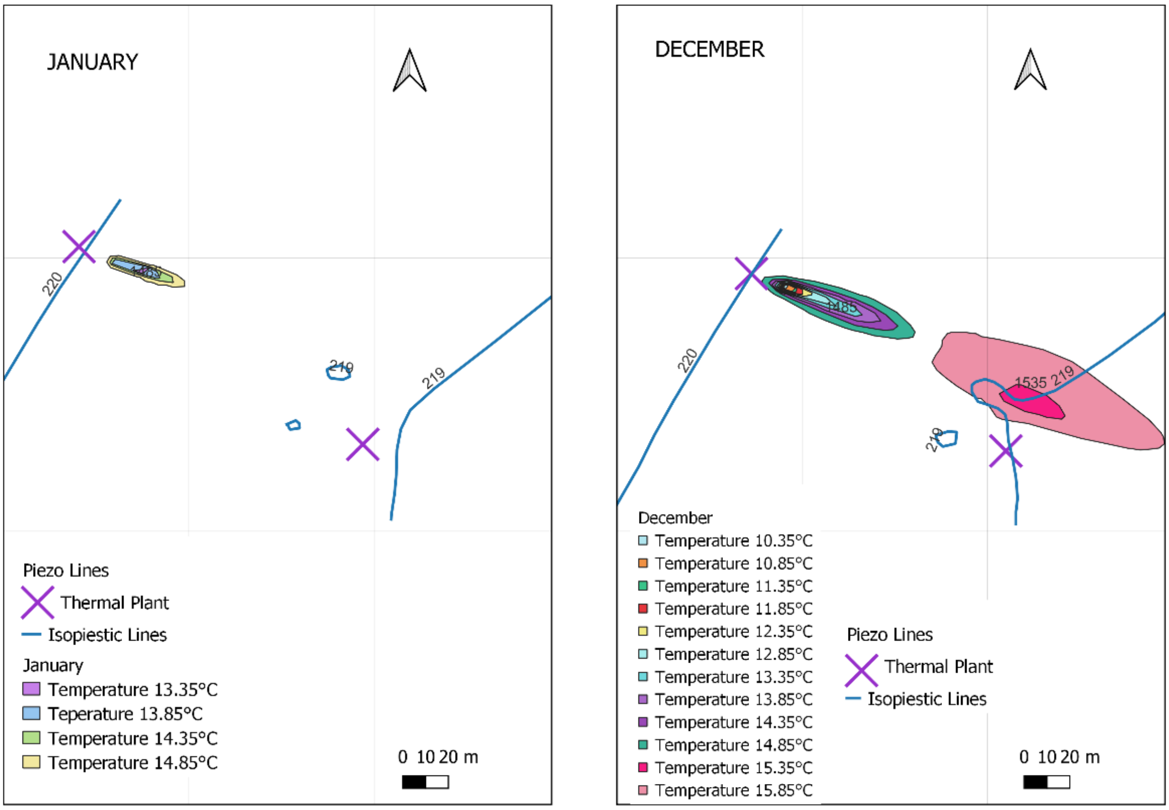


Figure 40 Thermal Plume Fluctuation Among January December Months

Those data highlights 3 phases in terms of temperature variation; between January to May it varies 13°C and 17°C from June to September an increase is present until 21°C in the last period again decreases of temperature is observed.

After May, propagation of thermal plume is appeared at a range of distance from approximately 50 to 300 meters around in wells location. Thermal plume is quite small along January, February, and March months. Piezometric surface provides an imaginary surface that indicates groundwater rising under hydrostatic pressure. As annual temperature changes, the isopiestic lines exhibit a progress towards wells close of year

Both geological investigations and thermal measurements examinations indicates the region is fruitful, this option could be assessed for alternative plant installation according to demands. Besides plants interact with buildings, historic buildings in urban. 3 main rivers surrounded around them in Turin city network. Thrust fault and main faults are passing nearby of present plant sites.

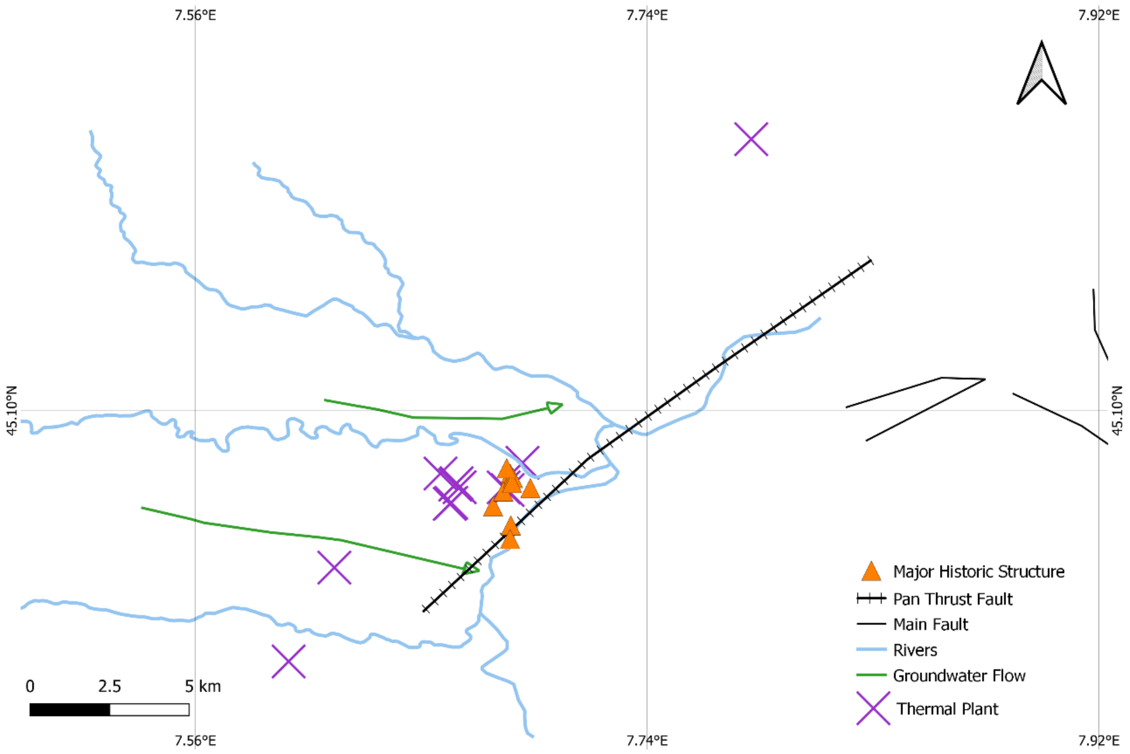


Figure 41Thermal Plant Overlayed to Features in One Map

CHAPTER 6

6. CONCLUSIONS

Before beginning the conclusion part of dissertation, it is concerning briefly to revise major topics of this study.

GIS technology applications are nowadays more and more preferred information systems on account of dealing with big dataset. It is a simple system with the whole of tools to store, manage, analysis, display and distribute information to authorities and communities. Likewise renewable energy systems exploring, development is based on spatial data which involves large information. Societies and states headed for less detrimental energy forms with the increasing of human energy demand. Geothermal as an alternative energy has popular fields of usage in many countries. Italy also exerts thermal sources considerably in last decades. Geographic information systems have integrated with improvement of thermal plants, sources for long in academic works. In our investigation, applying geographic information systems features enabled us to uniform datasets from different periods to be superimposed and directly compared with one another. Distinctive maps and images relevant gathered measurements of the study area were used to examine the spatial relation of plants and its surroundings. One map which is an indicator of hydrogeology of the area that attained rivers, streams, groundwater direction. Other is the geology map includes distribution of different types of rock, deposits, structures, faults. Plus, datasets which involve model images are concerned hydrodynamic and temperature and piezometric measurements.

Maps were combined with dataset through 2 basics processes via GIS technology, Georeferencing and Digitizing. 2 processes were performed primarily transforming a map in place to associate features with real world afterwards second step converting geographic data from georeferenced image into vector data by tracing features. Herewith processed images with adopted features fitted other spatial datasets. Hence, for each combination of output maps provided that obtaining and comparing with thermal plants dataset. GIS platform was used to integrate both data sources in the forms of layers, in the forms of Map plugins. After all processing done during the research it was demonstrated that visualization integrated data layers provide a perspective from the point of evaluation. By the help of GIS technology, we realized and approached given outcomes; Digitizing thermal plumes, observation of geological setting, faults, main rivers that affect the area, locally thermal distribution, potential thermal productivity of fieldwork.

That could be contributed to sustainable development, focusing on economic, environmental and community aspect. To this purpose it seems fundamental to investigate spatial analysis of thermal site within integration of other factors.

To sum up, the aim of paper was to use GIS system as a planning and monitoring tool for geothermal plants in urban areas, to find out the geological interaction around the plants, to display, to assess, to explore more information about thermal springs.
It can be addressed that application of GIS system to geothermal sites can be acknowledged a quick timesaver and effective both main and alternative solution.
It can be combined with the other GIS methodologies applied in renewable energy studied on. Proposed application could be used as preliminary survey in the interest of thermal resources exploration, plants construction planning for helping to speed up evaluation process, development of existing plants and to enable users displaying its proper format.
Additionally, this work is a preliminary to WebGIS in regard of any database presence thus far. The study will in future rely even more heavily on WebGIS as a tool for analysis, storage, decisions, and other application. GIS development processes faces new challenges as technology innovations in various environment by specialist and non-specialist users as is fulfilled in this paper. However, I believe that the heading in research would improve and help build a sound base from which to effectively use and evaluation.

BIBLIOGRAPHY

[1] Muffler, P., Cataldi, R., Methods for Regional Assessment of Geothermal Resources, Geothermics, Elsevier, Volume 7, pp. 53:89, https://doi.org/10.1016/0375-6505(78)90002-0

[2] Gizzi, M., Taddia, G., Abdin, E. C., Lo Russo, S., Thermally Affected Zone (TAZ) Assessment in Open-Loop Low-Enthalpy Groundwater Heat Pump Systems (GWHPs) Potential of Analytical Solutions, Hindawi Geofluids., Volume 2020, pp.1:13, https://doi.org/10.1155/2020/2640917

[3] Regulation of Europe Parliament and of the Council, European Commission Brussels, 14.07.2021, COM (2021) 555 Final 2021/0200(COD), pp. 1:226, https://ec.europa.eu/info/sites/default/files/proposal-amendment-effort-sharing-regulation-with-annexes_en.pdf

[4] Haenel, R., Rybach, L., Stegena, L., Handbook of Terrestrial Heat Flow Density Determination, Kluwer Academic Publisher, pp. 1:490, ISBN-13: 978-94-010-7780-4, https://my.u1lib.org/book/2239126/102292

[5] Chen, N.Y., Energy in the 21t Century, Chemical Innovations, Volume 31, pp. 14:20, https://pubsapp.acs.org/subscribe/archive/ci/31/i01/html/01chen.html#auth

[6] Geological Survey, Earth Structure Image Retrieved from https://www.gsi.ie/en-ie/education/our-planet-earth/Pages/The-Earth-structure.aspx

[7] Barbier, E., Geothermal Energy Technology and Current Status an Overview, Renewable Sustainable Energy Reviews, Elsevier, Volume 6, pp. 3:65, https://doi.org/10.1016/S1364-0321(02)00002-3

[8] Lingli, Z., Erving, A., Koistinen, K., Nuikka, M., Junnilainen, H., Heiska, N., Haggren, H., Georeferencing Multi Temporal and Multi Scale Imagery in Photogrammetry, pp. 1:6, https://www.academia.edu/21106195/Georeferencing_multi_temporal_and_multi_scale_imagery_in_photogrammetry

[9] Buckley, D. J., The GIS Primer an Introduction to Geographic Information Systems, Innovative GIS Solutions Inc., pp.2:115, ISBN: 978-14-625-2217-0, http://www.innovativegis.com/basis/primer/The_GIS_Primer_Buckley.pdf

[10] Ramachandra, T.V., Shruthi, B.V., Spatial Mapping of Renewable Energy Potential, Renewable and Sustainable Energy Reviews, Elsevier, Volume 11, pp. 1460:1480, https://doi.org/10.1016/j.rser.2005.12.002

[11] Meng, F., Liang, X., Xiao, C., Wang, G., Geothermal Resource Potential Assessment Utilizing GIS- Based Multi Criteria Decision Analysis Method, Elsevier, Volume 89, pp. 1:11, https://doi.org/10.1016/j.geothermics.2020.101969

[12] Manzella, A., Allansdottir, A., Pellizzone, A., Geothermal Energy and Society, Springer, Volume 67, pp. 1:288, 978-3-319-78286-7, DOI:10.1007/978-3-319-78286-7

[13] Caramiello, R., Polini, V., Siniscalco, C., Mercalli, L., A pollen Calendar from Turin (1981-1988) with Reference to Geography and Climate, Taylor&Francis, pp. 239:249, https://doi.org/10.1080/00173139009427757

[14] Noorollahi, Y., Application of GIS and Remote Sensing in Exploration and Environmental Management of Namafjal Geothermal Area, N Iceland, pp. 1:114, ISBN 9979-68-164-0

[15] Escidero, A. R., Garcia-Cascales, M. S., Urgueguia, J.F., Evaluation of the Shallow Geothermal Potential for Heating and Cooling and Its Integration in the Socioeconomic Environment: A Case Study in the Region of Murcia Spain, MDPI Energies, pp. 1:21, https://doi.org/10.3390/en14185740

[16] Fridleifson, B. I., Geothermal Energy for the Benefit of the People, Renewable and Sustainable Energy Reviews, Elsevier, Volume 5, pp.299:312, https://doi.org/10.1016/S1364-0321(01)00002-8

[17] Exploration for Deep Geothermal Reservoirs in Luxemburg and Surroundings Perspectives of Geothermal Energy Use, Schintgen Geothermal Energy, Springer, pp. 1:30, DOI 10.1186/s40517-015-0028-2

[18] Noorollahi, Y., Ghasempour, R., Jalilinasrabady, S., A GIS Based Integration Method for Geothermal Resources Exploration and Site Selection, Energy Exploration & Exploitation Volume 33, pp. 243:258, DOI:10.1260/0144-5987.33.2.243

[19] Hanano, M., Two Different Roles of Fractures in Geothermal Development, Proceedings World Geothermal Congress 2000, Volume 4, pp. 2597:2602, ISBN: 9-473-06811-7, https://www.researchgate.net/publication/265924852_Two_different_roles_of_fractures_in_geothermal_development

[20] Geothermal Power Station Image Retrieved from https://en.wikipedia.org/wiki/Geothermal_power#/media/File:Krafla_geothermal_power_station_wiki.jpg

[21] Mijnlieff, H., VanKempen, B., Tolsma, S., DeVries, C., Martins, J.E., Veldkamp, H., Struijk , M., Vrijlandt, M., Van Wees, J.D., Dutch Geothermal Resource Reporting. A First Attempt of Dutch Nationwide Geothermal Resource Using the UNFC Resource Classification System Status Date January 2019, 11-14 June 2019, pp. 1:6, https://www.researchgate.net/publication/337331184

[22] Malczeski, J., GIS -based Multicriteria Decision Analysis: A Survey of The Literature, International Journal of Geographical Information, Volume 20, pp. 703:726, ISSN: 1365-8816, https://doi.org/10.1080/13658810600661508

[23] Huttrer, G. W., The Status of World Geothermal Power Generation 1995-2000, Elsevier, Volume 30, pp. 1:27, https://doi.org/10.1016/S0375-6505(00)00042-0

[24] Bertani. R., Geothermal Power Generation in the World 2005-2010 Update Report, Proceeding World Geothermal Congress 25-29 April 2010, pp. 1:41, https://www.geothermal-energy.org/pdf/IGAstandard/WGC/2010/0008.pdf

[25] Hanssen, F., May, R., Van Dijk, J., Spatial Multi Criteria Decision Analysis Tool Suite for Consensus-Based Siting of Renewable Energy Structures, Journal of Environmental Assessment Policy and Management, World Scientific Publishing, pp. 1:27, https://doi.org/10.1142/S1464333218400033

[26] Lo Russo, S., Taddia, G., Advective Heat Transport in an Unconfined Aquifer Induced by the Field Injection of an Open-Loop Groundwater Heat Pump, American Journal of Environmental Sciences, pp. 253:259, http://dx.doi.org/10.3844/ajessp.2010.253.259

[27] Clarke, K., Advances in Geographic Information Systems, Pergamon Press, Elsevier, Volume 10, pp. 175:184, https://doi.org/10.1016/0198-9715(86)90006-2

[28] Ducker, K. J., Geographic Information Systems Research Issues, Center for Urban Studies, pp. 1:9, http://archives.pdx.edu/ds/psu/17944

[29] Parker, H. D., The Unique Qualities of a Geographic Information System: A Commentary, Cooperative GIS Technology Lab, Volume 54, pp. 1547:1549, ISSN: 0099-1112

[30] Yalcin, M., Kilic, F. G., A GIS-based Multi Criteria Decision Analysis Approach for Exploring Geothermal Resources: Akarcay Basin, Geothermics, Volume 67, pp. 18:28, https://doi.org/10.1016/j.geothermics.2017.01.002

[31] Nyemera, B. W., Jia, J., Effects of GIS Technology Application in Wellbeing Institutions, International Journal of Innovative Science and Research Technology, Volume 5, 1160:1175, ISSN No: -2456-2165

[32] Li, H., Chen, Z., Yong, L., Kong, S. C. W., Application of integrated GPS and GIS Technology for Reducing Construction Waste and Improving Construction Efficiency, Elsevier, Volume 14, pp. 323:331, https://doi.org/10.1016/j.autcon.2004.08.007

[33] Aydin, N. Y., Kentel, E., Duzgun, S., GIS-based Environmental Assessment of Wind Energy Systems for Spatial Planning: A Case Study from Western Turkey, Elsevier, Volume 14, pp. 364:373, https://doi.org/10.1016/j.rser.2009.07.023

[34] Zaher, M. A., Elbarbary, S., El-Shahat, A., Mesbah, H., Embaby, A., Geothermal Resources in Egypt Integrated With GIS-based Analysis, Elsevier, Volume 365, pp. 1:12, https://doi.org/10.1016/j.jvolgeores.2018.09.013

[35] Harris, J.R., Wilkinson, L., Grunsky, E.C., Effective Use and Interpretation of Lithogeochemical Data in Regional Mineral Exploration Programs: Applications of Geographic Information Systems (GIS) Technology, Elsevier, Volume 16, pp. 107:143, https://doi.org/10.1016/S0169-1368(99)00027-X

[36] Andreas Hack;oeer, Klaas Klasing, Jukka M. Krisp & Liqiu Meng ,Georeferencing: A Review of Methods and Applications, Taylor&Francis, pp. 61:69, ISSN: 1947-5683 (Print) 1947-5691 (Online), https://doi.org/10.1080/19475683.2013.868826

[37] Sommer, S., Wade, T., A to Z GIS: An Illustrated Dictionary of Geographic Information Systems, Esri Press, pp. 1:268, ISBN:978-1-58948-140-4

[38] Otto, J.C., Gunther, P., Blothe, J. H., Schrott, L., GIS Applications in Geomorphology, Elsevier, pp. 1:30, http://dx.doi.org/10.1016/B978-0-12-409548-9.10029-6

[39] Kraak, M. J, Ormeling, F., Cartography Visualization of Geospatial Data, Fourth Edition, pp.1:21, http://dx.doi.org/10.4324/9781315847184

[40] Chapman, A. D., Wieczorek, J. R., Version 743e3a1, Georeferencing Best Practices, Fourth Editon, pp.1:21, ISBN: 978-1-138-61395-9

[41] Lee, J. G., Kang, M., Geospatial Big Data: Challenges and Opportunities, Elsevier, Volume 2, pp. 74:81, https://doi.org/10.1016/j.bdr.2015.01.003

[42] Retrieved from https://www.researchgate.net/figure/GIS-has-capability-to-integrate-different-types-of-spatial-data-areas-ie-parts-of-the_fig8_221929448

[43] Casasso, A., Sethi, R., Assessment and Minimization of potential Environmental Impacts of Ground Source Heat Pump Systems (GSHP), MDPI Water 2019, pp. 1:19, https://doi.org/10.3390/w11081573

[44] Kumar, S., Katoria, D., Sehgal, D., Environment Impact of Thermal Power Plant for Sustainable Development, International Journal of Environmental Engineering, Volume 4, pp. 567:572, ISSN: 2231-1319, https://www.ripublication.com/ijeem_spl/ijeemv4n6_09.pdf

[45] Mutua, J., Ndombi, R., Use of GIS in Geothermal Resource Database Management – The case of AGID Web- GIS, Presented at SDG Short Course on Exploration and Development of Geothermal Resources, United Nations Environment Program Afrika Office Energy, pp. 1:7, http://theargeo.org/fullpapers/C7/Use%20of%20GIS%20in%20Geothermal%20Resource%20Database%20Management-converted.pdf

[46] Breunig, M., Bradley, P. E., Jahn, M., Kuper, P., Mazroob, N., Rosch, N., Al-Doori, M., Stefanakis, E., Jadidi, M., Geospatial Data Management Research: Progress and Future Directions, MDPI Information Journal of Geo-Information, Published 4 February 2020, pp. 1:20, https://doi.org/10.3390/ijgi9020095

[47] Retrieved from https://www.mnpower.com/ProgramsRebates/GroundSourceHeatPumps

[48] QGIS Desktop User Guide/ Manual, https://docs.qgis.org/3.16/en/docs/user_manual/index.html

[49] Forno, M. G., De Luca, D. A., Bonasera, M., Bucci, A., Gianotti, F., Lasagna, M., Luncchesi, S., Pelizza, S., Piana, F., Taddia, G., Synthesis on the Turin Subsoil Stratigraphy and Hydrogeology (NW ITALY), Alpine and Mediterranean Quaternary, pp. 147:170, ISSN (print): 2279-7327, ISSN (online): 2279-7335, http://dx.doi.org/10.26382/AMQ.2018.10

[50] Piana, F., Compagnoni, R., Barale, L., D'altri, A., Geological Map of Piemonte Region at 1:250000 scale. Explanatory notes ResearchGate, Academie Delle Scienza, Volume 41, pp. 1:147, ISSN: 1120-1630

[51] Luo, J., Wang, H., Zhang, H., Yan, Z., A Geospatial Assessment of The Installation Potential of Shallow Geothermal Systems in A Graben Basins, Elsevier, Volume 165, pp. 553:564, https://doi.org/10.1016/j.renene.2020.11.032

[52] Casasso, A., Sethi, R., Assessment and Mapping of Shallow Geothermal Potential in the Province of Cuneo (Piedmont, NW Italy), Elsevier, Volume 102, pp. 306:315, https://doi.org/10.1016/j.renene.2016.10.045

[53] Wekesa, F., The Use of GIS in Geothermal Resource Management: A Case Study of Olkaria Geothermal Project, Presented at SDG Short Course II on Exploration and Development of Geothermal Resources, pp. 1:7, ISSN: 1670-794x

[54] GIS Method Schema Retrieved from https://www.researchgate.net/figure/GIS-method-used-in-this-study_fig3_264812326

[55] Coordinate System Image Retrieved from https://www.esri.com/arcgis-blog/products/arcgis-pro/mapping/coordinate-systems-difference

[56] Map Projection Image Retrieved from https://googlemapsmania.blogspot.com/2017/10/working-with-map-projections.html

[57] De Nigris, S., Fraire, S., Energy Supply Analysis in the Province of Torino 4.2 Report August 2013, Central Europe,3sCE417P3 Introduction of Regional Energy Concepts, pp.1:30, http://www.cittametropolitana.torino.it/cms/risorse/ambiente/dwd/risenergetiche/osservatorio_energia/studi_analisi/energy_supply_analysis.pdf

[58] Casasso, A., Sethi, R., Territorial Analysis for the Implementation of Geothermal Heat Pumps in the Province of Cuneo, Elsevier, pp. 1159:1164, DOI: 10.1016/j.egypro.2015.11.083

[59] Santilano, A., Manzella, A., Donato, A., Nardini, I., Gola, G., Trumphy, E., Botteghi, S., Convective, Intrusive Geothermal Plays: What About Tectonics, Geothermal Energy Open Access Science, pp. 51:59, ISSN:21954771, http://dx.doi.org/10.5194/gtes-3-51-2015

[60] Manzelle, A., Serra, D., Cesari, G., Bargiacchi, E., Cei, M., Cerutti, P., Conti, P., Giudetti, G., Lupi, M., Vaccaro, M., Geothermal Energy Use Country Update for Italy, European Geothermal Congress 2019, Den Haag the Netherlands 11-14 June 2019, pp. 1:20, https://www.researchgate.net/publication/333995413_Geothermal_Energy_Use_Country_Update_for_Italy

[61] Taddia, G., Underground Exploitation in Urban Areas by Geothermal Heat Pump Systems: The Example of Turin Politecnico Test Site (NW Italy), Alpine and Mediterranean Quaternary, pp. 235:244, ISSN:2279-7327, https://doi.org/10.26382/AMQ.2018.18

[62] Abu-Nada, E., Akash, B., Al-Hinti, I., Al-Sarkhi, A., Nijmeh, S., Ibrahim A., Shishan, A., Modelling of a Geothermal Standing Column Well, International Journal of Energy Research, pp. 306:317, http://dx.doi.org/10.1002/er.1355

[63] Hecht-Mendez, J., Giraldo, N. A. M., Bayer, P., Blum, P., Evaluating MT3DMS for Heat Transporting Simulation of Closed Geothermal Systems, Ground Water, pp. 1:16, https://doi.org/10.1111/j.1745-6584.2010.00678.x

[64] Junger, S., Using Georeferenced Data in Social Science Survey Research, Gesis, pp.1:288, ISSN:1869-2869, https://doi.org/10.21241/ssoar.63688