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Orkustofnun, Grensásvegur 9,
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GEOTHERMAL ENVIRONMENTAL IMPACT ASSESSMENT WITH SPECIAL REFERENCE TO THE TUZLA, GEOTHERMAL AREA, CANAKKALE, TURKEY

Alper Baba
Canakkale Onsekiz Mart University
Engineering and Architecture Faculty
Geological Engineering Department
17020 Canakkale
TURKEY
alperbaba@comu.edu.tr

ABSTRACT

Environmental Impact Assessment (EIA) work is becoming more and more extensive in the world. The environmental assessment process has been defined differently in different countries. In fact, it appears that no two countries have defined it in exactly the same way. It is an aid to decision-making and to the minimization or elimination of environmental impacts at an early planning stage. The EIA process is potentially a basis for negotiations between the developer, public interest groups and the planning regulator. Geothermal energy is generally accepted as being an environmentally benign energy source, particularly when compared to fossil fuel energy sources. Geothermal fields contain heated fluids trapped beneath the earth, but the geological, physical and chemical characteristics of the geothermal resource can vary significantly. When these resources are utilized for geothermal production, the environment of an area can be affected. The Tuzla geothermal area is located within the Canakkale city boundary, where one of the important archaeological, historical and natural park sites of Turkey is situated. In this study, a brief review of the regulatory and legal requirements that will affect the utilization of the Tuzla geothermal field under Turkish law is presented. The assessment of impacts on each part of the environment, and recommendations for mitigating measures to ensure that impacts are maintained at an acceptable level will also be considered.

1. ENVIRONMENTAL IMPACT ASSESSMENT

1.1 Introduction

In recent years, there has been a remarkable growth of interest in environmental issues – sustainability and improved management of development in harmony with the environment. *Environmental Impact Assessment* (EIA) is the tool most widely used in environmental management. The first EIA process was established in the USA in 1969. EIA systems have been set up worldwide and become a powerful environmental safeguard in the project planning process. EIA has been established in various forms throughout the world, beginning with Canada in 1973, Australia in 1974, Germany in 1975, and France in 1976 –and later in other countries too (Thors and Thóroddsson, 2003). Many countries have adopted their own EIA procedures. Every country that has developed a process for making Environmental Impact Assessments has given it a different name and some slightly different meaning (Roberts, 1991). For example: in China, Iceland and Turkey it is *Environmental Impact Assessment* (EIA); the U.S. version is *Environmental Impact Statement* (EIS); in New Zealand it is *Assessment of Environmental Effects* (AEE). Elements of EIA in China, Germany, El Salvador, Iceland, Indonesia, Italy, Japan, Kenya, New Zealand, Philippines, Turkey and USA are discussed in this study. These countries have regulations that require an environmental analysis of a proposed geothermal project, as well as specific regulations that define the quantities of pollutants that may be emitted to the atmosphere or discharged to land and water.

The purpose of this study is:

- To compare EIA methods in different countries;
- To find a suitable EIA method for the geothermal field of Tuzla; and
- To assess environmental impact of the utilization of Tuzla (Canakkale) geothermal area.

1.2 Definitions and purpose

Environmental Impact Assessment (EIA) can be defined as*:* The process of identifying, predicting, evaluating and mitigating the biophysical, social, and other relevant effects of development proposals prior to major decisions being taken and commitments made (IAIA, 1999).

Environmental Impact Assessment is a process with several important purposes. The general purposes of EIA are summarized by IAIA (1999):

- To ensure that environmental considerations are explicitly addressed and incorporated into the development decision-making process;
- To anticipate and avoid, minimize or offset the adverse significant biophysical, social and other relevant effects of development proposals;
- To protect the productivity and capacity of natural systems, and the ecological processes which maintain their functions; and
- To promote development that is sustainable and optimizes resource use and management opportunities.

An *Environmental Impact Report (EIR)* is used to predict the environmental consequences of an action before the EIA report. EIR offers the public a way to be involved in the decision-making process. Although various countries and environmental professionals have developed slightly different procedures for the preparation of an EIR, the basic steps are the same. The general basic steps of the EIR and the general stages of the EIA are shown in Figures 1 and 2.

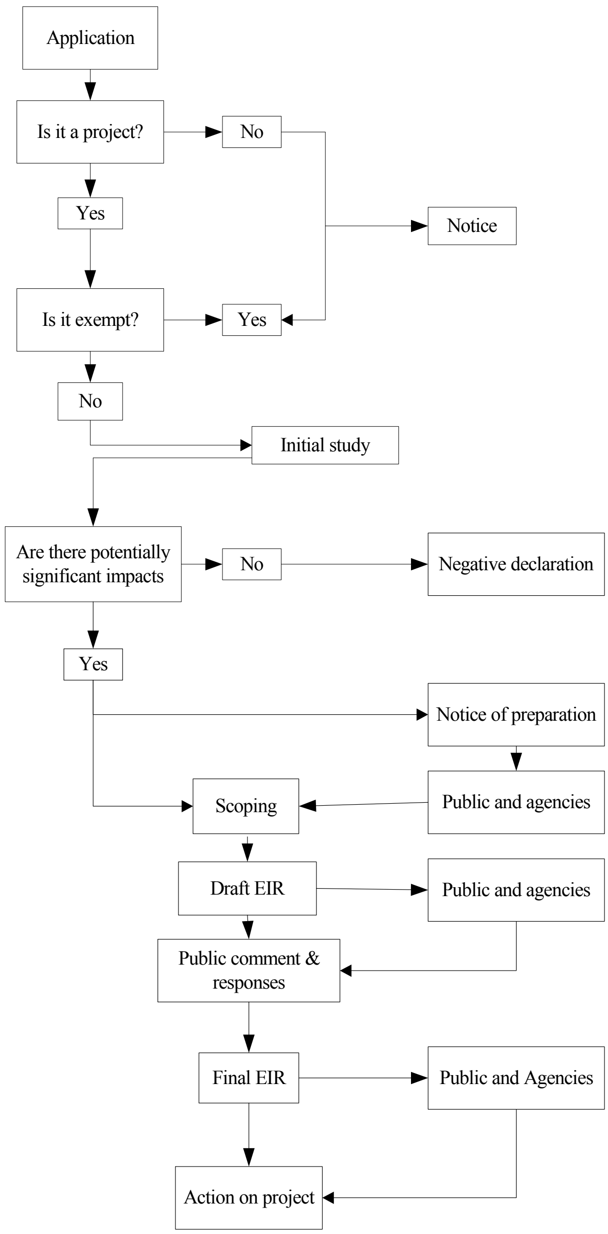

FIGURE 1: Basic steps in preparing an EIR (Roberts, 1991)

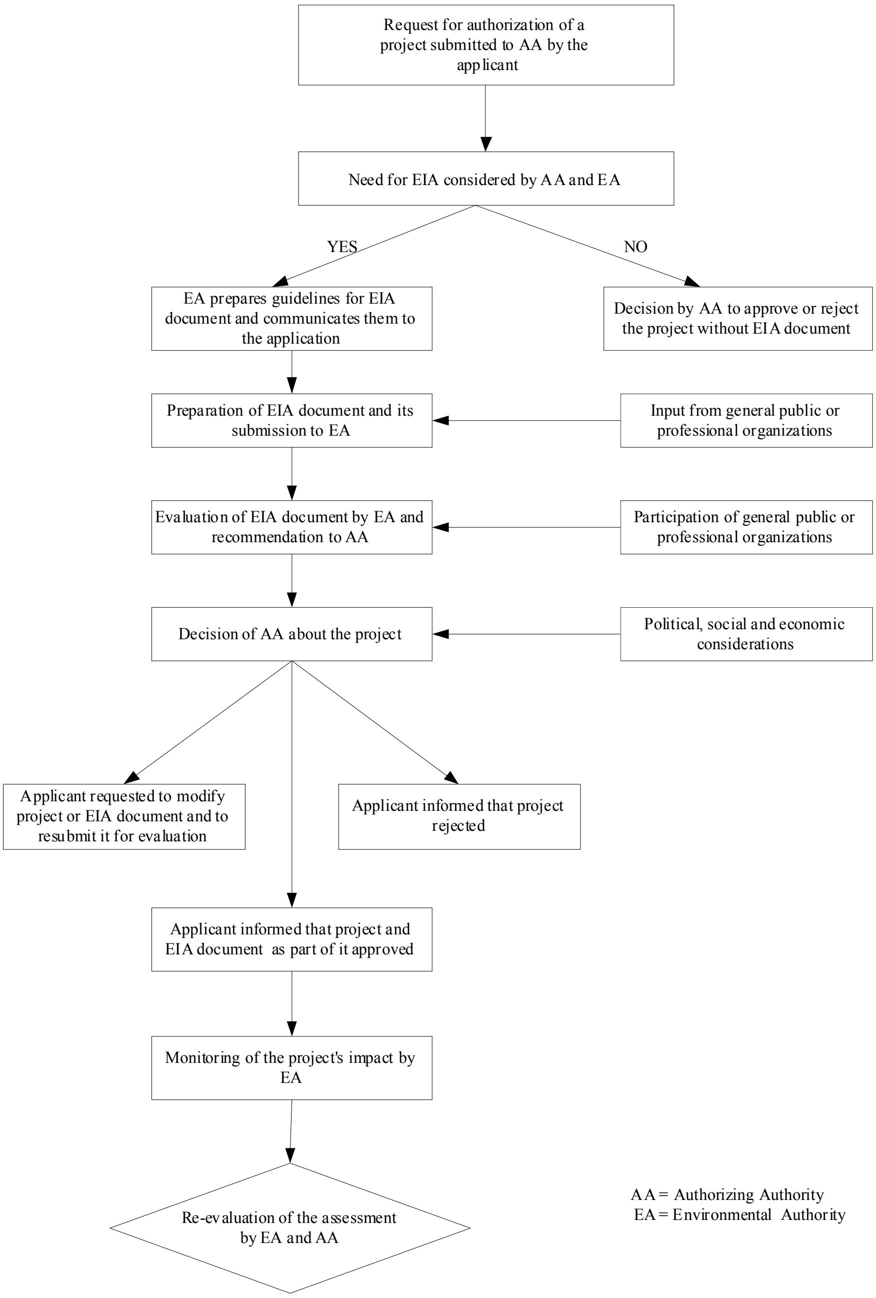

FIGURE 2: The general stages of the EIA (UNEP, 1990)

The purpose of a *Strategic Environmental Assessment (SEA)* is to inform planners, decision-makers and the affected public of the sustainability of strategic decisions; to facilitate the search for the best alternative; and to ensure a democratic decision-making process. This enhances the credibility of decisions and leads to more cost- and time-effective environmental assessment (EA) at the project level (IAIA, 2002). SEA expands EIA from projects to policies, plans, and programmes.

This general purpose of the strategic environmental assessment (SEA) process is tiered to policies in relevant sectors and regions and, where appropriate, to project EIA and decision-making, and addressing the interrelationships of biophysical, social and economic processes.

Development actions may not only affect the physical environment but also the social and economic environment. Social impacts can reduce the intended benefits of a proposal, and can threaten project viability if they are severe enough. In such cases, a *Social Impact Assessment (SIA)* is carried out as part of the EIA process, or sometimes as a parallel or separate review. This approach is used to analyze the impacts of a proposal on individuals and communities, and to mitigate the adverse effects and enhance the positive effects. It also provides a framework to manage social change.

Risk Assessment (RA) has been developed as an approach to the analysis of risk associated with various types of development. The focus of risk assessment on acute human health issues arising from major industrial hazards was broadened to encompass chronic health concerns. These include occupational health risks associated with the use of potentially harmful materials, and broader chronic health concerns linked to environmental pollution. More recently, the concept of risk assessment has been extended to natural systems. Such approaches include assessing risks to ecological resources, or investigating the risks arising from natural disasters such as floods, possible volcanic hazards, mud avalanches and earthquakes.

2. USE OF EIA IN THE WORLD

Environmental impact assessment (EIA) is now used world-wide as an instrument for development planning and control. Several countries have over 20 years of experience in applying EIA (e.g. Australia, Canada, New Zealand and the USA). Recently, the number of countries with an EIA process has increased rapidly, with possibly more than 100 now having some type of national system or equivalent international requirement (e.g. as a condition for lending). The success of EIA has been both driven and accompanied by innovations in law, procedures and methods (Sadler, 1995). In this study, elements of EIA in China, Germany, El Salvador, Iceland, Indonesia, Italy, Japan, Kenya, New Zealand, Philippines, Turkey and USA are described.

2.1 China - status of EIA for geothermal utilization

China has more than 2700 thermal springs and, if thermal wells and mine outflows are counted, more than 3200 thermal features (Zhang et al., 2000). 225 high-temperature geothermal systems have been identified and, of these, more than 50 have been studied and assessed. Most of the geothermal energy is applied to direct use. Installed capacity of geothermal energy is 2282 MWt and 29 MWe, respectively.

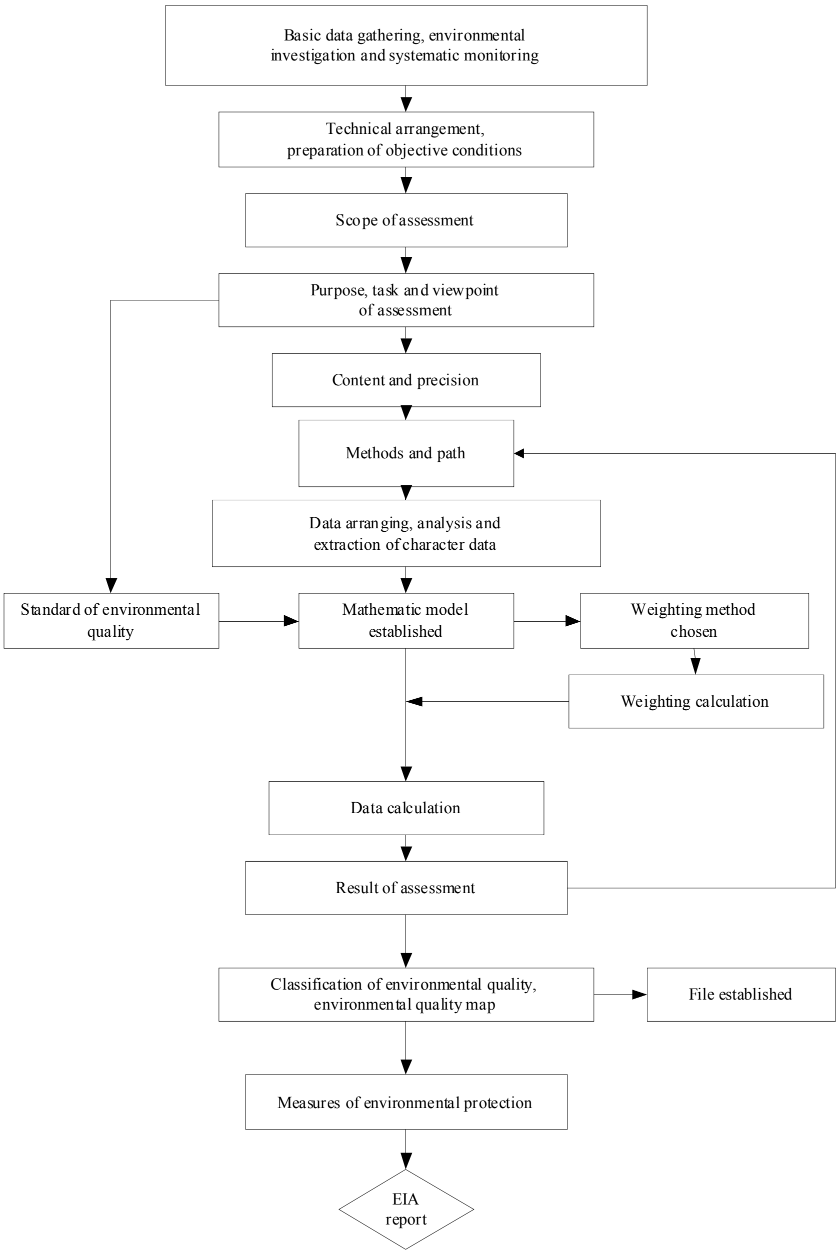

FIGURE 3: The Chinese EIA process (Zhou and Cai, 1998)

The essential regulations for Environmental Impact Assessment in China were published in 1989. It is stipulated that all large-to-medium scale projects of construction, including development of new districts and expansion of old districts, establishment of new enterprises and expansion of old ones, reconstruction of old cities and construction of new cities, etc., must be subjected to an Environmental Impact Assessment (EIA) (Figure 3) before they are planned to be carried out (Li, 2000). The improved law which was published in 1997 added some details. The main contents of an EIA are: The results of a survey and an assessment of environmental background conditions and sources of pollutants; an investigation of environmental factors and systematic monitoring; an assessment of environmental quality factors; a comprehensive assessment of environmental quality; and the relationship between human health and environmental quality of the proposed project. Generally, there are four stages in an EIA process: systematic preparation, systematic analysis, systematic designs and calculation, and systematic assessment. The Chinese EIA process is illustrated in Figure 3.

2.2 Germany - status of EIA for geothermal utilization

In Germany, at the end of 2002, 65 MWt in large plants, and more than 400 MWt in small and medium geothermal heat pump plants had been installed. The first geothermal power plant is expected to start in autumn 2003, with an installed capacity of ca. 0.25 MWe.

The use of geothermal energy in Germany is controlled by the Federal Mining Act. According to the Federal Mining Act, geothermal energy is not the property of the land owner, but belongs to the federal administration. Exploration for and exploitation of this kind of resource, like coal, various types of ore, oil, or natural gas, are regulated by the authorities and a permit is granted to an applicant, usually with a certain regular payment to be made according to the amount of the resource exploited. A particular problem recently arose from the fact that geothermal energy does not have a certain boundary like a coal seam, or body or oil deposit. With the number of applications for mining licenses on geothermal energy rising, the need for proper sizing of the geothermal fields became apparent (Sanner and Bussmann, 2003).

In April 2000, the *Renewable Energy Act* (Erneuerbare Energien Gesetz, EEG) was put into force. With the new law effective April 2000, geothermal energy was for the first time level with other renewable energy sources. Now there is a real chance to plan and install geothermal power plants on a foreseeable economic basis (Sanner and Bussmann, 2003).

2.3 El Salvador - status of EIA for geothermal utilization

Geothermal exploration began in El Salvador in 1954. As of 2003, the installed geothermal generation capacity in El Salvador was 161 MWe.

El Salvador, as a developing country, has up to now lacked an environmental law. There are, however, sections within the Political Constitution, the existing master legislation, that relate to the protection of the environment, but their application is not effective. These sections are concerned with the management and conservation of natural resources. At the beginning of this year, and after four years of consultation with the public, the environmental law was approved by parliament and a government environmental ministry was created. The minister in charge will oversee the fulfilment and application of the law to protect the environment and human health (Economic/Commercial section: Environmental Law, 1998). Therefore, the environmental impact assessment as a regulating process is in its early stages yet, and the absence of a legal instrument to facilitate the implementation of the policy means that the environmental impact assessment process cannot be carried out effectively. In addition, the Salvadorean law requires each general plan to conclude an accompanying EIR to cover all the major governmental and private projects (Arévalo, 1998). The EIA process in El Salvador is illustrated in Figure 4.

Some power plant environmental impact assessments were prepared by the *Inter-American Development Bank* (IDB) in El Salvador. For example, the Berlin condensing power station environmental impact assessment was prepared in an ad-hoc manner by the IDB as part of a funding approval process. The guide prepared by OLADE and IDB (1994) presents a fairly comprehensive discussion of the environmental impacts associated with geothermal development projects and proposed mitigation measures. The criteria and guidelines to protect the environment were based on World Bank guidelines.

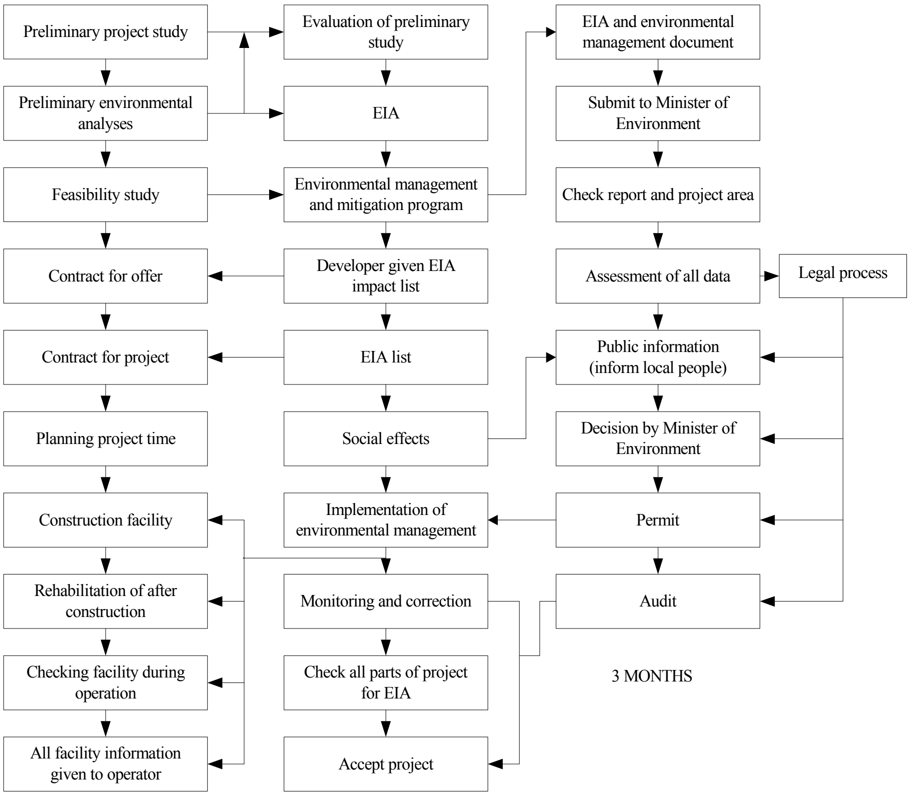

FIGURE 4: The EIA process of El Salvador

2.4 Iceland - status of EIA for geothermal utilization

The geothermal resources in Iceland are closely associated with the country's volcanism and its location on the Mid-Atlantic Ridge. The high-temperature resources are located within the active volcanic zone running through the country from southwest to northeast, while the low-temperature resources are mostly in the areas flanking the active zone (Ragnarsson, 2000). Due to the island's location on the plate boundary and its nature as a hot spot, the geothermal gradient is extremely high, 40-150°C/km outside known geothermal areas. About 1,000 hot spring locations are known in the country, and 26 high-temperature areas with steam fields (Fridleifsson, 2000).

Geothermal energy is used for many purposes in Iceland. The main sectors are space heating (64%), electricity production (17%), industry (7%), swimming pools (4%), greenhouses (3%), fish farming (3%), and snow melting (2%) (Ragnarsson, 2000).

A law requiring EIA has been in force in Iceland since May 1994 but was updated in 2000. The basic law is EC Directive 1985-11/1997, i.e. law on environmental impact assessment in Iceland. The Ministry for the Environment is the principal authority in the field covered by this directive. The Planning Agency consults the Minister and is responsible for the supervision of the implementation of the directive and providing guidelines.

In the law, it is stipulated that all projects which may have significant effects on the environment, on the ground, within territorial waters, within territorial air space or in the pollution territory of Iceland, should be made subject to EIAs. For geothermal development, an EIA is needed for projects >10 MWe or >50 MWt in Iceland. But geothermal projects that may or may not be subjected to an assessment, depending on their potential impacts are listed in Annex 2 of the regulation. The process relating to Annex 2 is shown in Figure 5. It shows how decisions are made, according to Annex 2, on whether projects need an

EIA or not. Those that are deemed to need an EIA according to this process, and projects that according to law need an EIA, are then subjected to the preparation of the EIR during which methodology based on checklists, matrices, networks and overlay maps is employed. When this is ready, it is handed to the Planning Agency and goes through the process shown in Figure 6.

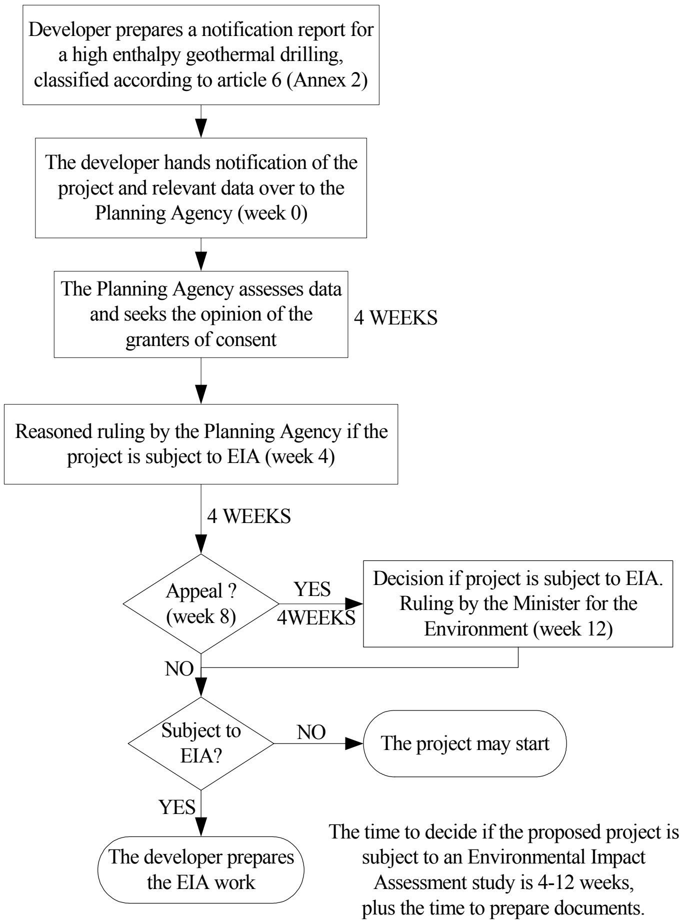

FIGURE 5: The process from the notification of a high-enthalpy geothermal drilling project, leading to the decision if the project is subject to an environmental impact assessment or not

The geothermal projects in Iceland that have been subjected to EIA are drilling at Ölkelduháls, Hengill area, which was granted; and utilization at Reykjanes, which was granted with restrictions on the drilling area. This has though been challenged, and a compromise solution has been granted (for the Reykjanes area). Several wells have been drilled, and others are pending. Drilling in Graendalur was rejected even though there was a Minister's ruling that drilling might be carried out at a different location. This did not interest the operators and the project was abandoned. The additional EIA for Bjarnarflag is now in progress and is now aimed at a 90 MW_e plant instead of a 40 MW_e plant in the first assessment. Additional plants at Krafla and Nesjavellir have been granted. Exploratory drilling in the western part of the Krafla area was deemed to be subject to an EIA and has now been granted; whereas drilling in the Leirhnjúkur area, Krafla, was also deemed to need an EIA but the National Power Company decided not to carry on there. Exploratory drilling at Hellisheidi, Hengill, did not need an EIA. Several wells have been drilled but EIA for utilization is underway. Exploratory drilling at Theistareykir also did not need an EIA. Two well have now been drilled there.

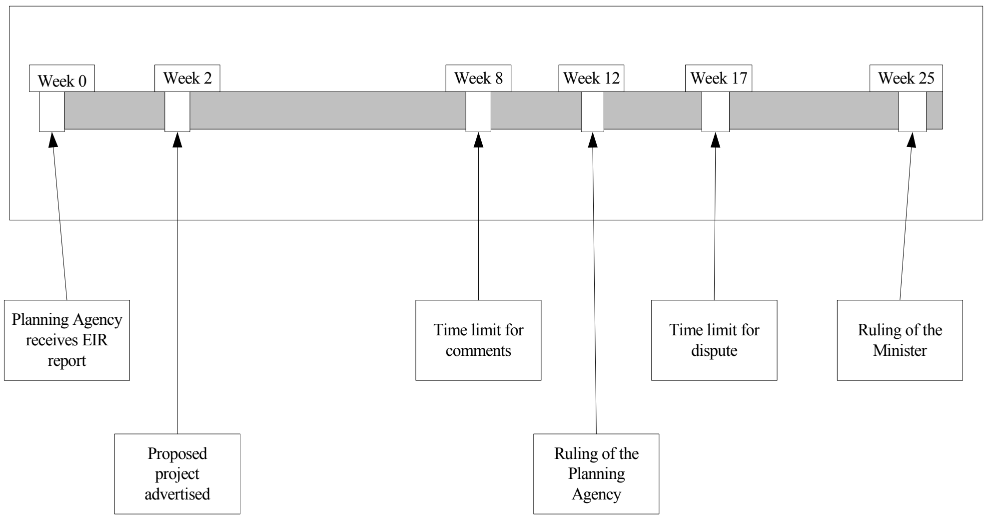

FIGURE 6: EIA from EIR to Minister's ruling in Iceland (Thors and Thóroddsson, 2003)

2.5 Indonesia - status of EIA for geothermal utilization

There are 217 geothermal fields recorded in Indonesia. Of these, 70 are classified as high-enthalpy with estimated reservoir temperatures of more than 200˚C (Rachman et al., 1995). Indonesia has 787 MWe and 2.3 MWt installed capacity. As of the year 2000, about 3.4% of the total electrical energy production can be attributed to geothermal sources (Sudarman et al., 2000). The only direct uses recorded are at five sites in Java. A total capacity of 2.3 MWt with an annual energy use of 42.6 TJ is used for bathing purposes (Lund and Freeston, 2001).

In 1982, the Indonesian government enacted a basic law dealing with the principal provisions of environmental management. Among other things, this law created an EIA process. EIA procedures were to be established by all ministries by 1987. The responsibility of the EIA is coordinated by the Indonesian *Environmental Impact Management Agency* (BAPEDAL). The agency which is responsible for the control of environmental impacts is defined as that agency, whose main duty is to assist the President in undertaking the control of environmental impacts, including efforts to prevent environmental pollution and damage, mitigate significant impacts, and restore the quality of the environment. Also, Indonesia has an *Environmental Impacts Assessment commission* (Komisi AMDAL); a commission established by the Minister or head of a non-departmental government agency at the central level of government, or by the Governor at the provincial level, which has the task of assisting in the implementation of the environmental impact assessment (AMDAL) process as part of the decision-making process. The *Environmental Impact Statement* (ANDAL), the *Environmental Management Plan* (RKL), and the *Environmental Monitoring Plan* (RPL) are submitted simultaneously by the proponent to the authorized government agency. The Indonesian EIA procedure is shown schematically in Figure 7.

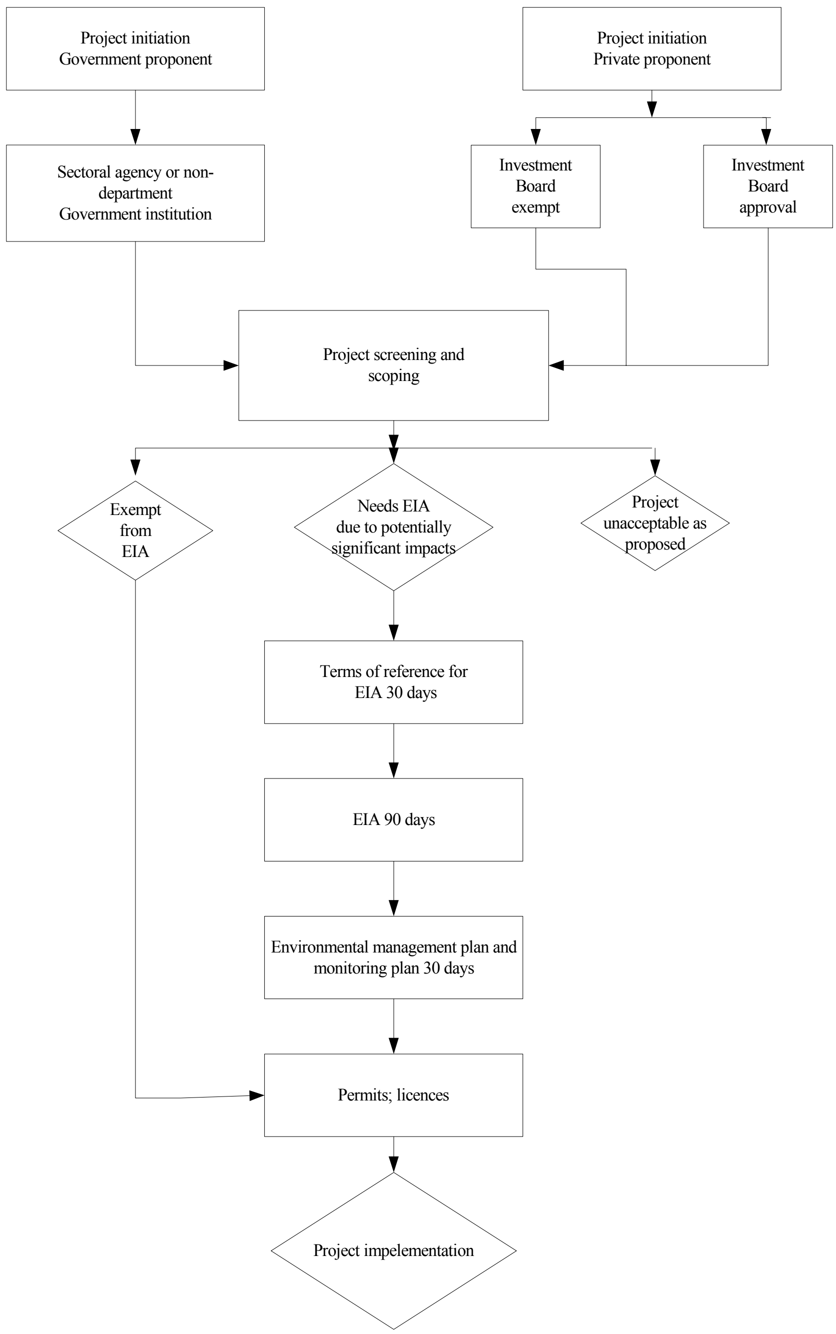

FIGURE 7: General EIA procedures in Indonesia (Gilpin, 1995

2.6 Italy - status of EIA for geothermal utilization

Italy has 762 MWe and 324.6 MWt installed capacity. Geothermal energy is used for many purposes in Italy. The main sectors are space heating (41%), bathing and swimming (28%), greenhouses (22%), industrial processes (9%), and fish farming (less than 1% of the annual energy use) (Cappetti et al., 2000).

Environmental regulations in Italy are based on the *European Union* (EU) directive 85/337 for *environmental impact assessment* (EIA). The EU directive was adopted and carried out in Italian regulations with two government decrees in 1988. The decrees require that industrial projects be subject to the EIA procedure. It is up to the applicant to submit the study of an environmental impact assessment (EIA). The EIA procedure requires the Ministry for the Environment to consult with the ministers of the region in which the project is carried out and to make a decision about the project's compatibility with the environment. The EIA is designed to establish a refereeing procedure founded on the analysis of the specific case and on social responsibility. The EIA does not define abstract consents or prohibitions, but attempts to establish harmony between the regulations and the requirements of development. The EIA focuses on the environmental compatibility of the project. The EU directive does not apply to geothermal developmental activities. The legislature modified the approach for energy production activities.

In Italy, the EIA is prepared by the applicant based on the expected project activities and the activity plan may be modified at any time. The EIA is, therefore, considered a provisional study, to be updated as the project progresses and is modified. If major changes to the project are made, a new EIA must be prepared and the approval procedure followed. Each modification to the original EIA should be approved by the National Mining Bureau for Hydrocarbons and Geothermal Activities (UNMIG), according to DPR 395/91 (Li, 2000).

Geothermal regulations in Italy are separate and distinct from the general mining law. In Italy, mineral deposits, including geothermal resources, belong to the state. The state grants exploration permits and mining leases. The exploration permit is for the preliminary exploration steps including geological and geochemical investigations and well drilling, with each activity requiring specific authorization. The mining lease is granted to develop the geothermal field if exploration is successful. Developmental activities are classified as surface exploration, deep exploration, and development and exploitation (Hietter, 1995).

2.7 Japan - status of EIA for geothermal utilization

There are about 200 volcanoes in Japan including 83 active ones – 4% and 10% of those in the world, respectively; in the narrow territory of only 0.27% of the land area of the world. Therefore, Japan is blessed with extensive geothermal resources including hot springs. Moreover, hot water carried up from sedimentary basins is also abundant. There are many possible sources for both production of electricity and the direct-use of geothermal energy (Sekioka and Toya, 1995). Japan is third in the world for utilization with a total installed capacity of 1167 MWt. Also, total installed capacity of power generation is 547 MWe (Fridleifsson, 2002).

In 1972, a cabinet resolution introduced environmental impact procedures for large-scale public works. In the mid-1970s, the government began drafting legislation for a comprehensive EIA system. In 1984, a cabinet resolution entitled "Implementation of Environmental Impact Assessment" was carried, immensely broadening the scope of EIA procedures. At the same time, practical guidelines were laid down and issued. By 1991, the broadened procedures had been applied to 123 projects (Gilpin, 1995).

Figure 8 shows the procedure of environmental assessment in Japan (Yamaguchi and Kawazoe, 1995). There are several steps involved in geothermal energy development including exploration, feasibility studies construction of the power plant and operation. A law on EIA could make reference to land

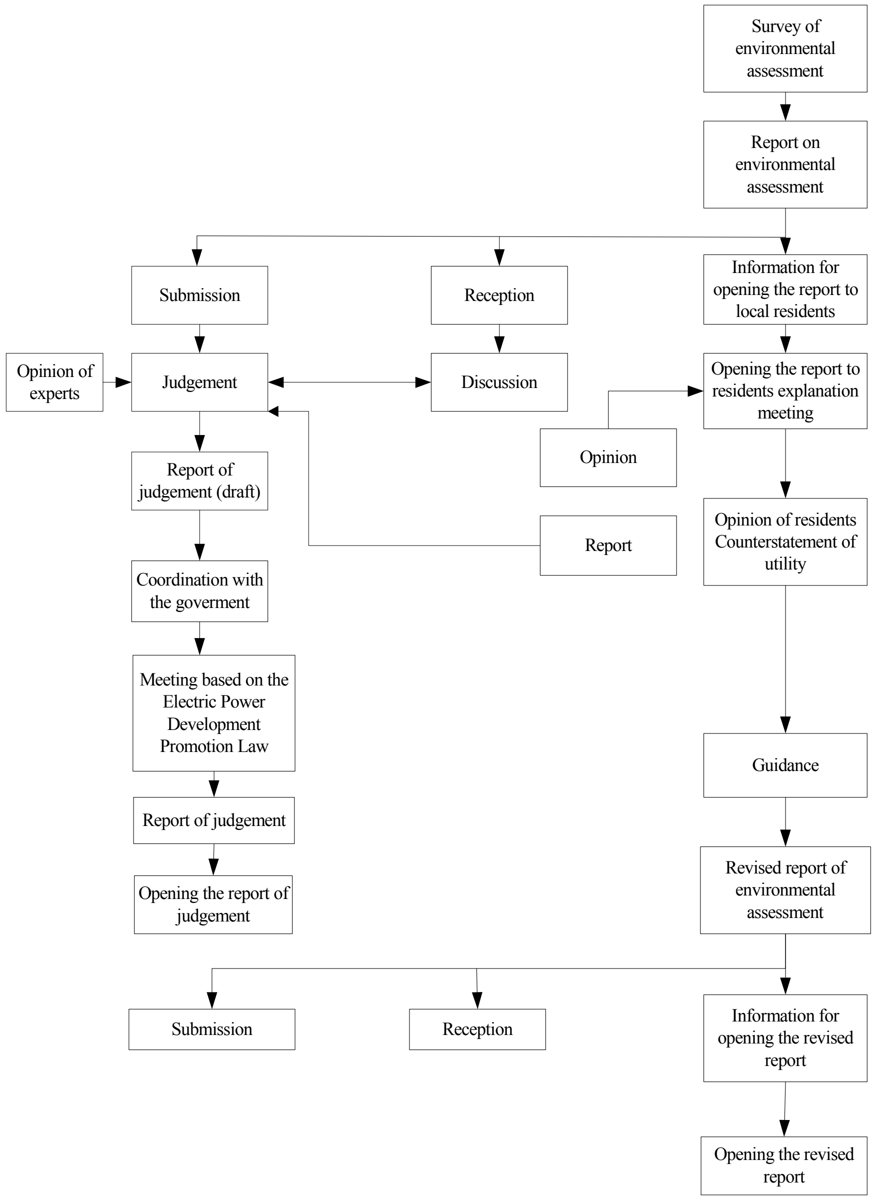

FIGURE 8: General EIA process in Japan
(Yamaguchi and Kawazoe, 1995)

management, well drilling, water management, construction work, safety, and environment. Power plant construction, except in case of small ones, is subjected to a review in accordance with the Electric Power Development Pro-motion Law, and appropriate geothermal organizations, together with an assessment of environmental impact. The plans are inserted into the National Basic Electric Power Source Plan.

For constructing a geothermal power plant with a capacity in excess of 10 MWe, the plant owner has to carry out the whole procedure. The plant owner needs to present data based on the guidelines for geothermal power plant construction published in 1992, and submit a report which includes results of measurements, a prediction of its likely influence, and a mitigation plan, to the Ministry of International Trade and Industry (MITI) (Yamaguchi and Kawazoe, 1995). For operation of geothermal power plants, plant operators need not only the regulations regarding the Electric Utility Law, but also the regulations related to such environmental laws as the Air Pollution Control Act, the Water Pollution Prevention Act, the Effluvium Prevention Act, the Noise Control Act, and the Vibration Control Act.

2.8 Kenya - status of EIA for geothermal utilization

In Kenya, a large part of the geothermal energy resources is manifested in the Rift Valley, which is a part of the Great African Rift system. With a large potential, Kenya has 121 MWe installed capacity. Direct utilization is very scarce in Kenya.

Environmental impact assessment as a regulated process is in its early days in Kenya, despite the adoption of the Environmental Management Policy in 1979, and the introduction of a system of environmental impact reports to cover all major governmental and private projects. In 1972, the National Environmental Secretariat (within the Ministry of Environment and Natural Resources) was established to coordinate environmental activities within the country. It is responsible for the coordination and application of environmental management policy. However, the absence of legal instruments to facilitate the implementation of the policy means that the environmental impact reporting process has not been carried out effectively. Despite attempts since 1979 to review existing legislation as it relates to the environment, and proposed changes to provide a legal framework for the reporting process, the appropriate statutory provisions have yet to be developed. Environmental control of geothermal development within Kenya is therefore subject to the requirements of both specific legislative instruments that relate to different aspects of the environment, and to the Common Law (KPC, 1992). The first EIA procedures were published in the Kenya Gazette Supplement in 07/05/1999 (KGS, 1999).

All unextracted geothermal resources are generally controlled by the Government, subject to any rights vested by others. To obtain a license for geothermal development, the approval of the Minister administering the act is needed; and anyone so authorized is entitled to undertake actions in connection with the survey and investigation of such areas. The rights of the licensee also include the right to claim and utilize any water. However, landowner rights with regard to entry, drilling and well testing exist, and the licensee is liable for damages and injury which may result from these activities. Compensation to the landowner or occupier is required. The licensee is also subject to conditions relating to safety or any other conditions which are imposed by the Minister (KPC, 1992).

2.9 New Zealand - status of EIA for geothermal utilization

Most regions of New Zealand have low-temperature geothermal resources, and three also have high-temperature geothermal systems with electricity-generating capabilities. Geothermally generated electric power in New Zealand totals 437 MWe and total capacity of direct use is 308 MWt. Geothermal energy is used to generate clean process steam for paper drying, and as a source of heat for evaporators, timber drying and electricity generation.

The principal environmental legislation in New Zealand is the *Resources Management* (RM) Act. The RM Act was designed to bring all resources under one set of environmental regulations. The Act was implemented in 1991 along with the 1991 Crown Minerals Act. These two laws consolidated and amended scores of acts to provide for a streamlined review and protection of natural resources. The RM Act focuses on the effects of projects, rather than on the type of project, in order to ensure that all activities are treated equally. Prior to implementing a geothermal project in New Zealand, the application for a resource consent process outlined in Figure 9 must be followed.

Applications for consent for activities that would have a major effect on the environment must include a detailed environmental review called an assessment of environmental effects (AEE). The RM Act requires that effects rather than impacts be analyzed (Hietter, 1995).

Geothermal drilling in New Zealand is governed by the code of practice for deep geothermal wells developed by the Deep Geothermal Wells Committee of the Standards Association of New Zealand. The code describes the requirements of design and work practices necessary to ensure the safe drilling and operation of geothermal wells. The code is based on modifications to accommodate the high subsurface temperature and pressures encountered in drilling in geothermal reservoir areas. The code of practice is very similar to the U.S. GROs (Hietter, 1995, see Section 2.12).

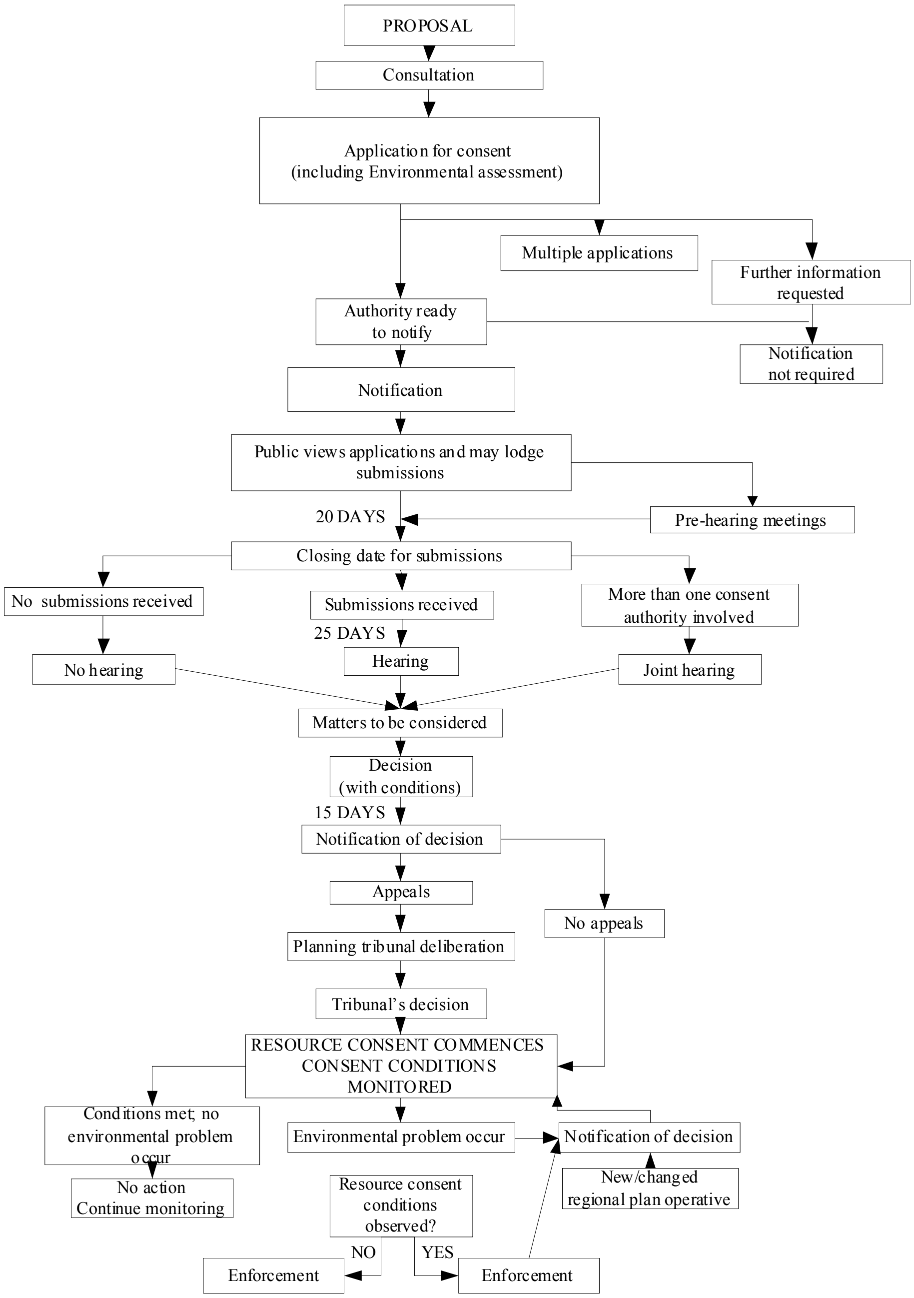

FIGURE 9: General EIA process in New Zealand (after Milne, 1992)

2.10 Philippines - status of EIA for geothermal utilization

The Philippines is the world's second largest producer of geothermally generated electricity. As of late 2003, there is a total installed capacity of 1,931 MWe. The total capacity of direct uses of geothermal energy is 1 MWt.

The environmental and geothermal laws in the Philippines are based on key *presidential decrees* (PD). The Philippines *Environmental Impact Assessment* (EIA) system was officially established in 1978 with the passage of PD 1586; although the EIA concept was first introduced in 1977, the year after the framework, working structure and procedures for the implementation of the system were defined. The Philippines Environmental Impact Assessment (EIA) system is similar to that of the NEPA in the U.S. in that it is designed to identify direct and indirect impacts, to assess the significance of the impacts, and to determine the significance of the predicted impacts on the quality of the human environment. The EIS system assesses "the significance of the effects of the physical developments on the quality of the environment". The EIA system mandated the acquisition of an environmental compliance certificate (ECC) for projects or undertakings classified either as environmental critical projects (ECPs) or those that are located in environmentally critical areas (ECAs). The areas and types of projects subject to the EIA system are listed in Presidential Proclamation 2146 (1981) (Pascual and Garcia, 2001). The key steps in the EIA process are shown in Figure 10.

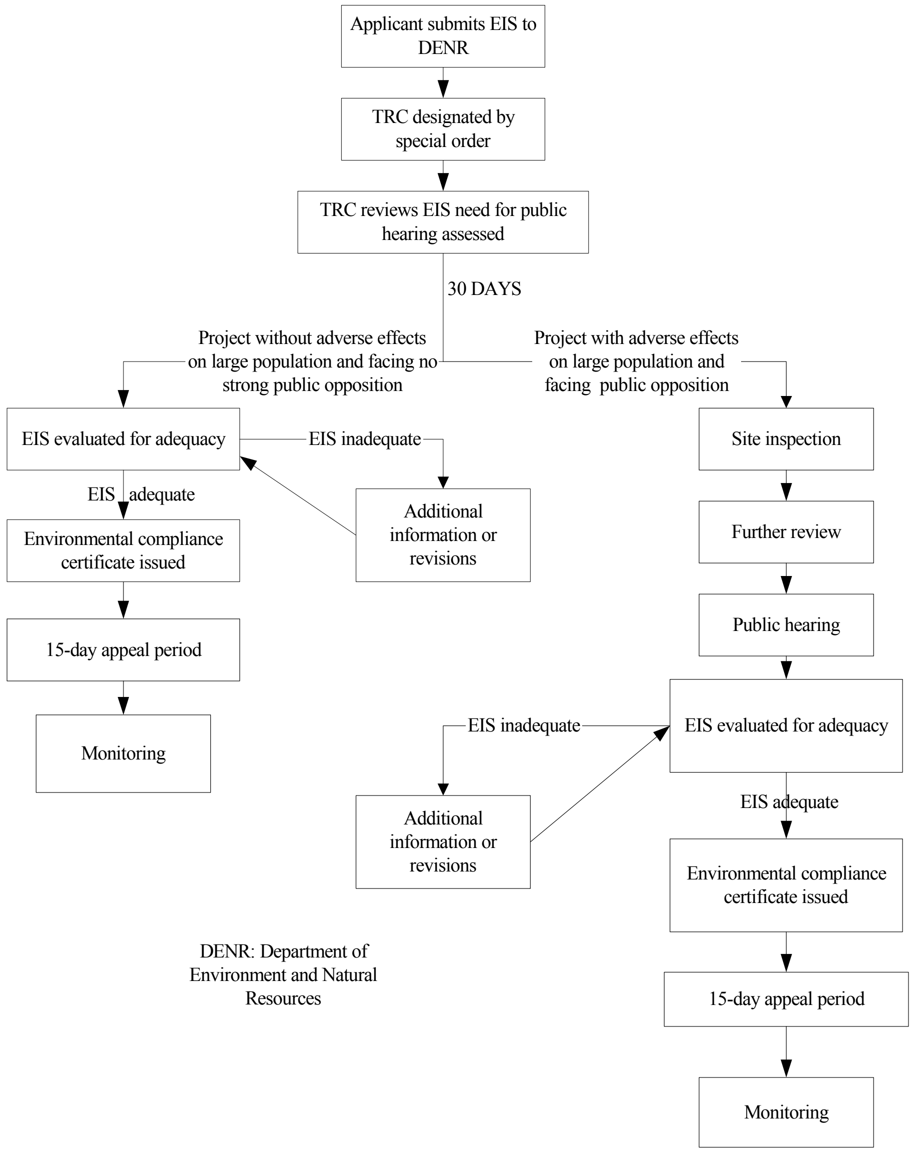

FIGURE 10: Philippines EIA Process (DENR, 1992)

The Philippines National Oil Company (PNOC) has developed a set of guidelines for geothermal operations. Presidential decree 1442 was issued in 1978. The decree states that the government may directly develop geothermal resources or it may do so under service contracts; the geothermal development under service contracts may take place on public or private land; holders of existing geothermal permits and leases may enter into service contracts and revoke existing permits; the Bureau of Energy Development issues development and utilization permits where service contracts are deemed inappropriate; and the director of energy development and the authority promulgate necessary rules and regulations to implement provisions of the Act (Hietter, 1995). Geothermal projects are classified as ECPs and are usually located in ECAs, thus subject to the EIA system. Since 1978, several amendments to the structure, assessment parameters and procedures, working definitions, and scope of operations, among others, have been made to strengthen the EIA system. The latest of these are the Department of Environment and Natural Resources administrative order 96-37 (1996), which has further streamlined the procedures in the conduct of an EIA and enhanced public participation as a major process in validating the social acceptability of the project (Pascual and Garcia, 2001).

2.11 Turkey - status of EIA for geothermal utilization

Turkey is situated in the Mediterranean sector of the Alpine-Himalayan tectonic belt, which is the main reason for its high geothermal potential. Around 1000 hot and mineralized natural self-flowing springs exist in Turkey (Batik et al., 2000).

Turkey is the 7th richest country in the world in geothermal potential. The total capacity of direct uses of geothermal energy is 992 MWt in Turkey. Most of the development is achieved in geothermal direct-use applications by 61,000 residences equivalence geothermal heating (665 MWt) including district heating, thermal facilities and greenhouse heating. Spas used for balneological purposes are 194 (327 MWt). Turkey has one power generation plant with a capacity of 20.4 MWe. A liquid CO_2 and dry ice production factory is integrated with this power generation plant (Batik et al., 2000; Gökcen et al., 2003; Mertoglu et al., 2003).

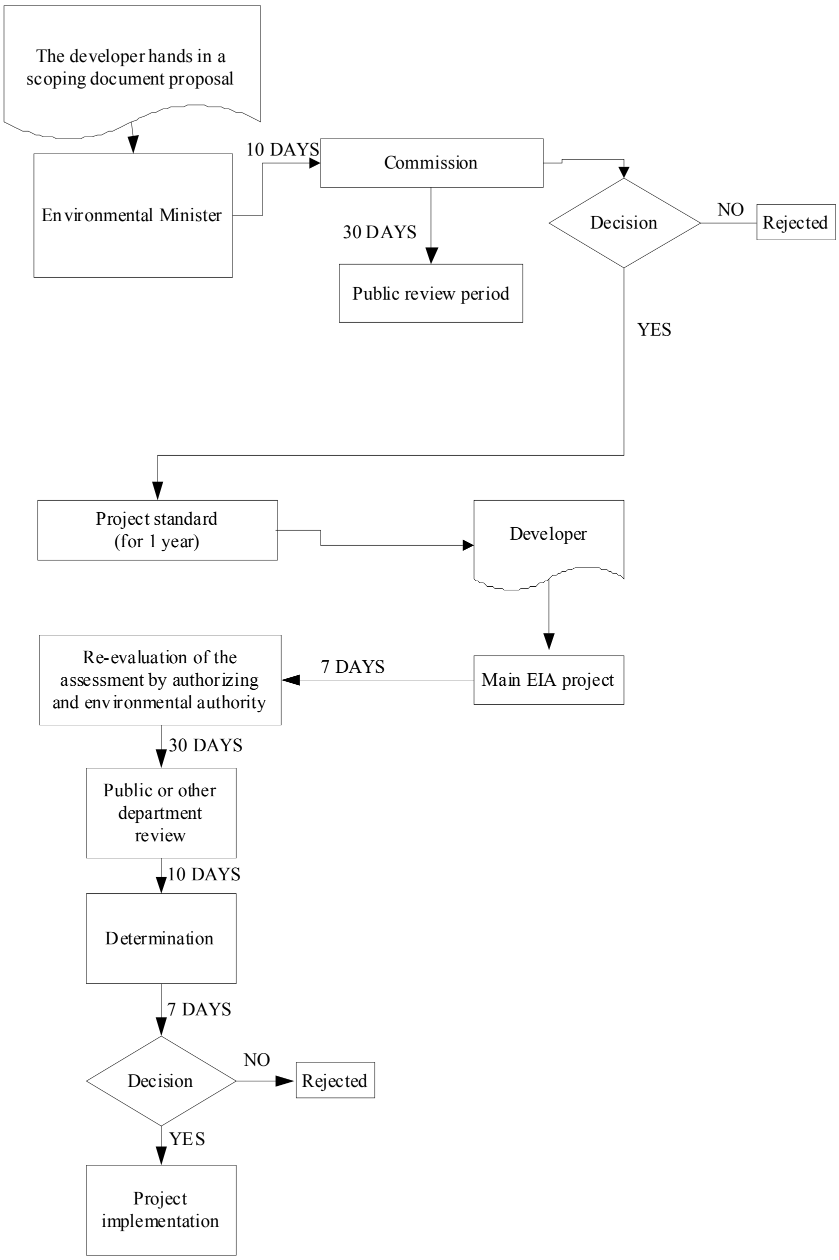

FIGURE 11: General EIA process in Turkey

Turkey's high rate of economic growth experienced during much of the 1990s, besides resulting in booming industrial production, also led to higher levels of energy consumption, imports, air and water pollution, and greater risks to the country's environment. With Turkey now a formal candidate for membership in the European Union, Turkey's environmental record will come under heavy scrutiny. In 1983, Turkey promulgated the country's overarching "Environmental Law", and a National Ministry of Environment was created in 1991.

In 1993, the Turkish government enacted a basic law dealing with the principal provisions of environmental impact assessment (EIA). First, EIA procedures were to be published in an official gazette, 07/02/1993. The EIA procedure was amended 06/06/2002. The Turkish EIA procedure is presented in Figure 11. The responsibility for EIA is coordinated by the *General Director of Environmental Impact Assessment and Planning.* He is responsible for the control of environmental impacts, and its main duty is to assist the

Republic of Turkey Ministry of Environment and Forestry in undertaking the control of environmental impacts, including efforts to prevent environmental pollution and damage, mitigate significant impacts, and restore the quality of the environment. The main purpose is to plan, organize and coordinate the tasks necessary to carry out each phase of the EIA process effectively. EIA reports are reviewed by an EIA technical committee which consists of ministry personnel, with other government agency and private sector representatives. About 838 final EIA reports were prepared between 1993 and 06/2003.

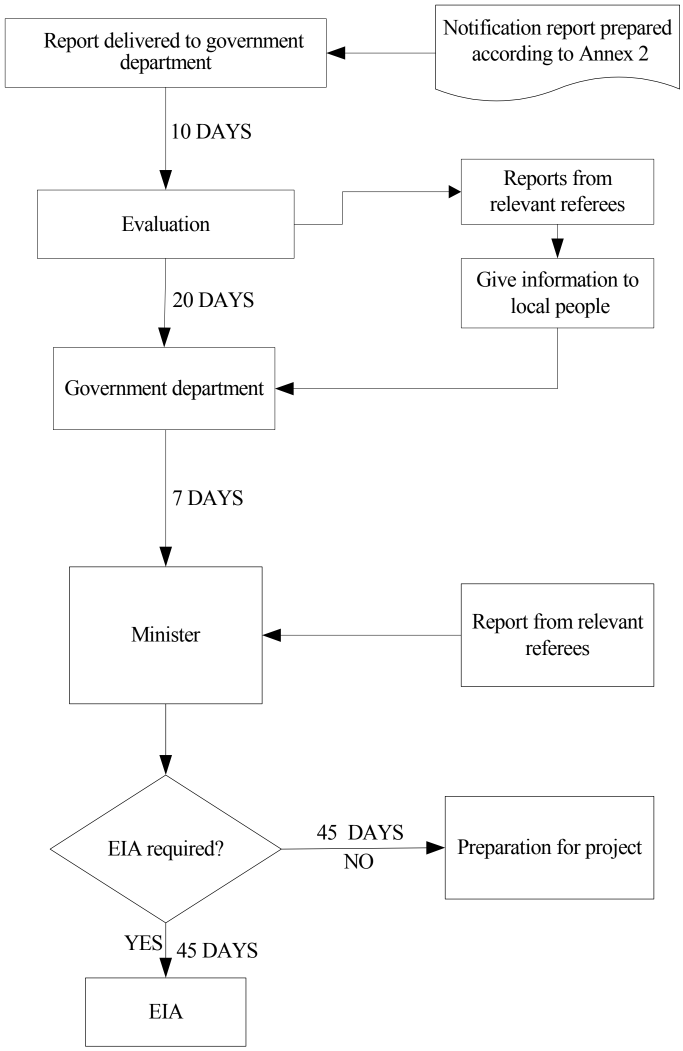

FIGURE 12: Process of Annex 2 in Turkey

Turkey has extended its involvement in geothermal energy projects, supported by loans from the Ministry of Environment. According to the EIA law, projects which may have significant effects on the environment, on water, air, and soil, should be made subject to EIA. If the capacity of geothermal generation is more than 5 MWt it needs to be reported to the ministry responsible for EIA; but geothermal projects that may or may not be subjected to an assessment, depending on their properties, are listed in Annex 2 of the regulation. The process of Annex 2 is presented in Figure 12. The status of environmental impact assessment for the geothermal field in Tuzla is discussed in this study; however, Turkey has not developed a set of guidelines for geothermal operations up to now.

2.12 USA - status of EIA for geothermal utilization

The USA is the world's largest producer of geothermally generated electricity. As of late 2001, there was a total installed capacity of 2,002 MWe. USA also leads the world in direct utilization with a total installed capacity of 3,766 MWt. The largest increase in geothermal direct use was in the heating of aquaculture ponds and raceways. USA has several space heating plants, geothermally heated greenhouses, agricultural drying, timber drying industries, and bathing and swimming pools.

Geothermal development in the United States is governed by a variety of broad, as well as resource specific laws developed and implemented at the federal, state, and local levels. Environmental regulations include requirements to prepare an environmental analysis for a proposed project, as well as specific laws designed to protect air, water, land, and the socio-cultural environment.

Development in the U.S. is governed by a lot of environmental laws at the federal, state and local levels. The key laws that pertain to the environmental aspects of geothermal development are:

- *Geothermal resources operational orders;*
- *National Environmental Policy Act;*
- *Specific resource protection laws.*

The National Environmental Policy Act (NEPA) is one of the primary U.S. laws for the protection of the environment. The environmental assessment (EA) document or environmental impact statement (EIS) is intended to provide an objective analysis of any significant or potential environment impact resulting from a proposed project, and all reasonable alternatives for that project. NEPA requires that federal agencies consider the potential significant adverse environmental impacts of any major action. However, the needs for economic growth are expressly recognized in the congressional declaration of policy under NEPA. The NEPA process is shown in Figure 13.

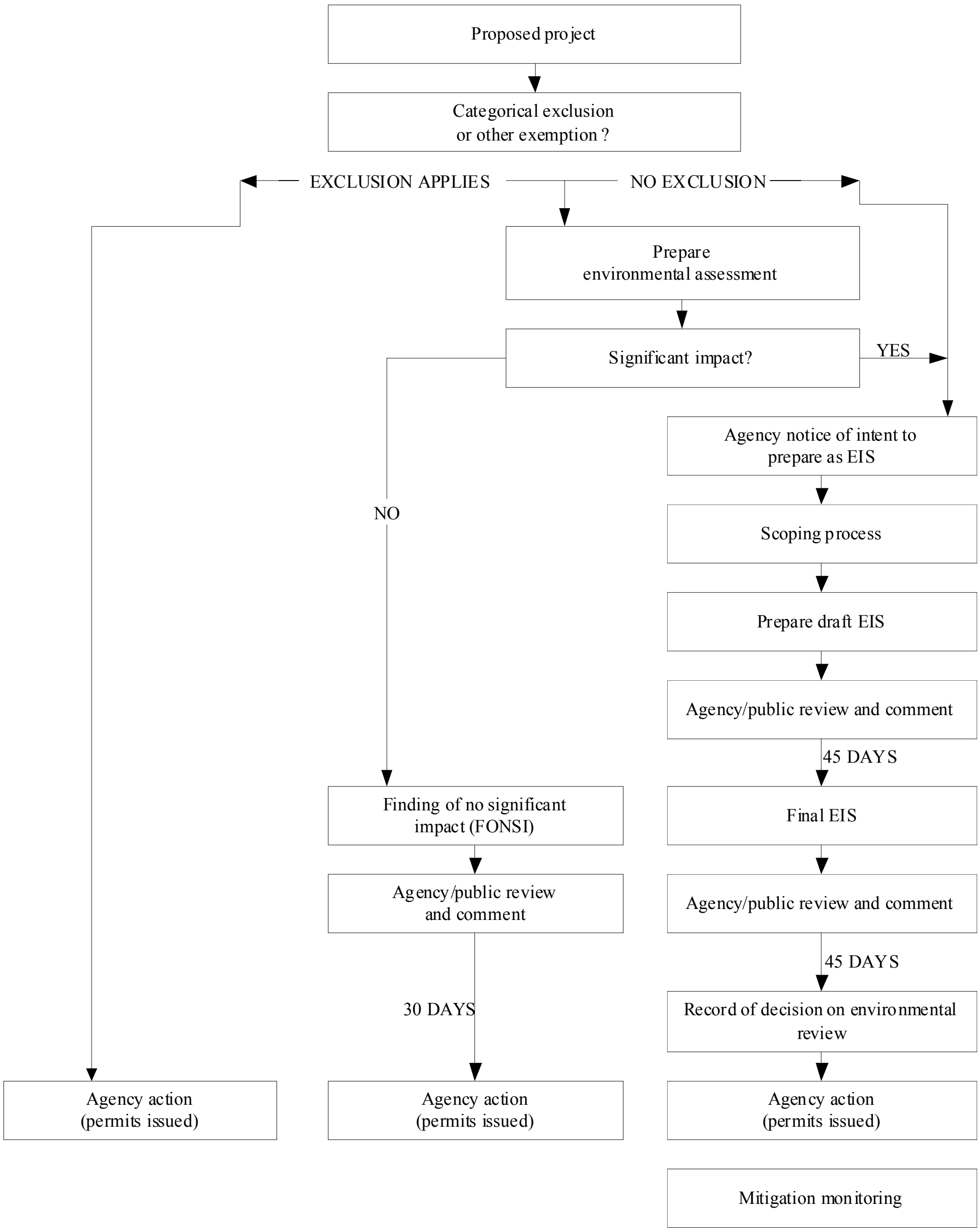

FIGURE 13: U.S. NEPA environmental review process (Bass and Herson, 1993)

The geothermal resources operational orders (GROs) were developed to define specific operating requirements for geothermal developers on federal land by the United States Geological Survey (USGS, 1980). The GROs address all phases of geothermal development, the technical aspects of exploration and development drilling, as well as outlining specific environmental protection procedures that generally need to be taken into account to minimize the environmental effects of drilling and utilization. The seven GROs are:

- GRO no 1: Exploration (operation)
- GRO no 2: Drilling, completion, and spacing of wells
- GRO no 3: Plugging and abandonment of wells
- GRO no 4: General environmental protection
- GRO no 5: Plans of operation, permits, reports, records, and forms
- GRO no 6: Pipelines and surface production facilities
- GRO no 7: Production and royalty measurement, equipment, and testing procedures

The environmental protection measures in GRO no: 4 were based on expected impacts. The authors of regulations realized that the environmental impact of geothermal development would vary with location, size, depth, temperature, and chemical composition of the fluids of the geothermal resources. The type of development, whether power generation or direct use, also affects the level of environmental effects. The GROs are therefore written to allow the agency the option to adjust requirements to fit each specific geothermal project (Li, 2000).

3. EVALUATION OF ENVIRONMENTAL IMPACT ASSESSMENT (EIA) IN THE WORLD

Geothermal energy is a relatively benign source of energy. There are, however, certain negative impacts that this development could have if appropriate mitigation action is not taken, and monitoring plans are not put into effect. With existing laws, the imminent passage of environmental laws and the strengthening of environmental agencies worldwide, it is becoming increasingly important that countries prepare to address environmental issues in a common, systematic manner.

Environmental legislations throughout the world, such as from the European Economic Community (EEC), the U.S., the Nordic Council, the UN Economic and Social Commission for Asia and the Pacific (ESCAP) etc. have been created to protect and conserve the environment and human health. These environmental regulations include requirements for preparing an environmental analysis for a proposed project, as well as specific laws designed to protect air, water, land and the socio-cultural environment. There is a significant variation in the numbers of agencies involved in the environmental review of a project, and the amount of time required from application to project approval (Thors and Thóroddsson, 2003).

The most important aspect of environmental regulations is the requirement for an environmental analysis report, otherwise called an environmental assessment (EA), an environmental impact assessment (EIA), an environmental impact statement (EIS), or an environmental impact report (EIR), which is applied to any project under development. The environmental impact assessment as a tool to decide between the benefits of development, or leaving the environment unchanged has become an integral part of the general planning process in developing countries (Morris and Therivels, 1995).

The environmental assessment process has been defined differently in different countries. In fact, it appears that no two countries have defined it in exactly the same way. General blanket statements are often made that the developing countries are all behind the industrial countries in terms of environmental issues (Goff, 2000). The United States was the first country to legislate for EIA. It is interesting to note that the Philippines have required EIAs for certain projects since 1977. The Federal Republic of Germany started to do so nearly a decade later (Biawas, 1991). In addition to the different approaches to the process, are the wide varieties of formats for EIAs that are available.

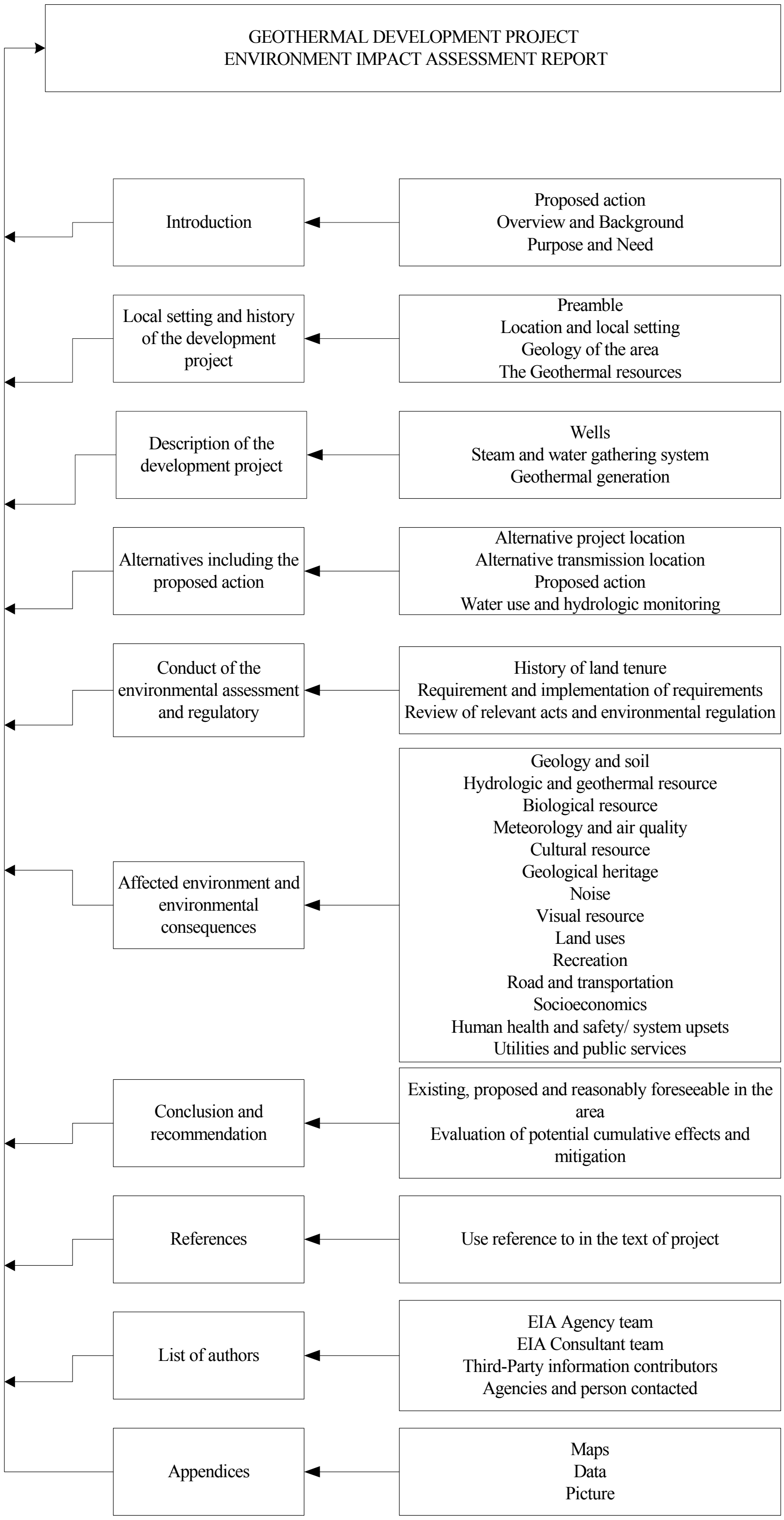

FIGURE 14: Geothermal development project environmental impact assessment report

Generally, studies of physical, chemical, biological and socio-economic impacts are carried out for an EIA. These parameters are differently defined in different countries. For these parameters, some countries use different EIA evaluation criteria. Matrices are the most commonly used technique for impact identification. But use of the Geographical Information System (GIS) has spread quickly in the world. Therefore, overlay maps can give a good evaluation of environmental impacts. Also, monitoring is important for checking the results of an EIA, but it is very difficult to develop for economical and technical reasons. An environmental impact assessment report for geothermal utilization should contain the information presented in Figure 14.

A survey of the relevant legislation in various countries results in the perception that the situation is different in each country. In many countries (such as Germany, France, Hungary and Romania), the geothermal resources are dealt with in a mining law, whereas the production of geothermal fluids from subsurface is regulated by water protection legislation. This implies that responsibilities are assigned to different Ministries, often with limited cooperation and interaction between them.

Clear energy and environmental policies and regulations are of paramount importance to the development of renewable energy sources. The institutional framework, legislation and legal constraints are borderlines to delimit development, especially in view of environmental protection. Environmental considerations are key elements in legislation relevant to geothermal energy. Herein not only the geothermal resources need to be clearly defined, but the sustainable use of the resources and protection of the environment need to be addressed (Rybach, 2003).

4. ROLE OF THE WORLD BANK'S POLICY IN ENVIRONMENTAL ASSESSMENT

The World Bank is one of the world's largest sources of development assistance. The purpose of the Bank's policies and procedures for environmental assessment (EA) are to ensure that development options under consideration are environmentally sound and sustainable, and that any environmental consequences are recognized early and taken into account in project design. As concern about environmental degradation and the threat it poses to human well being and economic development has grown worldwide, many industrial and developing nations, as well as donor agencies, have incorporated EA procedures into their decision-making. Bank EAs emphasize identifying environmental issues early in the project cycle, designing environmental improvements into projects, and avoiding, mitigating, or compensating for adverse impacts. By following the recommended EA procedures, the bank as well as implementing agencies, designers, and borrowers are able to address environmental issues immediately, thereby reducing subsequent requirements for project conditionality, and avoiding costs and delays in implementation due to unanticipated problems.

The World Bank introduced an *environmental assessment* (EA) policy, *Operational Directive* (OD) 4.01, for the first time in 1989. This policy was converted in 1999 into a new format:

Operational Policy (OP) 4.01 and *Bank Procedures* (BP) 4.01

These apply to any bank-financed or implemented project if there is potential for that project to result in adverse environmental impact. It is also designed as a tool to improve project performance and to enhance the quality and sustainability of projects. It does so by providing the guidance that allows borrowers, decision-makers, and bank operational staff the flexibility to ensure that the project options under consideration are environmentally sound and sustainable.

Several kinds of environmental analyses and reports are required by the World Bank, depending upon the nature of the project. Project-specific EAs are used to analyze investment projects, the detail and sophistication of the analyses being commensurate with the expected impacts. Proposed geothermal development has apparently been classified by World Bank environmental screening as "Category A", because the project may have diverse and significant environmental impacts. A Category A classification requires a complete EA, which would normally cover:

- Existing environmental baseline conditions
- Potential environmental impacts, both direct and indirect
- Systematic environmental comparison of alternatives
- Preventive, mitigating and compensating measures, generally in the form of an action plan
- Environmental management, training and monitoring

An environmental assessment (EA) report for a Category A project focuses on the significant environmental issues of a project. The report's scope and level of detail should be commensurate with the project's potential impacts. The EA report should include the following items:

- Executive summary;
- Policy, legal, and administrative framework;
- Project description;
- Baseline data;
- Environmental impacts;
- Analysis of alternatives;
- Environmental management plan ;
- Appendices.

Several geothermal projects have been supported by the World Bank, for example: the Olkaria Power Plant in Kenya.

5. ENVIRONMENTAL IMPACT ASSESSMENT - IMPORTANCE TO GEOTHERMAL POWER GENERATION PROJECTS

Geothermal energy is generally accepted as being an environmentally benign energy source, particularly when compared to fossil fuel energy sources. Geothermal developments in the last 40 years, however, have shown that it is not completely free of impacts on the environment. These impacts are becoming of increasing concern, and to an extent which may now be limiting development. History shows that hiding or ignoring such problems can be counterproductive to the development of an industry because it may lead to a loss of confidence in that industry by the public as well as by regulatory, and financial sectors. If the aim is to further the use of geothermal energy, then all possible environmental effects should be clearly identified, and countermeasures devised and adopted to avoid or minimize their impact (Hunt, 2001). The most important environmental effects of geothermal utilization have been reviewed by Axtmann (1975); Ellis (1978); Ármannsson and Kristmannsdóttir (1992); and Hunt (2001). Geothermal utilization can cause surface disturbances, physical effects due to fluid withdrawal, noise, thermal effects and emission of chemicals as well as affecting the communities concerned socially and economically (Ármannsson and Kristmannsdóttir, 1992).

All geothermal fields contain heated fluids trapped beneath the earth, but temperature and chemical characteristics of the geothermal resource can vary significantly. When these resources are abstracted for geothermal generation, the environment of an area can be affected. Some of the low- and high-temperature geothermal systems can impact the physical environment. In Table 1, the possible environmental effects of geothermal development, both in low- and high-temperature areas, are summarized (Hunt, 2001).

Environmental impacts from geothermal development will vary between the various phases of development. Environmental effects of geothermal development are summarized below.

TABLE 1: Possibilities of environmental effects of geothermal development (Hunt, 2001)

	Low-temperature systems	**High-temperature systems**	
		Vapour-dominated	**Liquid-dominated**
Drilling operations			
Destruction of forests and erosion	1	2	2
Noise	2	2	2
Bright lights	1	1	1
Contamination of groundwater by drilling fluid	1	2	2
Mass withdrawal			
Degradation of thermal features	1	2	3
Ground subsidence	1	2	3
Depletion of groundwater	0	1	2
Hydrothermal eruptions	0	1	2
Ground temperature changes	0	1	2
Waste liquid disposal			
Effects on living organisms surface disposal	1	1	3
Re-injection	0	0	0
Effects on waterways surface disposal	1	1	2
Re-injection	0	0	0
Contamination of groundwater	1	1	1
Induced seismicity	0	2	2
Waste gas disposal			
Effects on living organisms	0	1	2
Microclimatic effects	0	1	1

0 = No effect; **1** = Little effect; **2** = Moderate effect; **3** = High effect

5.1 Surface disturbances

A drill site is usually between 200 and 2500 m^2 in area (Ármannsson and Kristmannsdóttir, 1992). The construction of road access to drill sites can involve destruction of forests and vegetation which, particularly in tropical areas with high rainfall (Indonesia, the Philippines), can result in erosion (Hunt, 2001). As geothermal areas tend to be associated with soft rocks such as pumice or in hydrothermally altered rock, development can cause land erosion and slips if care is not exercised (Ellis, 1978).

5.2 Physical changes due to fluid withdrawal

Fluid withdrawal may cause subsidence and lowering of the groundwater table. The largest recorded subsidence in a geothermal field (15 m) was in a part of Wairakei (New Zealand) (Hunt, 2001). Generally low- and high-temperature geothermal systems are overlain by cold groundwater. During production from the geothermal system, a large pressure drop can occur in the reservoir. Because of the pressure change, groundwater may be drawn down into the upper part of the reservoir. For example: at Wairakei, a localized drop of more than 30 m in groundwater level has occurred associated with a cold downflow (Hunt, 2001). The lowering of the groundwater table may cause the mixing of fluids between aquifers, and cause difficulties such as the deterioration of piped water; a danger that has needed watching in Seltjarnarnes (Iceland) (Kristmannsdóttir, 1983). At the low-temperature geothermal fields utilized for district heating in Reykjavík, surface geothermal activity has disappeared both in Reykjavik (Laugarnes area) and at Reykir. The name of the capital Reykjavik is derived from steam emitting from hot springs, which have now disappeared (Gunnlaugsson, 2003).

5.3 Noise

The development of a geothermal field creates considerable noise, particularly during drilling and well-testing, which can disturb animals and humans living nearby (see Table 1). Drilling operation noise exceeds 90 dB, and the noise from the discharge of boreholes may exceed 120 dB - the pain threshold at 2-4000 Hz (Ármannsson and Kristmannsdóttir, 1992).

5.4 Ground temperature changes

Steam is much more mobile than water. The generation and movement of steam can increase ground temperatures so that vegetation becomes stressed or killed. If excess heat enters the environment via geothermal steam, it may affect cloud formation and even cause changes in the local weather. Where wastewater is piped into a stream, a river, a lake or even local groundwater, it may seriously affect the biota in the local environment and eventually the whole ecological system (Ármannsson and Kristmannsdóttir, 1992). For example: The Nesjavellir plant (Iceland) is located near Lake Thingvallavatn, approximately 6 km from the power plant. The warm water disposal of the power plant discharges into parts of Lake Thingvallavatn. The temperature of water in the lake is about 4-5˚C. But after the start of electricity generation at the Nesjavellir Power Plant, increased discharge of hot water has lead to a marked temperature rise, from 20 to 26˚C in very localized parts of the lake (Wetang´ula and Snorrason, 2003)

5.5 Fluid composition

Gas discharges from low-temperature systems do not usually cause significant environmental impacts. In high-temperature geothermal fields, power generation using a standard steam-cycle plant may result in the release of non-condensable gases and fine solid particles into the atmosphere (Webster, 1995). Gas concentration and composition covers a wide range, but the predominant gases are carbon dioxide (CO_2), and hydrogen sulphide (H_2S). CO_2 occurs in all geothermal fluids but is most prevalent in fields where the reservoir contains sedimentary rocks, and particularly those with limestones. The following reaction controls its concentration:

$$CaCO_3 + SiO_2 \rightarrow CaSiO_3 + CO_2$$

In an acidic region, CO_2 can accelerate the uniform corrosion of carbon steels. The pH of geothermal fluids and process steam is largely controlled by CO_2 (Conover et al., 1980). For example, the Kizildere geothermal reservoir, Turkey, is a single-phase liquid reservoir. The surface steam discharge from this field contains between 10 and 20% CO_2. CO_2 degassing of the water causes an increase in pH as it boils and, as a result, an increase in the aqueous CO_3^{-2} concentration. Calcium concentration also increases due to steam loss. These changes cause the water to become strongly calcite supersaturated (Gökgöz, 1998).

Hydrogen sulphide (H_2S) is characterized by a "rotten egg odour" detectable by humans at very low concentrations of about 0.3 ppm. The following reaction controls its concentration:

$$CaSO_4 + FeS_2 + 3\ H_2O + CO_2 \rightarrow CaCO_3 + 1/3\ Fe3O4 + 3\ H_2S + 7/3\ O_2$$

The main potential pollutants in the liquid effluent are: hydrogen sulphide (H_2S), arsenic (As), boron (B), mercury (Hg), and other trace metals (e.g. lead (Pb) and cadmium (Cd)) (Ármannsson and Kristmannsdóttir, 1992). Most high-temperature geothermal bore waters include high concentrations of at least one of the following toxic chemicals: Li, B, As, H_2S, Hg, and sometimes NH_3. Arsenic is preferentially retained (>99 %) by the water phase in steam/water separation, and the measured levels of arsenic in geothermal steam are usually less than 40 μg/kg. However, the arsenic concentrations in geothermal waters do present a disposal problem (Ellis, 1978). Boron in geothermal water is probably controlled by degassing of magmatic intrusives. The geothermal fields of western Turkey provide a unique setting of extremely high enthalpy combined with a large variation in chemical composition. Effluents from the power plant in Denizli-Kizildere that have B concentrations of more than 20 mg/l are released into adjacent creeks, and endanger natural biota that are sensitive to B (Vengosh et al., 2002). In addition, a natural underground discharge of geothermal waters into overlying aquifers in western Anatolia (Filiz and Tarcan, 1995; Gemici and Tarcan, 2002), has been described.

The waters with greatest pollution potential are those with very high deep temperatures and/or high salinities. As pointed out by Ellis (1978), the concentrations of heavy metals tend to rise in proportion to the square of the water salinity so that brines that may have these associated with them pose a heavy metal contamination problem even greater than expected from their salinity. For example: Fluids from the Salton Sea field (USA), which is hosted by evaporate deposits, are acidic and highly saline (pH<5, Cl = 155,000 ppm). At the other extreme, those of the Krafla, Námafjall, and Nesjavellir fields (Iceland) are alkaline and of very low salinity (pH > 9, Cl ~ 100 ppm).

5.6 Socio-economic effects

In the context of geothemal utilization, a socio-economic study's aim is to determine changes in conditions due to geothermal projects. The purpose of any socio-cultural and economic impact assessment is to determine ways to attain acceptability of social changes due to the project. To gain social acceptability, each sector has a role to play. The proponent must facilitate public participation; the government or local authority must ensure that the benefits and burden of the project are equitably distributed; and the affected sectors must weight the quality and quantity of the benefits they will acquire as well as the costs that they will have to bear because of the project (De Jesus, 1995).

Political and public acceptance of geothermal energy as a "green" and economically feasible energy source is weaker than for most other alternative energy sources (Popovski, 2003). For example, local people of Milos Island, Greece believed it to be undesirable to have an industrial plant with smelly steam and dirty effluent water in town. Also the local people of Nisyros Island, Greece believed that geothermal power generation is dangerous and disturbs the balance of the volcano (Popovski, 2003). Therefore, the local people of Milos and Nisyros islands have reacted negatively to geothermal energy production.

6. STATUS OF ENVIRONMENTAL IMPACT ASSESSMENT FOR THE GEOTHERMAL FIELD IN TUZLA, CANAKKALE, TURKEY

6.1 Introduction

The Tuzla geothermal field is located in northwestern Anatolia 80 km south of Canakkale and 5 km from the Aegean Sea (Figure 15). Tuzla is an active geothermal area in northwest Turkey hosted by rhyolite lavas and pyroclastic deposits (Figure 16). Geothermal studies of the Tuzla field have been ongoing since 1966. The general geological and volcanological characteristics have been studied by Samilgil (1966); Erdogan (1966); Urgun (1971); Öngur (1973); and Alpan (1975). Geophysical surveys were carried out by Demirörer (1971), and Ekingen (1972). Ten thermal gradient wells were drilled from 50 to 100 m depth in 1974, based on the results of geological and geophysical surveys. Temperatures up to 145˚C were observed at 50 m depth in some of these wells, and due to vigorous boiling, some were lost in blow-outs (Karamandersi and Öngur, 1974). Two deep exploration wells (814 and 1020 m) were drilled in 1982 and 1983. The reservoir depth is in the range 333-553 m in volcanic rock with a temperature of 173˚C; a production rate of 130 tons/h; and steam content of 13%. The general characteristics of alteration in this field were described by Gevrek and Sener (1985). Hydrothermal alteration mineral assemblages indicate that geothermal fluids, with temperatures of 150-220˚C have been present (Sener and Gevrek, 2000). The nature and origin of the thermal springs in the Tuzla area have been described by Mutzenberg (1997).

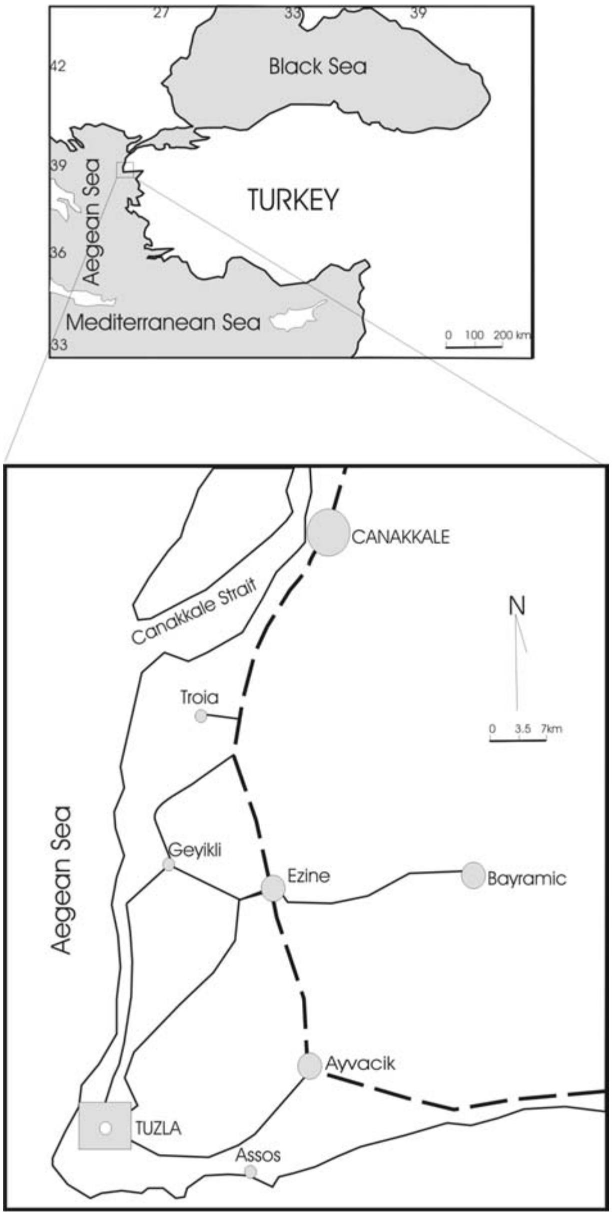

FIGURE 15: Location map of the Tuzla field, Turkey

The long-term strategy and 8th five-year development plan in Turkey was published by the Prime Minister's State Planning Organization. Potential and future prospecting of the Tuzla geothermal field was described in a study report on geothermal energy by the State Planning Organization (Table 2).

TABLE 2: An overview of present and future prospects for the Tuzla field (State Planning Organization, 2000)

	Spring		**Well**		**Actual situation (January 2000)**	**8th five-year development prospecting plan**
	T (˚C)	Q (l/s)	T (˚C)	Q (l/s)		
Tuzla Canakkale	50.9-97.2	7.5	90-174	120	A- Simple spa B- Salt production C- Greenhouses (50,000 m^2)	A- Thermal tourism B- Space heating C- Greenhouses (300,000 m^2) D- Power generation 25 MWe E- Gurpinar space heating

One salt factory, one spa, and a greenhouse are located in the Tuzla geothermal field. According to one estimate, the total production capacity of this resource is about 50 MWe. An environmental impact assessment of power production in this area will be discussed.

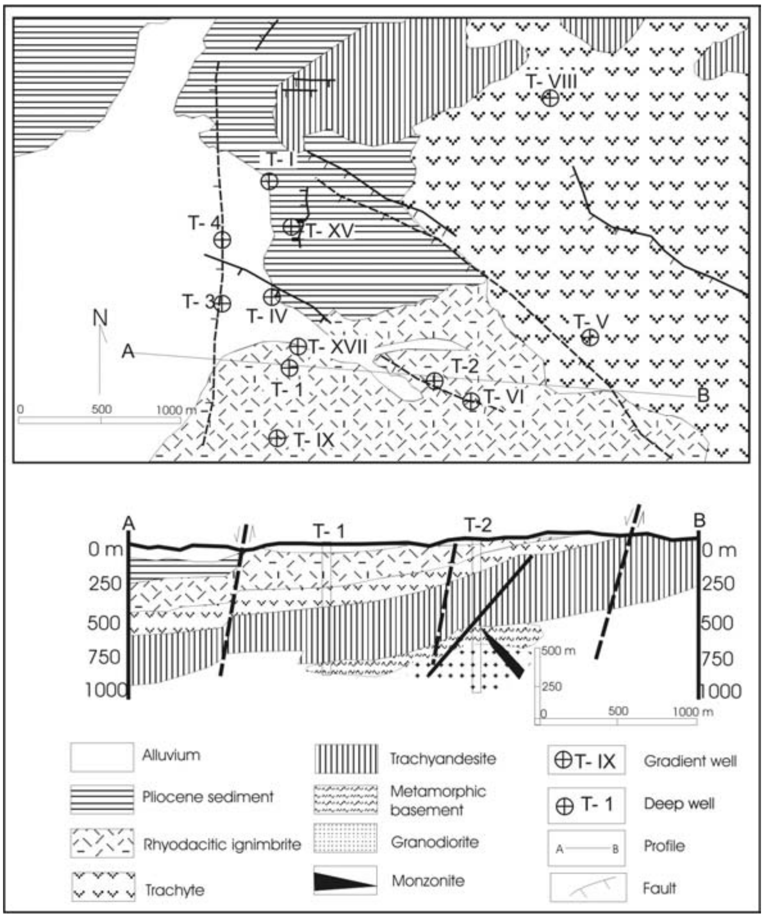

FIGURE 16: A geologicaly map and a cross-section of the Tuzla geothermal field (Karamanderesi, 1986)

The following factors will be dealt with:

- A brief review of the regulatory and legal requirements that the project will be affected by under Turkish law;
- Description of the existing environment;
- An assessment of impacts for each element of the environment, and recommendations for mitigating measures to ensure that impacts are maintained at an acceptable level; and
- A summary of the major conclusions reached in the impact assessment section, and the recommended mitigating measures and monitoring that should be undertaken.

6.2 Conduct of the environmental assessment and regulatory and legal requirements affecting geothermal development

Energy utilization and its major environmental impacts are discussed from the standpoint of sustainable development, including anticipated patterns of future energy use, and subsequent environmental issues in Turkey. Turkey is an energy importing country; more than half of its energy requirement being supplied by imports (Kaygusuz, 2002). Due to increasing energy consumption, air pollution is becoming a great environmental concern for the future of the country. In this regard, renewable energy resources appear to be among the most efficient solutions for sustainable energy development, and environmental pollution prevention in Turkey. Therefore, new energy efficiency legislation and regulations that will go some way towards using renewable potential are in preparation.

Geothermal utilization started before environmental impact assessment (EIA) work in the Tuzla area. However, the scale of geothermal utilization is much smaller than of projects requiring EIAs. The Tuzla area is located within the Canakkale city boundary, where one of the important archaeological, historical, and natural parks of Turkey is situated. Compared with other Turkish cities, a very large number of EIA reports have been prepared for projects within the border of Canakkale city. Also the first draft of a strategic environmental assessment (SEA) report was prepared by the Minister of Environment for this city. However, in recent years following greater uses of geothermal energy, and some responsible national environmental policies, geothermal development and utilization have become more and more widespread, and at the same time attracted more and more governmental attention.

The Tuzla geothermal area is very sensitive to environmental impacts. Therefore, this area needs an EIA report for geothermal utilization projects. Such reports that deal with environmental aspects, although they are not real EIAs, can be regarded as descriptions of rudimentary EIA work in the geothermal field.

6.3 Existing environment

A power station requires land for the physical components of the power station, which include the turbine building, cooling towers, offices, workshops, stores, car parking areas, roads, well pads and separators, pipelines, and drains. Land is also required as a buffer zone for safety, security and to allow an adequate area for the dispersal of odours. The principal potential impacts of a power station are water and air pollution. However, the physical presence of a power station, and the disturbance to the land required for its development, will also have local impacts. This part of the study is concerned with describing existing conditions.

6.3.1 Geology and soil

The basement of the Tuzla geothermal field consists of metamorphic rocks including calc-schist, quartzite and marble. A stratigraphic cross-section of the study area is shown in Figure 16. The metamorphic basement is intruded by a large granodioritic pluton. The basement rock is overlain by andesitic lavas. Sediments of the Neogene overlie discordantly the metamorphic, granodioritic pluton and andesitic lavas. The Neogene sediment consists of tuffitic claystones, siltstones and volcanic conglomerate. The alluvium is the youngest rock in the study area.

The geology assessment includes the effects of the project on geology, and potential adverse effects of the project that could result from possible geologic hazards, such as seismically-induced surface ruptures, ground shaking, ground failure, slope stability failure, or subsidence. Each of these possible effects and concerns should be evaluated in an EIA. Some of the possible potential impacts of geology, and measures to reduce the adverse effects are summarized below:

- Ground shaking from earthquakes could damage project facilities, but conformance with applicable construction and building requirements would prevent any significant adverse effects.
- The removal of large quantities of groundwater could result in land subsidence.
- Similarly, the removal of large quantities of geothermal fluid could result in subsidence, but produced fluid would be injected back into the geothermal aquifer; and the geothermal aquifer is a fracture system within volcanic and metamorphic rock that would prevent compaction of the aquifer.
- Construction and decommissioning of roads, well pads, transmission lines, pipeline corridors, and other surface facilities could result in soil erosion. But the project will implement best management practices to prevent substantial erosion, and potential adverse effects will be further reduced by implementation of measures to be developed in comprehensive soil conservation and erosion control plans required for the project.
- Construction of roads, well pads, and power plant site would result in cut and fill slopes that would reshape the topography in the area; but very few parts of the area would be directly affected, and the effect on the area's topography would not be significant.

6.3.2 Hydrologic and geothermal resources

In a hydrologic and geothermal resource assessment the effects of the project on existing surface water and groundwater resources, and the effects associated with geothermal heat extraction are considered. Production or injection of shallow groundwater or geothermal fluid can affect the quality and quantity of cold groundwater. Groundwater is mostly extracted from alluvium for irrigation in the Tuzla area. The chemical composition of the Tuzla geothermal water is very interesting from a hydrogeochemical viewpoint (Tables 3 and 4). At the surface, the waters reach temperatures between 35 and 95˚C. The chemical and isotopic compositions of the waters indicate the presence of a fossil-altered seawater, which is diluted up to 70% with freshwater of meteoric origin (Mutzenberg, 1997). The total salinity reaches 61,000 mg/l which is approximately that of seawater. The amounts and ratios of Mg, Mg/Ca, Na/Ca, Cl/F, and Cl/HCO_3 indicate a hot water system. The Na/K ratio of 13 indicates a reservoir temperature of ~215˚C; while a low SiO_2 concentration (56-100 mg/l) suggests lower temperatures of 130-150ºC (Kurtman and Samilgil, 1975). Water outflow from about 100 springs in the Tuzla field is estimated to be close to 50 l/s of about 102˚C hot water.

TABLE 3: Chemical composition of geothermal waters (Sener and Gevrek, 2000)

Constituent	Spring A	Spring B	Spring C	Spring D	T-1
pH	7.82	8.04	7.72	7.8	7
T (˚C)	102	72	73	40	173
Ca (mg/l)	3069	3110	931	753	5715
Mg (mg/l)	90.4	80.8	88	57	101
Na (mg/l)	17260	18740	7148	6032	22250
K (mg/l)	1912	1904	451	405	2125
SO_4 (mg/l)	155	166.2	210	174	176
HCO_3 (mg/l)	98	122	111	90	100
Cl (mg/l)	33855	36159	13116	10989	44140
SiO_2 (mg/l)	100	98	96	88	123

TABLE 4: Chemical composition of hot water from wells in the Tuzla geothermal field (Karamanderesi, 1986)

Constituent	T-K 102	T-K (99)
pH	7.3	-
T (˚C)	102	99
Ca (mg/l)	3080	2920
Mg (mg/l)	30	70.7
Na (mg/l)	19000	16640
K (mg/l)	1800	1280
SO_4 (mg/l)	172	150
Cl (mg/l)	35500	33600
SiO_2 (mg/l)	113	93.90
F (mg/l)	2.7	4.4
Fe (mg/l)	<0.1	1.95
TDS (mg/l)	58700	

General information from fluid chemistry: The chemical composition of groundwater changes, due to either water-rock interaction, or mixing with different waters. To follow the whole process from original groundwater, to geothermal water, and back to mixing of the geothermal water with the original groundwater, is quite a complex process involving complex thermodynamic calculations with assumptions about thermodynamic data and underground conditions. Each possible effect and concern should be considered in the EIA. Some of the possible potential impacts and measures to reduce the adverse effects of the impacts are summarized below.

- During well drilling, permeable groundwater aquifers can be penetrated resulting in a loss of drilling fluids into the reservoirs.
- There is some possibility that geothermal fluid could mix with shallow groundwater downhole through damaged well casings, or from the surface following an accident such as well blowout, sump overflow, or pipeline rupture. Monitoring should be conducted throughout the construction, operation and decommissioning phases of the project.

- Geothermal re-injection should be considered an essential part of any modern, sustainable, environmentally-friendly geothermal utilization project.

Estimation of reservoir temperatures and mineral saturation: Chemical analysis of geothermal fluids can be used to estimate subsurface reservoir temperature. Chemical geothermometers depend on the water-mineral equilibria, and give the last equilibration temperature for the reservoir (Nicholson, 1993). Several geothermometry techniques have been developed to predict reservoir temperatures in geothermal systems (e.g. Fournier and Truesdell, 1973; Fournier, 1977; Fournier and Potter, 1982; Arnórsson et al., 1983; Giggenbach et al., 1983; Giggenbach, 1988). All of them are based on the premise that temperature dependent water-mineral equilibrium is attained in the reservoir. In this part, solute geothermometry techniques have been applied to hot waters from springs in the Tuzla geothermal field. The results are presented in Table 5. Surface temperatures of thermal waters from the study area vary between 40 and 102˚C. According to chemical geothermometers, the temperature of the reservoir varies between 61 and 241˚C. Compared to the measured reservoir temperature (173˚C in well T-1), the Na-K-Ca and some of the Na/K geothermometer temperatures are generally higher than the measured temperatures. These results may reveal older temperatures when the system was hotter. Quartz geothermometers give lower reservoir temperatures, probably because of the old seawater, which has low silica content mixing with the geothermal water after equilibration.

TABLE 5: Calculated aquifer temperatures of the thermal waters in the Tuzla geothermal area, Turkey

Geothermometers	Reference	Spring A	Spring B	Spring C	Spring D
SiO_2 (amorphous silica)	Fournier, 1977	111.7	91.2	91.9	61.1
SiO_2 (chalcedony)	Fournier, 1977	106.9	104.4	105.0	100.0
SiO_2 (quartz)	Fournier and Potter, 1982	134.1	131.9	132.0	127.9
Na/K	Arnórsson et al., 1983	206.3	196.8	151.7	157.8
Na/K	Fournier, 1979	225.9	218.3	180.4	185.1
Na/K	Giggenbach, 1988	240.6	233.6	198.0	202.4
Na/K	Truesdell, 1975	198.0	188.4	142.0	147.5
Na-K-Ca	Fournier and Truesdell, 1973	230.0	226.0	190.0	192.0

The ternary plot of Na/1000-K/100-$Mg^{0.5}$ of Giggenbach (1988) is a method to discriminate between mature waters, which have attained equilibrium with relevant hydrothermal minerals, from immature waters and waters affected by mixing and/or re-equilibration at low temperatures during their circulation. Four spring waters of the study area fall into the field of equilibrated water (Figure 17). Reservoir temperature values estimated by this method are between 140 and 200˚C.

A different approach to geothermometry is shown in Figure 18, where the changes in saturation index (SI) of relevant minerals with temperature (Reed and Spycher, 1984) were investigated for the four springs in the Tuzla area. Figure 18 shows SI with respect to selected hydrothermal minerals versus temperature for the thermal waters of the Tuzla area. SI for each mineral was plotted versus temperature. SI with respect to chalcedony approaches zero at ~100˚C in all four cases. SI for quartz approaches zero at ~135˚C for all four springs. SI for anhydrite approaches zero at ~185˚C in A and B water. In C and D water, anhydrite approaches zero at ~165˚C and ~175˚C, respectively. The waters of all four springs

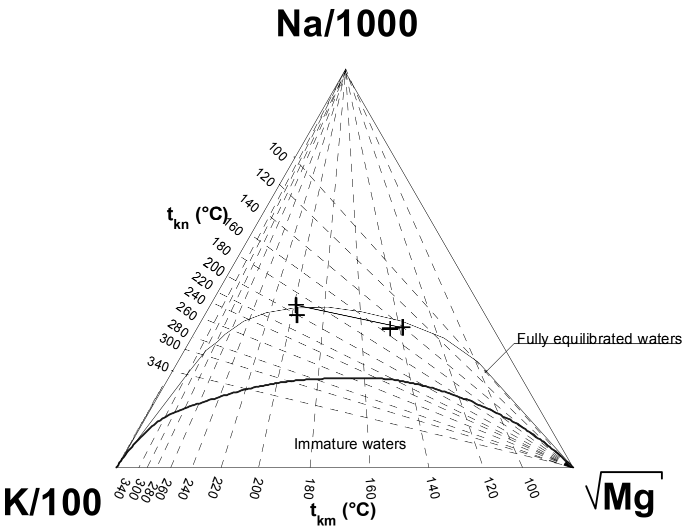

FIGURE 17: Distribution of the thermal waters from the Tuzla geothermal area in a Na-K-Mg ternary diagram

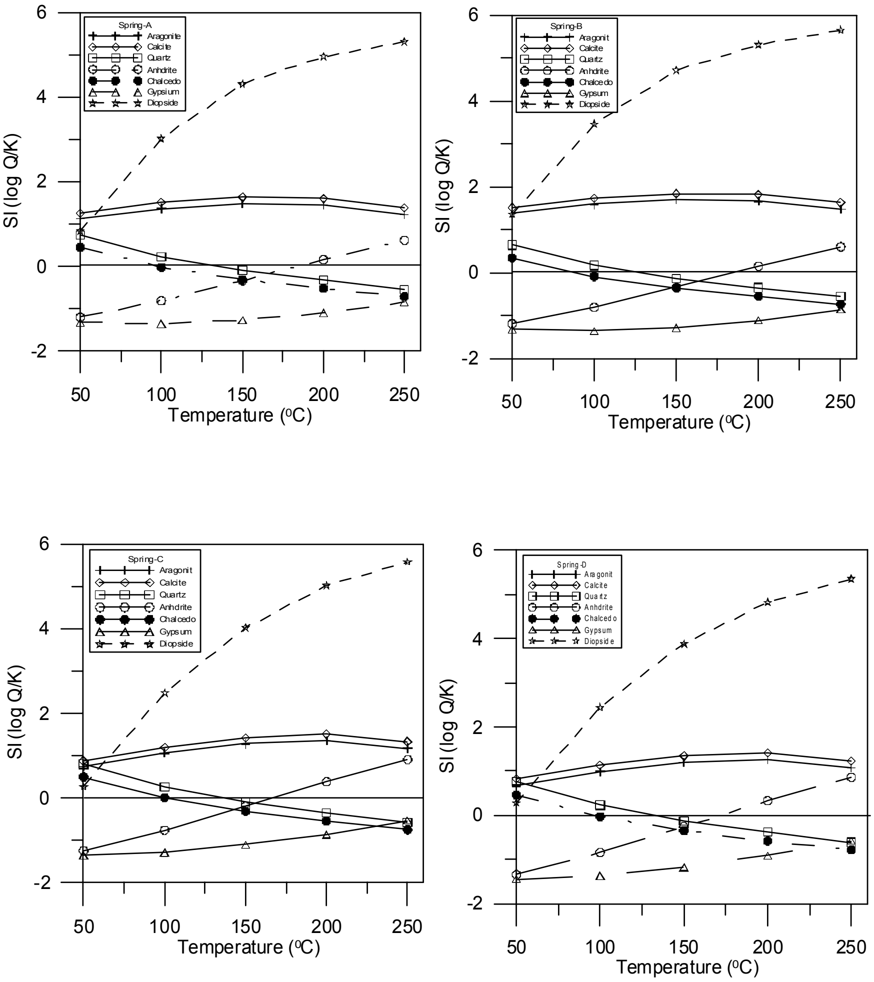

FIGURE 18: Mineral equilibrium diagrams for thermal waters from the Tuzla geothermal area, Turkey

are oversaturated with respect to aragonite, calcite and diopside, but undersaturated with respect to gypsum at 50-250˚C (Figure 18). These calculations confirm that the thermal waters of the Tuzla geothermal field are not completely equilibrated waters derived from mixed fluids of different temperatures. The SI results show that aragonite, calcite and diopside scaling can be expected in the Tuzla geothermal area.

Metal concentrations: Residents in Tuzla use groundwater which is abstracted from alluvium aquifers. The geothermal fluid generally contains more heavy metals than the cold groundwater. Some metals were analyzed in open spring pools in Tuzla (Table 6). The most outstanding feature is high concentrations of Zn, Pb, As, and Sb. Of these trace metals Zn and Pb are known to form stable chloride complexes at high temperatures (White, 1968). As and Sb can be used, in addition to NH_4 and B, to give a qualitative indication of the age of a geothermal system (Giggenbach et al., 1983). Since these volatile constituents evaporate at an early stage of a geothermal system, the relatively high concentrations in the present hydrothermal system of the Tuzla area may indicate a young age for this system, with a sufficient supply of fresh thermal water (Mutzenberg, 1997).

TABLE 6: Metal, Si and Ca concentrations in upper Miocene ferromanganese crusts and deposits from present thermal springs in Tuzla (all in ppm) (Mutzenbberg, 1997).

Sample no.	**1ExhR**	**2 T6/1**	**3 T3/1**
Si	$1.5\times10^5 - 2\times10^5$	$6\times10^4 - 10^5$	$10^5 - 1.5\times10^5$
Ca	7,000 – 10,000	$10^5 - 1.5\times10^5$	$2\times10^4 - 4\times10^4$
Mn	700 – 900	2,000 – 3,000	1,000 – 3,000
Fe	$4\times10^5 - 5\times10^5$	$4\times10^5 - 5\times10^5$	$4\times10^5 - 5\times10^5$
Zn	700 – 900	3,000 – 5,000	2,000 – 4,000
As	500 – 700	3,000 – 4,000	3,000 – 5,000
Sb	n.d	1,000 – 2,000	500 – 600
Ba	1,000 – 2,000	500 – 800	500 – 800
Pb	150 – 200	3,000 – 4,000	4,000 – 6,000
U	300 – 500	n.d.	n.d.

6.3.3 Biological resources

A biological resource assessment should be included in the estimation of the effect of project activity on vegetation, habitat, wildlife, and special status plant and animal species. Project pipelines and other facilities could impact plant and animal species. Most of the olive trees in Canakkale city grow around the Tuzla area. Also, a great part of the area is used for agriculture by people from Tuzla village. Kaz dagi (Mount Ida) is also located inside the city boundary. Mount Ida, overlooking the Aegean Sea, where Greek mythology, Anatolian legends, and history combine, is a paradise with its waterfalls, fruit gardens, different tones of green and the National Park where wildlife abounds.

6.3.4 Meteorology and air quality

Information on local meteorological conditions is important for assessing the dispersion of gaseous emissions from sources associated with development. Dispersion of stack emissions is influenced by wind speed, wind direction, temperature, and atmospheric stability. Climate in that area is mostly Mediterranean. Generally, summers are hot and winters rainy.

Gases and dusts would be released to the air during all phases of the operation. During construction and decommissioning, fugitive dust would result from surface disturbance and vehicle travel on unpaved roads. Non-condensable gases including hydrogen sulfide (H_2S) would be released from the geothermal fluid during well drilling and testing, and during power plant operations from the power plant facilities. Oxides of nitrogen, carbon monoxide, and oxides of sulphur from internal combustion engines would be released during all phases of the project. Toxic air emissions from the project would affect humans in the area. Also, cooling water evaporation from cooling towers might affect the local climate, and project emissions could contribute to global warming. Each of these possible effects and concerns should be evaluated in an EIA for this project.

6.3.5 Cultural resources

The area is located in northwestern Turkey on the Biga Peninsula, known in antiquity as the Troas (the famous city of "Troy" in Homer's Ilias lies within the Troas). The springs of Tuzla were described by Demetrios of Skepsis (born around 205 BC), and the Greek geographer Strabo (63 BC-26 AD). The springs of Tuzla, known as Tragasai in antiquity, were of greater importance during this period (Mutzenberg, 1997). Since classical times, the thermal springs of Tuzla have been used as spas. Three important archaeological sites (Assos, Temple of Apollo Smintheus, and Alexandria Troas) are located about 20 km from the study area. The project should not affect these historical sites. All possible effects and concerns should be evaluated in the EIA.

6.3.6 Noise

The potential for disturbing noise levels depends on the intensity relative to existing noise levels. Thus, to undertake an impact assessment, it is necessary to determine the existing noise environment in the absence of noise from the project. In addition, it is necessary to obtain information about the noise level from the project during its various phases. Also, data on background noise levels are important from the point of view of noise impact assessment, because it is the difference between the background noise and the project-related noise that most intensely disturbs the public.

Project construction, well drilling, and power generation can all result in intrusive noise impacts on residents in Tuzla village.

6.3.7 Land use

The project area and vicinity is largely undeveloped with little human occupation, and provides a variety of recreational opportunities. The residents use some parts of the field for agriculture. The project could be incompatible with existing land use. Visual impact, noise, traffic, or odours could also affect existing land use, as well as its use for emergency transportation and first-aid training exercises.

6.3.8 Roads and transportation

During all phases of the project, local traffic would increase. Also, heavy trucks for moving materials and equipment could damage the Ezine-Tuzla and Tuzla-Ayvacik roads, which would require increased maintenance. Water is necessary to control dust during road construction and maintenance.

Transportation of hazardous substances would increase the potential for accidental release during loading and unloading at the project site and along the transportation route. However, such potentially adverse effects are diminished by an emergency action plan required to respond to spills or releases of hazardous substances; and the requirement that all hazardous substance deliveries and pickups be coordinated with the appropriate emergency response agencies.

Such potential effects and concerns should be evaluated in an EIA. Also, potential impacts and mitigation measures to reduce the adverse effects of the impacts should be determined in an EIA.

6.3.9 Socio-economics

In considering socio-economic impacts, the type, duration, spatial extent, and distribution of impacts needs to be clarified; that is, the analyst needs to ask questions about what to include, over what period of time, over what area, and who will be affected? All potential effects should be explained in an EIA. The project would require both short and long-term employment, but this could be accommodated by the resident population without the need to import employees, and would be a beneficial impact of the project.

6.4 Rapid Impact Assessment Matrix (RIAM) method for the Tuzla geothermal power plant

This method seeks to overcome the problems of recording subjective judgments by defining the criteria and scales against which these judgments are to be made; and by placing the results in a simple matrix that allows for a permanent record of the arguments in the judgment process (Pastakia, 1998).

The Rapid Impact Assessment Matrix (RIAM) method is based on a standard definition of the important assessment criteria, as well as the means by which semi-quantitative values for each of these criteria can be collected to provide an accurate and independent score for each condition. The impact of project activities is evaluated against the environmental components; and for each component a score is determined, which provides a measure of the impact expected from the component (Pastakia, 1998). The important assessment criteria fall into two groups:

- *Group A:* Criteria that are of importance to the condition, and which can individually change the score obtained
- *Group B:* Criteria that are of value to the situation, but should not be individually capable of changing the score obtained

The value allotted to each of these groups of criteria is determined by the use of a series of simple formulae. These formulae allow the scores for the individual components to be determined on a definite basis. The process can be expressed:

If	(A1) * (A2) = AT	and	(B1) + (B2) + (B3) = BT
then	(AT) * (BT) = ES	is the assessment score for the condition	

Environmental components: The RIAM requires a specific evaluation of the components to be defined through the process of "scoping", and these environmental components will be in one of four categories that are described as follows:

- *Physical-chemical (PC):* Covering all physical-chemical aspects of the environment;
- *Biological-ecological (BE)*: Covering all biological aspects of the environment;
- *Sociological-cultural (SC)* : Covering all human and cultural aspects of the environment ;
- *Economic-operational (EO)*: Qualitatively identifying the economic consequences of the environment change, both temporary and permanent impacts.

Assessment criteria: The criteria should be defined for both groups, and should be based on fundamental conditions that may be affected by changes rather than be related to activities of the project (Table 7).

The method of the RIAM makes it possible to carry out a global analysis of the results based on the individual environmental scores (ES) for each component, which are classified in ranges and so can be compared to each other. Table 8 provides the established ranges for the conversion of those obtained.

The results of the evaluation for the Canakkale field are presented in Tables 9-13 and are illustrated in Figure 19. Most impacts are of class–B (impact), and there is a majority of positive impacts. No major negative impact has been identified by RIAM. Because of the geothermal fluid, physico-chemical effects are prominent in the study area. This power plant will cause positive impacts resulting from its sociological-cultural and economic-operational changes.

TABLE 7: Assessment criteria for RIAM

Group	Category	Scale	Description
Group A	**A1:** Importance of condition	4	Important to national / international interest
		3	Important to regional / national interests
		2	Important to immediate surroundings of the local condition
		1	Important only to the local condition
		0	No importance
	A2: Magnitude of change-effect	+3	Major positive benefit
		+2	Significant improvement in "status quo"
		+1	Improvement in "status quo"
		0	No change / "status quo"
		-1	Negative change to "status quo"
		-2	Significant negative effect or change
		-3	Major negative effect or change
Group B	**B1:** Permanence	1	No change / not applicable
		2	Temporary
		3	Permanent
	B2: Reversibility	1	No change / not applicable
		2	Irreversible
		3	Irreversible
	B3: Cumulative	1	No change / not applicable
		2	Non – cumulative /single
		3	Cumulative / synergistic

TABLE 8: Range bands used for RIAM (Pastakia, 1998)

Environmental score (ES)	Range value (Alphabetic)	Range value (Numeric)	Description
72 to 108	E	5	Impact / major positive change
36 to 71	D	4	Impact / significant positive change
19 to 35	C	3	Impact / moderate positive change
10 to 18	B	2	Impact / positive change
1 to 9	A	1	Impact / slight positive change
0	N	0	No change / status quo / not applicable
-1 to - 9	-A	-1	Impact / slight negative change
-10 to -18	-B	-2	Impact / negative change
-19 to -35	-C	-3	Impact / moderate negative change
-36 to -71	-D	-4	Impact / significant negative change
-72 to -108	-E	-5	Impact / major negative change

TABLE 9: Physical and chemical components (PC)

Components		ES	RB	A1	A2	B1	B2	B3
PC1	Land use change	-10	-B	2	-1	2	2	1
PC2	Noise	-12	-B	1	-2	3	2	1
PC3	Surface water	-12	-B	1	-2	2	2	2
PC4	Air	-18	-B	3	-1	2	2	2
PC5	Landscape	3	A	1	1	1	1	1
PC6	Geology	0	N	0	0	1	1	1
PC7	Agriculture	-18	-B	3	-1	3	2	1
PC8	Groundwater	-14	-B	1	-2	3	2	2

TABLE 10: Biological and ecological components (BE)

Components		ES	RB	A1	A2	B1	B2	B3
BE1	Vegetation	-12	-B	2	-1	2	2	2
BE2	Fauna	-12	-B	2	-1	3	2	1
BE3	Flora	-12	-B	2	-1	3	2	1
BE4	Habitat loss	0	N	0	0	1	1	1
BE5	Recreation	3	A	1	1	1	1	1

TABLE 11: Sociological and cultural components (SC)

Components		ES	RB	A1	A2	B1	B2	B3
SC1	Cultural	14	B	2	1	3	2	2
SC2	Natural protection	-12	-B	2	-1	2	2	2
SC3	Archaeological	18	B	3	1	2	2	2
SC4	Science	42	D	3	2	3	2	2
SC5	Education	7	A	1	1	3	2	2

TABLE 12: Economical and operational components (EO)

Components		ES	RB	A1	A2	B1	B2	B3
EO1	Transport	28	C	2	2	3	2	2
EO2	Services	42	D	3	2	3	2	2
EO3	Work	21	C	3	1	3	2	2
EO4	Tourism opportunity	42	D	3	2	3	2	2
EO5	Access roads improvement	28	C	2	2	3	2	2
EO6	Employment opportunity	42	D	3	2	3	2	2

TABLE 13: Summary of scores

Range	-108 -72	-71 -36	-35 -19	-18 -10	-9 -1	0 0	1 9	10 18	19 35	36 71	72 108
Class	-E	-D	-C	-B	-A	N	A	B	C	D	E
PC	0	0	0	6	0	1	1	0	0	0	0
BE	0	0	0	3	0	1	1	0	0	0	0
SC	0	0	0	1	0	0	1	2	0	1	0
EO	0	0	0	0	0	0	0	0	3	3	0
Total	0	0	0	10	0	2	3	2	3	4	0

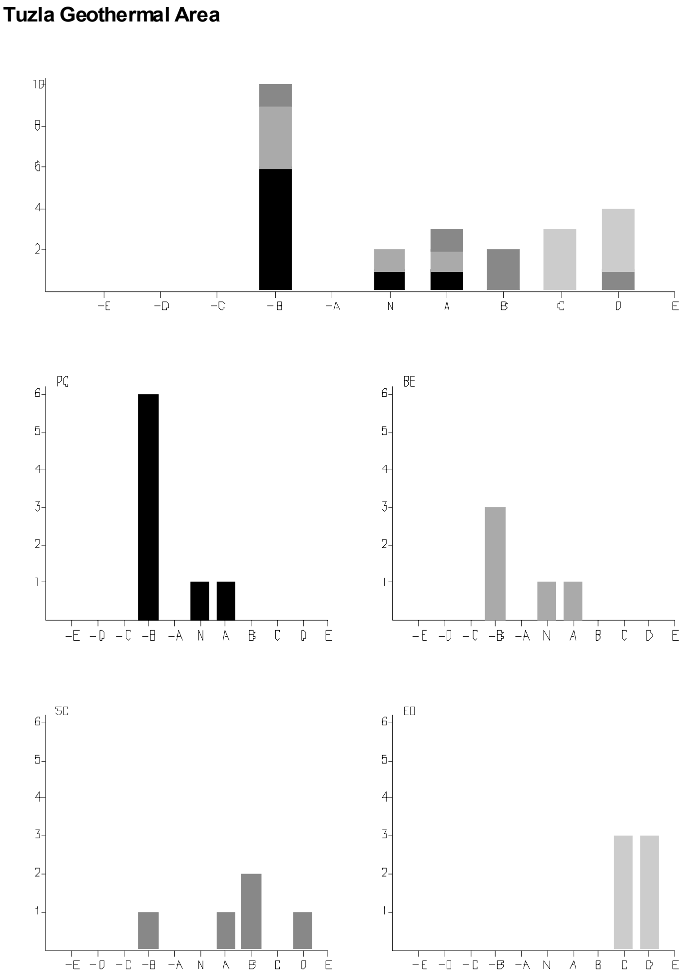

FIGURE 19: RIAM results for the four components, and the overall assessment

7. CONCLUSIONS AND RECOMMENDATIONS

Like most geothermal operations, the project is located in a geological environment where seismic activity and faulting has taken place. Geological processes associated with this type of environment, usually create the geothermal resource. However, as a result there are also numerous potential geological hazards associated with this environment. The majority of project impacts on area's geology and soil would probably occur during construction and well drilling activities.

During the project, some environmental impacts will be observed in the Tuzla geothermal area. The potential effects are summarized below:

- Project could result in increased subsidence due to fluid extraction in the Tuzla area;
- Soil pollution could be caused by the release of geothermal fluid from Tuzla;
- Geothermal fluid could adversely affect surface or groundwater resources;
- Water temperature of surface waters could change due to production of the geothermal fluid;
- Botanical resources could be adversely affected, therefore, pre-project detailed biological surveys of the transmission line corridors will be required;
- Steam from the power plant could affect air quality or cause localized temperature changes;
- Hydrogen sulfide from power generation could cause air pollution and carbon dioxide contribute to greenhouse effect;
- Tuzla residents and visitors would be impacted by project construction, drilling, and power plant operational noises;
- Project facilities, particularly pipelines and plowed access roads, could conflict with designated facilities;
- Project-generated traffic could increase traffic and clog roadway facilities in the Tuzla area.

Therefore, monitoring should be stipulated in an EIA whenever there is uncertainty about:

- The level, extent or duration of impacts; and
- The effectiveness of proposed mitigation measures, or the proficiency with which they will be carried out.

This is also important for assessing residual impacts and for a cumulative database for use in future EIAs. Monitoring should be carried out throughout the construction, operation and decommissioning phases of the project, and should be funded by the developer. Parameters used in establishing the baseline conditions can be monitored, and their inclusion in a monitoring programme can help to justify the collection of field survey data in the baseline studies.

Geographical information systems (GIS) are computer-based databases that include spatial references for the different variables stored, so that maps of such variables can be displayed, combined and analyzed with relative speed and ease. Superimposing maps produces combined maps (map-overlay) from simple maps. Overlay maps are easy to use and understand, and are popular in practice. They are a very important way of showing the spatial distribution of impacts. They also lead intrinsically to a low-impact decision. Therefore, overlay maps should be used for EIA for the development of the Tuzla field.

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