

## Evaluation of the Aggregate Potential of the Northern Kocaeli Province with the Help of a Geographical Information System (GIS)

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### Abstract

In this study, existing and potential aggregate areas in the north of the province of Kocaeli in Turkey were determined by using a geographic information system (GIS). In order to perform the analysis, the status of the existing quarries and geological units where quarries were operated, and identification of areas that are suitable to be operated in the future were considered in the process as five basic criteria. These criteria were classified as the geology, land use, elevation, roads and settlement (distance to the county centers) factors. Each criterion in the study represented a layer within the geographic information system. Overlaying these layers in the system, a map showing potential areas was created. According to this map, areas that could be considered as crushed rock aggregate potential areas in the North of the Province of Kocaeli were classified as low, medium, good and high zones.

**Keywords:** Aggregate, Potential, GIS (Geographic Information System).

### 1. Introduction

Aggregates are non-organic materials that have natural origin such as sand, gravels and crushed rock or materials with artificial origin such as blast furnace slag, expanded perlite and expanded clay that are combined in concrete making with the help of the binding material that consists of water and cement (Erkol and Aydımdağ 2012).

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In developing and growing countries, in parallel to the population, settlements also increase fast. In this context, the amounts of aggregates that are produced and consumed increased. It has become a necessity to find new aggregate resources to meet these needs. To determine these resources, one should consider the geological and engineering-related characteristics of crushed rock raw materials, their mineralogical compositions and significance in the construction sector (Esenli 1996). In addition to these, the aggregate quarries that are operated should also be evaluated amongst each other. This is because it would be easier this way to determine what kind of problems related to aggregates are experienced in several sectors (Arioğlu 2003). Moreover, this will provide advantages in determining the areas where these resources may be found. One should consider aggregate quarries' capacity and usage, production method and technology, standards, production quantities, foreign trade status, sectoral problems, environment policies and the objectives that are aimed to be reached (DPT 2001). Arioğlu and Tokgöz evaluated quarries in and around the province of Istanbul based on several parameters. They prepared a report as a result of their evaluation. In the report, they examined these quarries based on research, operation permits, problems of quarries with expired permits, production and reserve capacity and the lithological, physical and mechanical characteristics of rocks (Arioğlu and Tokgöz 1996). Nasser conducted a supply-demand analysis within the Colorado Denver Metropolitan area. According to the results of their analysis, they divided aggregate production areas into two groups as operational and potential areas (Nasser 1987). Erdoğan studied the distributions of the quarries, and the lithologic, chemical, physical, mechanical and technological properties of rocks in the quarries from west of Istanbul (Çatalca) to west of Kocaeli (Gebze) (Erdoğan 1993). Doğan et al., evaluated the general conditions of quarry mines and engineering properties

of rocks in the quarries in Istanbul Province and its surroundings (Doğan et al 2003). The studied area covered the north of the province of Kocaeli (north of the Northern Anatolia Fault Line) in north-western Turkey (Figure 1).

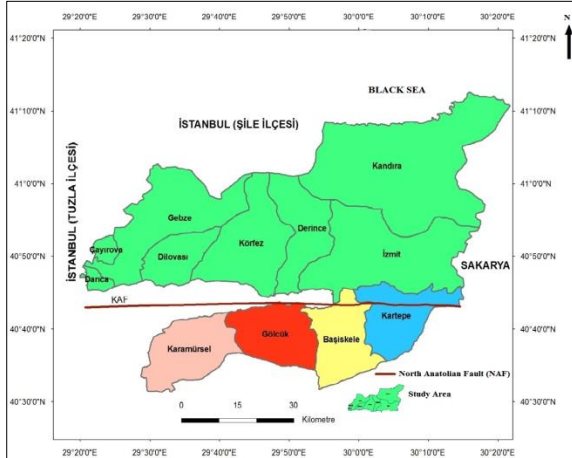


Figure 1. The map of study area

The units in this area usually consisted of sedimentary rocks. Among these rocks, especially limestone and dolomitic limestones had a broad area of distribution, while the dolomite clast contents were high and slightly separated. Due to such characteristics, these rocks were determined to be more suitable for usage as concrete aggregates, road aggregates and filling material (Erkol and Aydınadağ 2012). The units on which the existing aggregate quarries in the examined area were operational were demonstrated based on their locations with the help of a geographical information system (GIS). The areas that could have potentials were divided into certain regions (Demir 2010). Karakaş and Coruk evaluated aggregate supply-demand status by monitoring the flow of aggregate distribution over the transportation network in the “Front Range Corridor” area of the State of Colorado (Karakas and Coruk 1999). Kerri, Ferbey and Levson determined potential aggregate resource areas for Northwestern British Columbia (Canada) by using GIS remote sensing and GPS (Kerr et al 2005). The most important purpose for using GIS in this study was to helping easiness in tangible modelling for aggregate areas that might have a potential. For this purpose, in the system, certain criteria (geology of the investigated area, roads, elevation settlement status and land usage) were determined, and with the help of these criteria, areas that could be potential sources were determined.

## 2. Materials and Methods

A GIS (Geographical Information System) was used as the material to determine the aggregate areas in the studied region that were operational and those that could have a potential.

**Method:** With the help of the GIS, the studied area was analyzed in two parts. The first part consisted of those that was operational in the year 2010, while the second part consisted of those that could have a potential. In the examined area, there were 14 different crushed rock quarries. 10 of these were in and around the district of Gebze, while 4 were in the Körfez-Derince area, and there were none in the Kandıra-İzmit area. The quarries in and around Gebze usually consisted of units of limestone and dolomitic limestone (Table 1). Previous studies determined the petrographic, chemical and mechanical properties of these units, as well as their potentials of becoming aggregates, by using various experiments. To determine the physical and mechanical characteristics of aggregates, dry unit weight, effective porosity and uni-axial compressive strength experiments were carried out, while specific weight, water absorption, fine material rate, Los Angeles abrasion rate, flatness and length index experiments were conducted to assess their usability as aggregates (Table 2).

With the data that were obtained, the aggregates were evaluated in terms of the areas where they could be usable. Among these areas of usage, the most frequently encountered ones were ready-mixed concrete, asphalt, fertilizer industry, filling, road and infrastructure materials, as well as raw material for cement [10]. The aggregate units that were operated in the Körfez-Derince region consisted of limestones in the lithologic sense (Table 3).

To determine the physical and mechanical characteristics of aggregates, dry unit weight, effective porosity and uni-axial compressive strength experiments were carried out, while specific weight, water absorption, fine material rate, Los Angeles abrasion rate, flatness and length index experiments were conducted to assess their usability as aggregates. These results are given in Table 4 (Zarif et al 2003).

The aggregates that were obtained from the crushed rock quarries were used in concrete, asphalt, filling materials and road construction. There was no aggregate quarry in the İzmit-Kandıra region. However, the unique Kandıra stone was processed there. It was determined that the aggregates in this region consisted of biomicritic limestone units in the lithologic sense (Tansel 1989). These units are soft and have a homogenous structure, while they do not

contain crack fillings that lead to changes in hardness and characteristics or mineral irregularities. Due to such characteristics, they are used in cutting or decorative stones, façade and garden wall covers, paving stones and barbecue and fireplace construction. The destruction caused by the 1999 earthquake in the region, increased population and large-scale projects like MARMARAY have led people to search for new aggregate resources. For this reason, determination of new aggregate resource areas has great importance for the province of Kocaeli in the economic sense (Karakaş 2014). The potential aggregate regions in the north of Kocaeli were evaluated by a GIS based on certain criteria (classified geology, elevation roads, settlement status and land usage). As a result of the assessment, the areas where aggregates could be obtained were classified as low, medium, good and high levels. Geologically, the studied area usually consisted of sedimentary rocks. However, there were occasionally magmatic and metamorphic rocks, too. Magmatic rocks have a stronger structure in comparison to sedimentary and metamorphic rocks. This is why the aggregates obtained from these rocks have higher quality in comparison to others. However, the granites in the studied area in the magmatic rock group had very thick separation characteristics. Aggregates to be obtained from these units might not have much quality. This is why these units were assessed as low-level aggregate potentials (LLAP). As another member of the magmatic rock group, the volcanites in the studied area had relatively thicker tuff and agglomerate contents and limited fresh lava levels in occasional places, and therefore, they were considered to be medium level (MLAP). In the metamorphic rock group, chlorite schist, epidote schist and sericite schist covered a very small area. As these rocks had experienced metamorphosis, they were considered to have a medium-level aggregate potential. Sedimentary rocks constituted a large part of the studied area. Especially limestones in this rock group were the most frequently observed and had the highest quality, while they were divided into different classes of potential based on their copresence with different units (Table 5). These were considered to have low-, medium-, good- and high-level aggregate potentials (LLAP, MLAP, GLAP, HLAP).

While determining the potential areas within the studied area, land usage was considered as the second criterion. In areas where aggregate quarries would be established, the operations of such quarries would lead to environmental pollution, and as a result of explosions, mudslides, rock falls and tremors on the ground. In order to minimize the negative effects of such issues, attention should be paid to select areas

outside settlement areas and agricultural land, while choosing areas close to main roads for the sake of cost minimization. It was observed that the quarries that were operational in the studied area were established on agricultural lands. These agricultural lands turned to unproductive for this reason. The land usage statuses in the studied area were of Classes I to VII, including 7 classes in total (Table 6).

The studied area was assessed based on the parameter of elevation and it was observed that the land consisted of different layers of elevation levels starting at the sea level. This is why the studied area was divided into 4 classes of elevation, as 0-200 m, 200-400 m, 400-600 m and 600-640 m (Table 7). The greatest effect of the elevation parameter in determining aggregate potential is that it affects operational costs.

Considering the aggregate areas that could have a potential in the studied area based on the parameter of road status, the most important factor is the proximity to main roads. This is because this distance significantly affects the costs of transporting the aggregate that is obtained from the quarry to the place where it will be used. As the province of Kocaeli is an industrial province and a transition point between Istanbul and Ankara, its roads are developed. This is why it is desired to establish aggregate and crushed rock quarries at places close to residential areas and concrete stations. In short, considering the road status in terms of aggregate production, as the distance to main roads increases, costs will also increase, and this is why roads are an important factor for determining aggregate potentials. Thus, as a main factor that affects costs, distance to main roads was considered. Here, these distances were evaluated as very far from main roads (farther than 60 km), far from main roads (20-60 km), close to main roads (5-20 km) and very close to main roads (0-5 km) (Table 8).

The studied area was finally evaluated in terms of settlement status. The evaluation included firstly Gebze and its surroundings as it is an industrial zone, secondly İzmit Bay coastal line and finally the district of Kandıra. Due to the presence of several industrial facilities in this region and the fast increase in settlement areas, the need for aggregates increased. In the environmental sense, quarries established within residential areas lead to several problems such as air shock as a result of explosions, tremors on the ground, loose rocks and dust that result out of breaking and sieving. These make it difficult for crushed rock quarries to be operated economically and continuously. Aggregate production areas based on their locations of operation relative to settlement

areas were evaluated under 4 categories as very problematic areas in the center of residential areas (0 km), problematic ones very close to residential areas (5-6 km), slightly problematic ones close to residential areas (6-8 km) and very slightly problematic ones outside residential areas (8-39 km) (Table 9).

The aggregate areas that could have potential in the north of the province of Kocaeli were evaluated in the GIS based on geological unit, land usage, elevation, roads and settlements, and the areas with low-, medium-, good- and high-level potentials were determined (Table 10).

A chart was created to show the LLAP, MLAP, GLAP and HLAP areas that were determined with the help of the GIS and how much area they covered (Figure 2). In this chart, LLAP (low-level aggregate potential) took an area of 473 km<sup>2</sup>, MLAP (medium-level aggregate potential) covered 1205 km<sup>2</sup> of area, GLAP (good-level aggregate potential) had an area of 778 km<sup>2</sup>, HLAP (high-level aggregate potential) covered an area of 104 km<sup>2</sup>. Accordingly, in the studied area, MLAP had the highest land area, while HLAP had the lowest.

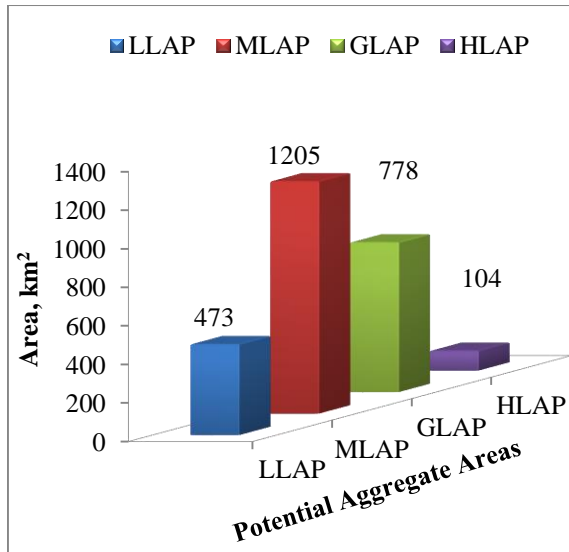


Figure 2: Distribution of the potential aggregate areas

### 3. Results and Discussion

The studied area consisted of magmatic, metamorphic and sedimentary rocks, while the most suitable ones were sedimentary rocks in terms of their potential to be aggregates.

In the group of magmatic rocks, granites were considered to have a low-level aggregate potential (LLAP) as they had very thick separation characteristics, while volcanites were accepted to have a medium-level aggregate potential (MLAP) as they had relatively thicker tuff and agglomerate levels, limited thickness of fresh lava levels and the occasional presence of them.

In the group of metamorphic rocks, chlorite schist, epidote schist and sericite schist were considered to have MLAP as they surfaced in a very limited area and had been exposed to metamorphosis. Sedimentary rocks constituted a large part of the studied area. Especially limestones in this rock group were the most frequently observed and had the highest quality, while they were divided into different classes of potential based on their copresence with different units.

For the aggregate material obtained from the operated quarries, the most frequent usage areas were ready-mixed concrete, fertilized industry, filling, road and infrastructure materials, as well as cement raw material, based on previous studies.

When the locations of 14 different existing aggregate quarries were visualized on the geological map that was prepared by using the GIS, it was determined that they processed units of limestone and dolomitic limestone.

By using GIS, the areas in the north of Kocaeli with the potential to be sources of aggregates were determined based on geological units, land usage, elevation, roads and settlement areas. In this process, a chart and a map were created to show the areas that could have low, medium, good and high potentials for aggregates.

With the help of this map, the areas suitable for processing the units in the north of the province of Kocaeli as aggregates were modelled, and this resulted in this preliminary study which may be guiding for firms or individuals who will operate such quarries.

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## Appendix

Table 1: General Information on Quarries in and around Gebze (Modified from [7])

| No | Firm Name                    | Quarry Location | Quarry Ownership Status          | Date of Starting Production | Lithology           | Annual Production, ton | Sales, ton/year | Usage Areas  |
|----|------------------------------|-----------------|----------------------------------|-----------------------------|---------------------|------------------------|-----------------|--|
| 1  | Aytaç Ayhanlar Madencilik    | Gebze           | Forest-Privately Registered Land | 1997                        | Dolomitic Limestone | 1.5-2.5 million        | 1.5-2.5 million | Ready-mixed concrete, asphalt and fertilizer industry              |
| 2  | De-Taş Madencilik            | Gebze           | Forest                           | 2000                        | Limestone           | 350.000                | 350.000         | Ready-mixed concrete   |
| 3  | Kancataş Maden               | Gebze           | Forest                           | 1995                        | Dolomitic Limestone | 1.5-2 million          | 1.5-2 million   | Concrete and asphalt   |
| 4  | Kıbsaş Maden                 | Gebze           | Forest-Privately Registered Land | 1988                        | Limestone           | 1.5 million            | 1.5 million     | Concrete, asphalt, filling, road and infrastructure material       |
| 5  | Koca Beton Agrega Madencilik | Gebze           | *                                | *                           | Limestone           | *                      | *               | *  |
| 6  | Laferge Beton                | Darıca          | *                                | *                           | Limestone           | *                      | *               | *  |
| 7  | Madeks Madencilik            | Gebze           | Forest                           | 2006                        | Limestone           | 1.5 million            | 1.5 million     | Concrete and road construction                                     |
| 8  | Maden Yapı Beton Madencilik  | Gebze           | Forest                           | 2002                        | Limestone           | 2-2.5 million          | 2-2.5 million   | Concrete, asphalt and cement raw material                          |
| 9  | TCT İnş. Maden               | Gebze           | Forest-Privately Registered Land | 2004                        | Dolomitic Limestone | 1.5-2 million          | 1.5-2 million   | Concrete and asphalt   |
| 10 | Akçansa Çimento              | Gebze           | Forest                           | 1994                        | Limestone           | 2 million              | 2 million       | Ready-mixed concrete, asphalt, filling and infrastructure material |

\*Infirmination not provided

Table 2: Experimental analysis results for aggregate quarries in and around Gebze

| Specific Weight Gs | Dry Unit Weight $\gamma_d$ , ton/m <sup>3</sup> | Water Absorption $W_a$ , % | Effective Porosity $n_e$ , % | Uni-Axial Compressive Strength $\sigma_c$ , kg/cm <sup>2</sup> | Resistance to Sodium Sulfate ( $Na_2SO_4$ ), % | Los Angeles Abrasion Value (500 rev.), % | Flatness Index, % | Length Index, % |
|--------------------|---|----------------------------|------------------------------|--|--|--|-------------------|-----------------|
| 2.71-2.84          | 2.71-2.82                                       | 0.30-0.47                  | 0.98-1.55                    | 1050-1280  | 1.7-2.2  | 19.2-21.6                                | 17.9-18           | 27.1-28.4       |

Table 3: General Information on Quarries in the Körfez-Derince Region

| No | Firm Name  | Quarry Location | Quarry Ownership Status | Date of Starting Production | Lithology | Annual Production, ton   | Sales ,ton/year        | Usage Areas                             |
|----|--|-----------------|-------------------------|-----------------------------|-----------|--------------------------|------------------------|---|
| 1  | Me-ka Küçükaya Madencilik                              | Hereke          | Forest                  | 1998                        | Limestone | 500 thousand - 1 million | 1 million              | Concrete, asphalt and road construction |
| 2  | Örgüç Madencilik                                       | Hereke          | Forest-Mine             | 1969                        | Limestone | 600.000                  | 600.000                | Ready-mixed concrete                    |
| 3  | Özmaş Müt. Ve Tic. A.Ş.                                | Hereke          | Forest                  | 1998                        | Limestone | 1 million 250 thousand   | 1 million 250 thousand | Concrete, asphalt and filling           |
| 4  | Simgekocafalt Kocaeli Asfalt İnşaat Madencilik ve San. | Hereke          | Forest                  | 2003                        | Limestone | 1 million 250 thousand   | 400-500 thousand       | Asphalt                                 |

Table 4: Experimental results on the aggregate quarries in the Körfez-Derince region.

| Specific Weight Gs | Dry Unit Weight $\gamma_d$ , ton/m <sup>3</sup> | Water Absorption Wa, % | Effective Porosity $n_e$ , % | Uni-Axial Compressive Strength $\sigma_c$ , kg/cm <sup>2</sup> | Resistance to Sodium Sulfate (Na <sub>2</sub> SO <sub>4</sub> ), % | Los Angeles Abrasion Value (500 rev.), % | Flatness Index, % | Length Index, % |
|--------------------|---|------------------------|------------------------------|--|--|--|-------------------|-----------------|
| 2,69               | 2,66  | 0,65                   | 2                            | 760  | 0,45   | 21                                       | 21,4              | 34,8            |

Table 5: Assessment of geological units based on their aggregate potentials.

| Classified Geology | Geological Units  | Potential Level | Explanations |
|--------------------|---|-----------------|--------------|
| Water              | Water   | 1               | -            |
| Slope Wast         | Slope Wash  | 20              | LLAP         |
| Aluvion            | Aluvion   | 30              | LLAP         |
| Granite            | Granite   | 35              | LLAP         |
| Shale              | Shale   | 39              | LLAP         |
| Metamorphics       | Chlorite schist, epidote schist and sericite schist                       | 51              | OKAP         |
| Volcanites         | Aglomerate, andesite, basalt and tuff                                     | 59              | MLAP         |
| Sedimentary 2      | Sandstone and shale   | 50              | MLAP         |
| Sedimentary 8      | Limestone, shale, mudstone, pebbles, marl, chert, siltstone and claystone | 54              | MLAP         |
| Sedimentary 5      | Limestone, shale and sandstone  | 55              | MLAP         |
| Sedimentary 9      | Limestone, pebbles and shale  | 58              | MLAP         |
| Sedimentary 6      | Pebbles, sandstone and mudstone   | 75              | İKAP         |
| Sedimentary 4      | Limestone, shale and sandstone  | 77              | GLAP         |
| Sedimentary 3      | Pebbles and sandstone   | 79              | GLAP         |
| Sedimentary 7      | Limestone, pebbles and sandstone  | 80              | HLAP         |
| Sedimentary 1      | Limestone and shale   | 84              | HLAP         |
| Limestone          | Limestone   | 90              | HLAP         |

Table 6: Assessment of land usage in terms of aggregate potentials.

| Land Classes   | Land Status                     | Potential Level | Explanations                           | Potential Level |
|----------------|---------------------------------|-----------------|--|-----------------|
| Class I land   | Agriculture-settlement-industry | 30              | Aggregate production not suitable      | Low             |
| Class II land  | Settlement-low agriculture area | 50              | Aggregate production slightly suitable | Medium          |
| Class III land | Settlement-industry             | 50              | Aggregate production slightly suitable | Medium          |
| Class IV land  | Industry-low settlement area    | 70              | Aggregate production suitable          | Good            |
| Class V land   | Field-orchard-pasture           | 70              | Aggregate production suitable          | Good            |
| Class VI land  | Forest-pasture-forage           | 90              | Aggregate production very suitable     | High            |
| Class VII land | Settlement area                 | 30              | Aggregate production not suitable      | Low             |

Table 7: Determining aggregate potentials based on elevation

| Elevation Classes, m | Elevation Status | Explanations            | Potential Level |
|----------------------|------------------|-------------------------|-----------------|
| 0-200 m              | Very low parts   | Costs very suitable     | High            |
| 200-400 m            | Low parts        | Costs suitable          | Good            |
| 400-600 m            | High parts       | Costs slightly suitable | Medium          |
| 600-640 m            | Very high parts  | Costs not suitable      | Low             |

Table 8: Determining aggregate potentials based on road status.

| Distance to Main Roads | Distance, km | Explanations    | Potential Level |
|------------------------|--------------|-----------------|-----------------|
| Very far               | Over 60 km   | Very high costs | Low             |
| Far                    | 20-60 km     | High costs      | Medium          |
| Close                  | 5-20 km      | Low costs       | Good            |
| Very Close             | 0-5 km       | Very low costs  | High            |

Table 9: Determining aggregate potentials based on settlement status.

| Distance to Settlement   | Distance, km | Explanations              | Potential Level |
|--------------------------|--------------|---------------------------|-----------------|
| Center of Settlement     | 0 km         | Very problematic          | Low             |
| Very Close to Settlement | 4-6 km       | Problematic               | Medium          |
| Close to Settlement      | 6-8 km       | Slightly problematic      | Good            |
| Outside Settlement       | 8-30 km      | Very slightly problematic | High            |

Table 10: Criteria for Determining Potential Areas



| Aggregate Potential | Classified Geography  | Land Status   | Elevation           | Road Status                       | Settlement Status                 |
|---------------------|---|---|---------------------|-----------------------------------|-----------------------------------|
| LLAP                | Aluvion, water, granite, slope wash and shale   | I (agriculture-settlement-industry) and VII (settlement)            | 600–640 m           | Very Far (over 60 km)             | Center of Settlement (0 km)       |
| MLAP                | Sedimentary 2 (sandstone and shale), sedimentary 5 (limestone, shale, sandstone and marl), sedimentary 8 (limestone, shale, mudstone, pebbles, marn, chert, siltstone and claystone), sedimentary 9 (sandstone, pebbles and shale), metamorphic (chlorite schist, epidote schist and sericite schist) and volcanites (agglomerate, basalt, andesite and tuff) | II (settlement-low agricultural area) and III (settlement-industry) | 400–600 m           | Far (20-60 km )                   | Very Close to Settlement (4-6 km) |
| GLAP                | sedimentary 3 (pebbles and sandstone), sedimentary 4 (limestone, shale and sandstone) and sedimentary 6 (pebbles, sandstone and mudstone)   | IV (industry-low settlement area) and V (field-orchard-pasture)     | 200–400 m           | Close or Could Be Close (5-20 km) | Close to Settlement (6-8 km)      |
| HLAP                | limestone, sedimentary 1 (limestone and shale) and sedimentary 7 (limestone, pebbles and sandstone)   | VI. (forest-pasture-forage)   | 0-200 and 200-400 m | Very Close (0-5 km)               | Outside Settlement (8-30 km)      |