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GEOTHERMAL ENVIRONMENTAL IMPACT ASSESSMENT STUDIES IN HEBEI PROVINCE, CHINA

Li Hongying
Bureau of Geology and Mineral Resources,
209 North Chaoyang Road, Baoding City,
071051 Hebei Province,
P.R. CHINA
hyli68@hotmail.com

ABSTRACT

Environmental impact assessment (EIA) work is becoming more and more extensive in the world because of its importance and practicality and is becoming a powerful safeguard in the project planning process. Every country has its own EIA system. 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. There are many techniques used in EIA in the world, such as matrices, checklists, overlay maps, and networks. Geothermal resources are abundant in the Hebei province, China and are widely utilized, providing considerable economic and environmental benefits. EIA work in this field has not yet been developed there. The purpose of this report is to find suitable techniques for carrying out EIA for the geothermal fields in Hebei province, by comparison of several EIA methods used throughout the world. This work led to the following recommendations for Hebei province: Use matrices and checklists for impact identification and potential impacts. Use the pollution factor index method for quantitative analysis of pollutant components and degrees of pollution. Prediction and mitigating measures should be improved beyond the present local technical level.

1. ENVIRONMENTAL IMPACT ASSESSMENT

1.1 Introduction

Since the first *Environmental impact assessment* (EIA) system was established in the USA in 1970, EIA systems have been set up worldwide and become a powerful environmental safeguard in the project planning process. Many countries have adopted their own EIA procedures. Some national and international organizations or legislatives refer to the World Commission on Environment and Development that espoused the principle of sustainable development in its 1987 report, and the 1992 United Nations Conference on Environment and Development established to adapt human activities to nature's carrying capacity (Morris and Therivel, 1995), seeking to influence the relationship between development and the environment. Environmental impact assessment (EIA) is the tool most widely used in environmental management.

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). In England and China it is the *Environmental impact assessment* (EIA); the U.S. version is *Environmental impact statement* (EIS); in New Zealand it is *Assessment of environmental effects* (AEE). Each tends to vary both in the meaning of terms and the scope of their applications. For example, EIA is the official appraisal of the likely effects of a proposed policy, programme, or project on the environment, alternatives to the proposal, and measures to be adopted to protect the environment. EIS is a document prepared by a proponent or developer applicant describing a proposed policy, programme, or project, alternatives to the proposal, and measures to be adopted to protect the environment. The EIS can be seen as one step within the framework of an EIA (Gilpin, 1995).

1.2 Definition of EIA

The objective of an EIA is to determine the potential environmental, social and health effects of a proposed development. It attempts to assess the physical, biological and socio-economic effects in a form that permits a logical and rational decision to be made. Attempts can be made to reduce or mitigate any potential adverse impacts through the identification of possible alternative sites and/or processes. There is, however, no general and universally accepted definition of EIA and there never can be. Thors and Thóroddsson (1999) stated that: *EIA can be considered as a process which combines both a procedure to ensure that appropriate projects are subjected to an EIA and that the results influence the planning and execution of a project, and a method for analysing and assessing the effects of a proposal on environmental systems and the quality of the environment.*

1.3 Other relevant definitions

Development actions may have impacts not only on the physical environment but also on the social and economic environment. Typically, employment opportunities, services (e.g. health, education) and community structures, life-styles and values may be affected. *Socio-economic impact assessment* or *Social impact assessment* (SIA) is regarded here as an integral part of EIA.

Strategic environmental assessment (SEA) expands EIA from projects to policies, plans and programmes. Development actions may be suitable to a project (e.g. a nuclear power station), a programme, a plan, or a policy. In theory, EIA should be carried out first for policies, then plans, programmes, and finally for projects.

Risk assessment (RA) is another term sometimes found associated with EIA. Risk assessment has developed as an approach to the analysis of risks associated with various types of development.

1.4 The purpose of EIA

Environmental impact assessment is a process with several important purposes. It is an aid to decision-making. For the decision-maker, for example the local authority, it provides a systematic examination of the environmental implications of a proposed action, and usually alternatives before a decision is made. EIA is normally wider in scope and less quantitative than other techniques, such as cost-benefit analyses. It is not a substitute for decision-making, but it does help to clarify some of the trade-offs associated with a proposed development action, which should lead to more rational and structured decision-making. The EIA process has the potential, not always used, to be a basis for negotiations between the developer, public interest groups and the planning regulator. This can lead to an outcome that balances the interests of the development action and the environment. EIA can be of great benefit to them since it can provide a framework for considering location and design issues and environmental issues in parallel. It can be an aid to the formulation of developmental actions, indicating areas where a project can be modified to minimize or eliminate environmental impacts at an early planning stage and can lead the developer, the planning authority and the local communities to a smoother planning permission process.

The purpose of this report is to find a suitable EIA method for the geothermal field in Hebei province, China through comparison of several EIA methods used throughout the world.

2. INTRODUCTION TO EIA IN HEBEI PROVINCE

2.1 Hebei province

Hebei province (Figure 1) is located at latitude 36°03'-42°40'N; and longitude 113°27'-119°51'E in the North China Plain, stretching north towards the Inner Mongolia Plateau, and facing the Bohai Sea in the east. It surrounds Beijing and Tianjin in its central part. Liaoning province and Inner Mongolia autonomous region lie to the north, Shanxi province to the west, and Henan province and Shandong province to the south. The terrain of the province slopes northwest to southeast. Mountains, hills and a plateau cover its territory in the northwest with basins and valleys distributed within. Vast plains stretch out across the southeast part of the central land. The coastal line of the province is 487 kilometers long. The province has a temperate continental monsoon climate, which varies greatly due to its vastness, and most of the territory has clear-cut seasons. Annual sunshine totals 2400-3100 hours. The annual frost-free period is 120-200 days. The annual precipitation varies with location from 300 to 800 mm, and annual average temperature is 13°C in most areas except that it is below 4°C in the northwest highlands. Days with temperature below -5°C are, on average, more than 30 a year. Space heating is required four months a year. The province is named after its geographical location, being situated to the north of the lower reaches of the Yellow River. The capital city of Hebei province, Shijiazhuang, is 4 hours by train south of Beijing. It is an important railway centre. The province covers an area of 188,000 km² and has a population of 65 million, which is distributed between 11

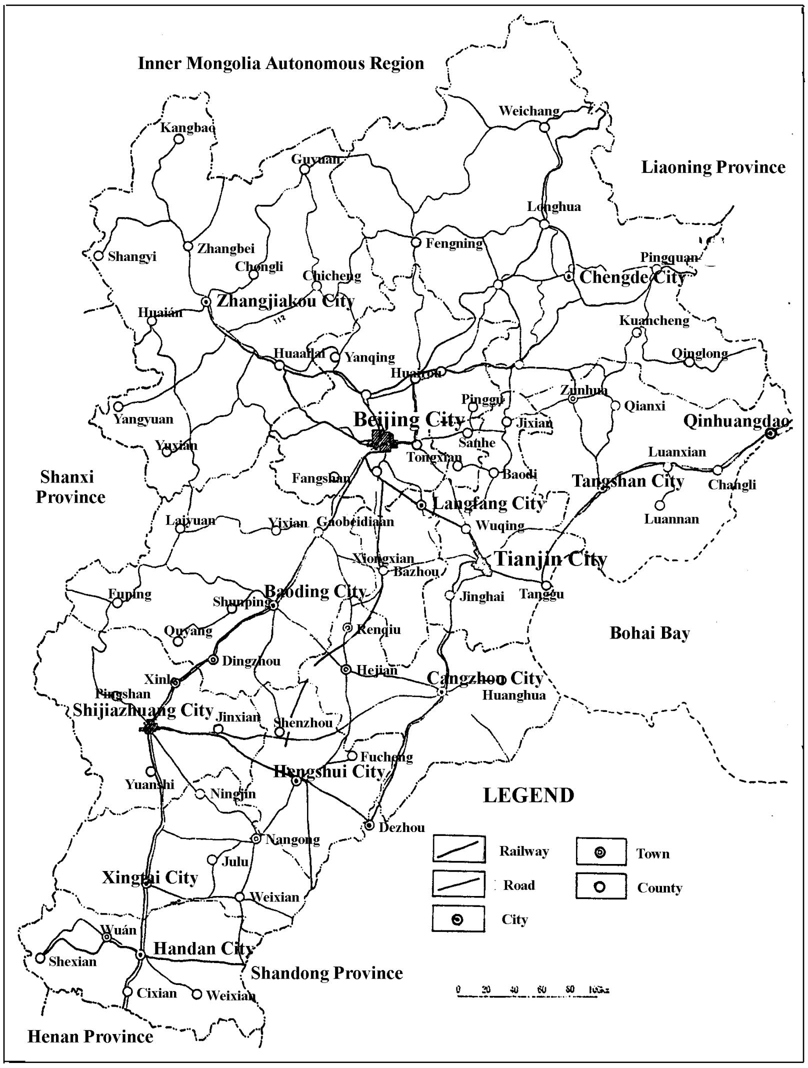

FIGURE 1: Map of Hebei province

administrative regions. The northwest part is a mountainous area (elevation 500-2882 m) and flatlands comprise the southeast part (elevation below 50 m).

The province, geographically favourable and rich in natural resources, has a long history with brilliant culture. It occupies an important position in the national economy of China. In 1997, the overall economic strength of the province ranked sixth of all the mainland provinces.

Hebei province, with 6.5 million hectares of cultivated land, is one of the major production areas of cereals, cotton and vegetable oils. Its coastal belt, with a surface of 1 million hectares, and more than 200 marine living species, serves as an important base of aquatic products in North China. Hebei is also among the major provinces with rich mineral resources in China. More than 80 industrial mineral deposits have been discovered so far, among which nearly 60 varieties have been proven. Among those are 42 varieties whose reserves are from first to the tenth in extent in the mainland provinces. These resources are widely spread and present a fairly systematic distribution which provides favourable conditions and proper bases for building large complexes of steel and iron, building materials and chemical industries, etc., and for developing coal chemical, salt chemical, and petrochemical industries. Hebei is also known as one of the few provinces with the most abundant tourist resources. There are 304 ancient ruins and ancient building groups across the province, including 37 places designated by the state as units of top grade preservation of cultural relics, rivalling their counterparts in Shanxi province. The total number of local natural and cultural landscapes ranks Hebei second in the country. The best known are the Imperial summer resorts in Chengde, Shanhaiguan (the east end of the Great Wall), Beidaihe seaside resorts, Chingdongling and Chingxiling (both are imperial tombs of the Ching Dynasty).

With Shijiazhuang City as the provincial capital, Hebei province consists of 11 municipalities directly under the jurisdiction of the provincial government. They are Shijiazhuang, Tangshan, Handan, Qinhuangdao, Xingtai, Baoding, Zhangjiakou, Chengde, Langfang, Cangzhou and Hengshui. Under the jurisdiction of these municipalities, there are 23 county-level cities, 115 counties and 34 urban districts in all. The province has 1,970 townships and 50,201 village committees as its lowest administrative units.

2.2 Introduction of EIA in China

SEPA, State Environmental Protection Administration of the People's Republic of China is in charge of environmental protection directly under the State Council. It is primarily responsible for unified supervision and management of nationwide environmental protection according to laws and regulations, the prevention and control of pollution and other public hazards, and the protection and improvement of the living environment and the ecological system in order to achieve a sustainable, integrated and sound development of economy and society. Its branches are provincial, municipal, and county environmental protection administrations.

SEPA's major responsibilities are:

- To formulate national guidelines, policies, laws and regulations on environmental protection and provide supervision for their implementation.;
- To formulate and organize the implementation of national policies for environmental protection;
- To assist in the formulation of China's basic principles on global environmental issues and to participate in negotiations dealing with international conventions;
- To work out national plans and programmes for environmental protection; to participate in the formulation of medium and long-term programmes and annual plans for national economic and social development;
- To formulate and issue national standards for environmental protection;
- To oversee environmental protection concerning the atmosphere, water, soil and oceans; to provide supervision and management for the control and prevention of pollution;

- To supervise and administer the country's work in nature conservation and to make programmes and plans for the establishment of nature reserves, preparing and presenting proposals to the State Council for approval in establishing new national nature reserves;
- To organize the implementation of environmental management and enforcement, provide monitoring and perform environmental impact assessments;
- To manage and supervise environmental monitoring, nationwide;
- To direct and coordinate nationwide education on environmental protection.

The essential regulation for the environment in China is, the *Law of environmental protection in P.R. China* which was published in 1989. In this law the definition of environment is: *Summation of natural and man-made factors that affect subsistence and development of human society, including atmosphere, water, land, mineral resources, forest, grassland, wild animals, scenic spots and historical sites, landscape, nature preservation zones, and residential living zones, and so on.* 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) before they are planned to be carried out. The improved law which was published in 1997 added some details, for instance, there must be an environmental scheme within the total scheme of a city or developing zone, an environmental impact assessment should be carried out before the environmental scheme; before the environmental impact assessment, it is necessary to carry out status assessment of environmental quality. The assessment work is done by certified institutes of environmental study.

EIA work in Hebei province started in the middle of the 80s when EIA work started in China. Since then several hundred EIAs for proposed projects have been organized by the Hebei Provincial Environmental Protection Administration and its branches with some other relevant departments' cooperation. These departments are, for example, the Department of Geology and Mineral Resources, Department of Forestry, and the Planning Committee. The projects have dealt with the construction of the city, chemical industry, energy development, food industry, mineral mining, and so forth. The executive standards and regulations in Hebei province are mostly national standards with a few local regulations. Hence, in the following discussion if there isn't a special note, these national standards are generally suitable for situations in Hebei province.

2.3 Executive standards and regulations

Chinese environmental standards are divided into three categories and two classes. The three categories are: standard of environmental quality, standard of waste disposal and standard of basis and method. The two classes are national and local classes. At present there are 23 national standards of environmental quality and 78 national standards of waste disposal. The local governments can set down regulations or rules depending on their respective situations. The standard of basis and method is the regulation for some necessarily unified principles, methods and terminologies. Table 1 shows national environmental quality standards and some national waste disposal standards as well as two local regulations for Hebei province.

2.4 The EIA process

The main contents of an EIA are: survey and assessment of environmental background conditions and sources of pollutants, investigation of environmental factors and systematic monitoring, assessment of environmental quality factors, comprehensive assessment of environmental quality, the relationship between human health and the environmental quality of the proposed project, the study of environmental prediction, etc.

TABLE 1: Main national-published standards of environmental quality and local regulations

Order	Standard number	Name of standard
1	GB5749-85	Standard of sea water quality
2	GB5749-85	Sanitation standard for potable water
3	GB3838-88	Environmental quality standard for surface water
4	GB9137-88	Maximum limits of concentrations of air pollutants for protected crops
5	GB9660-88	Environmental standard of noise around airports
6	GB10070-88	Environmental vibration standard in urban areas
7	GB11607-89	Water quality standard for fishing
8	GB11730-89	Sanitation standard of water quality for potable water in the countryside
9	GB12941-90	Quality standard of water used for recreation and landscaping
10	GB5084-92	Water quality standard for irrigation
11	GB3096-93	Standard of environmental noise in urban areas
12	GB/T14848-93	Quality standard for groundwater
13	GB15618-95	Environmental quality standard for soils
14	GB3095-96	Ambient air quality standard
15	GB5979-86	Regulation of magnitude of noise from marine shipping
16	GB5980-86	Regulation of magnitude of noise on inland river basins
17	GB11339-89	Environmental standard of noise in city harbour and shore side of river
18	GB12348-90	Standard of noise at boundaries of industrial enterprises
19	GB12523-90	Limit value of noise at boundaries of contractual buildings
20	GB12525-90	Limit value of noise and standard of monitoring at boundary of railway
21	GB14227-93	Limit value of noise from platform of subway station
22	GB16169-96	Limit value of noise of motors and motor-bicycles
23	GB16170-96	Limit value of noise from parked cars
24	GB8978-88	Standard of comprehensive discharge of waste water
25	GB13271-91	Standard of discharge of boiler gas pollutants
26	GB16297-96	Standard of emission of ambient pollutants
27	GB1495-79	Permitted noise of vehicles
28	GB4281-84	Standard of waste water disposal in the oil-chemical industry
29	GB4285-89	Standard for the safe utilization of pesticide
30	GH (86) N003 (Deptm. regulation)	Means of management concerning the protection of the environment within a construction project
31	JG (88) N53 (Local regulation)	Means of enforcement concerning the protection of the environment within a construction project of Hebei province

Generally, there are four stages in an EIA process: systematic preparation, systematic analysis, systematic design and calculation, and systematic assessment. Figure 2 shows the Chinese EIA process.

2.5 EIA methods

EIA methods are different in different fields, because the essential principles and processes are almost the same although the focuses are different. Geological environmental quality assessment is introduced in this paper in detail, as EIA work in the field of geothermics in Hebei province is almost non-existent and this is the nearest relevant field to the field of geothermics.

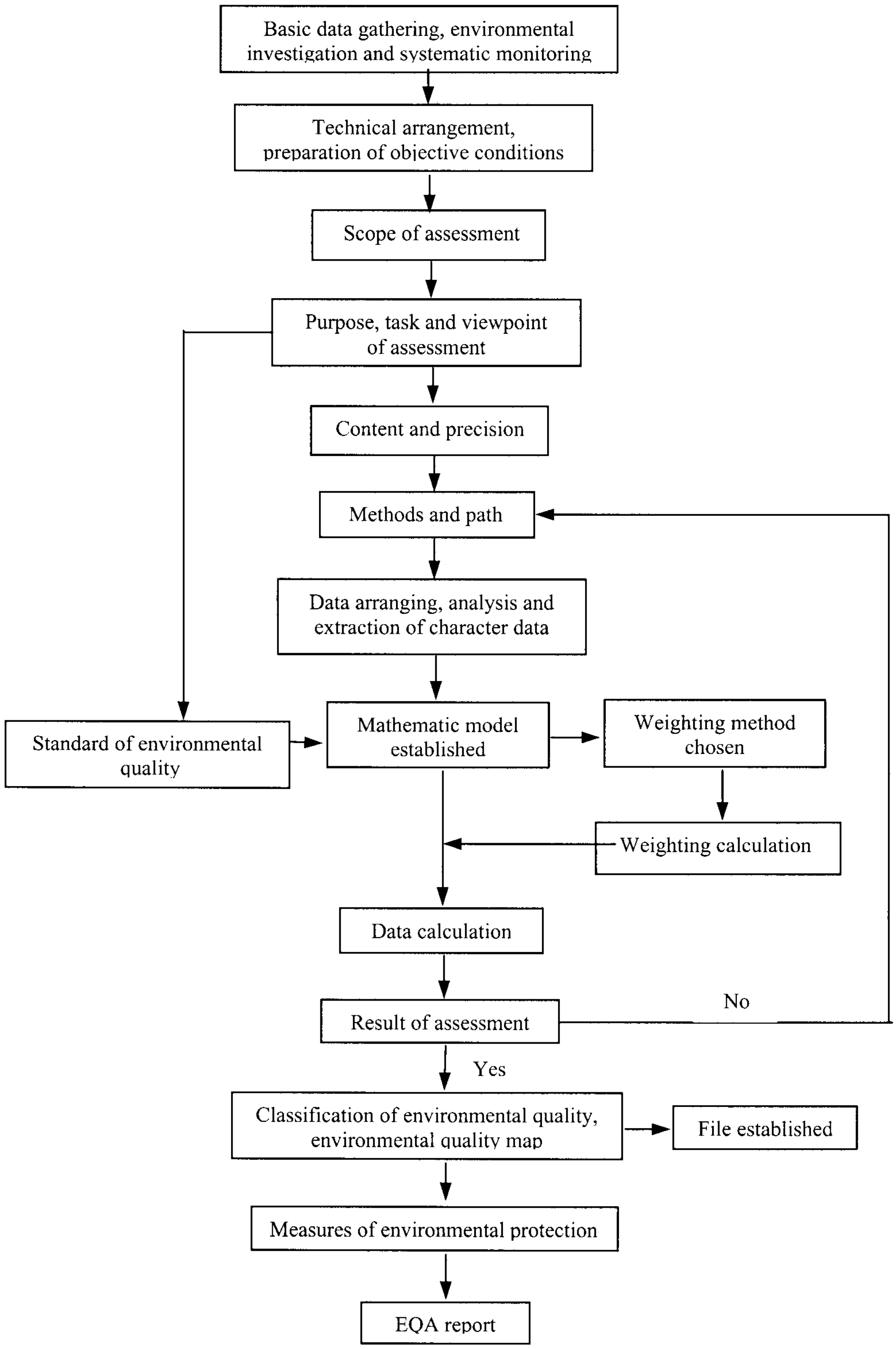

FIGURE 2: Chinese EIA process (from Zhou and Cai, 1998)

Geological environmental quality assessment (GEQA) involves the following items: Natural geological conditions, which are divided into three parts, i.e. soil and rock material, geological structure and dynamic action; ability for anti-interference caused by human activity; and the degree of damage or pollution. At present the main types of GEQAs are: soil environmental quality assessment, surface water environmental quality assessment, groundwater environmental quality assessment and regional geological environmental quality assessment. Within regional geological environmental quality assessment there are: geological environmental quality assessment in urban areas, development zones, bank and coastal areas, drainage areas and decline areas. The process of GEQA is similar to the general Chinese EIA process.

2.5.1 Soil environmental quality assessment

Soil environmental quality assessment is divided into three categories: original soil environmental quality assessment, soil environmental pollution assessment and soil quality assessment. At present, the so-called soil environmental quality assessment refers to a soil environmental pollution assessment and is underway in most cases. Hence, what is discussed here is a soil environmental pollution assessment.

Soil environmental quality assessment method includes:

- Status survey of soil environmental quality, such as choice of sampling spots, sample collection, preparation for monitoring and analysis, and a vegetation survey including sample collection.
- Chemicals considered include heavy metals and poisonous materials, i.e. Hg, Cd, Zn, Pb, Cu, Cr, Ni, Fe, As, Se, F, CN; organic poisonous materials, such as phenol, oil, DDT, 666 chloral, chlorobenzilate; acidity, total N, total P, and so on.
- Choice of standards for acumulation assessment, includes regional background value, concentrations of reference chemicals in soil and vegetation (based on Environmental quality standard for soils, GB 15618-95).
- Mathematical models for soil environmental quality assessment. The quality index model is most used; it includes a single-factor quality index model and a multi-factor quality index model. The single-factor quality index model is given by

$$P_1 = \frac{C_i}{S_i}$$

where P_i = Index of pollution;
C_i = Measured concentration of pollutant in soil;
S_i = Standard value for assessment.

- Area and degree classification using comprehensive index *P*: $P = 1$, non polluted; $P > 1$, polluted.

2.5.2 Environmental quality assessment for a surface water body

The surface water body is divided into a mainland surface water body and a marine surface water body. The mainland surface water body is discussed here and includes surface water, suspension in water, bottom mud and aqua-organism. Four kinds of pollutants in a surface water body are considered: inorganic nontoxic, inorganic toxic, organic nontoxic, and organic toxic. The indices which describe pollution in a water body are: oxygen demand, i.e. BOD (Biochemical oxygen demand), COD (Chemical oxygen demand), TOD (Total oxygen demand), TOC (Total organic carbon); vegetation nutrients, i.e. water body eutrophication, oil pollutants, phenolic pollutants and heavy metal pollutants.

Oxygen demand pollutants are derived from living waste water, livestock feeding waste water, and food, brewing, paper making, leather making, cooking, printing and dyeing, and oil chemical industry, etc. This pollution has an adverse impact on fishing because dissolved oxygen in surface water is absorbed by oxygen demand pollutants.

Vegetation nutrients are necessary for growth, but overabundant nutrients can be harmful to surface water environmental quality. Abundant nutrients cause eutrophication i.e. overgrowth of algae, hence reduce fish living space and consume dissolved oxygen in the water. The sources of this kind of pollution are domestic waste water, farming irrigation and fertilizer and some industrial waste water.

Oil pollutants originate in oil drilling, oil transportation and the oil industry. This pollution is very deleterious to the growth of aqua-organisms, and destroys bank facilities, reduces coastal environmental values, affects hydro-meteorological conditions of specific areas and reduces the self-cleaning ability of a water body.

Phenolic pollutants originate in phenolic waste water from industries and affect the quality and quantity of aquatic products. Heavy metal pollutants originate in oil, coal burning, mining and smelting. This is serious poisonous pollution which adversely affects the food chain.

Environmental quality assessment for a surface water body is divided into water quality assessment, bottom sediment quality assessment, biological assessment, and comprehensive environmental quality assessment of a water body. The methods and processes for this assessment are similar to those for soil environmental quality assessment; the difference lies in the choice of assessment parameters, e.g. establishment of sensory perception parameters, oxygen-balance parameters, nutritional brine parameters, toxic parameters and microbial parameters, and so on. The standard for assessment is the *Environmental quality standard for surface water* (GB 3838-88).

2.5.3 Environmental quality assessment for groundwater

Pollution of groundwater is different from pollution of surface water. Its main characteristics are concealment and irreversibility. Environmental quality assessment for groundwater includes water quality assessment, water quantity assessment and relevant geological environmental quality assessment. Assessment parameters chosen are generally general physical properties that derive from the chemical properties of groundwater and reaction characteristics of groundwater, common heavy metals and poisonous materials, organic pollutants and bacteria. Models for assessment are adopted depending on the contents of assessment. Generally a quality index model is used to study whether groundwater is polluted and the magnitude of the pollution; a mathematical-physical statistic model is used for zone separation, and pollution study, etc.

2.5.4 Geological environmental quality assessment in an urban area

Geological environmental quality assessment in an urban area involves, safety of the geological environment in an urban area, development of environmental resources in city construction, geological environmental quality in city construction and running, comprehensive assessment and prediction of the geological environmental quality of a city, and synthetic harnessing, sensible exploitation and amelioration of the geological environment in an urban area. Commonly the problems of geological environmental quality are: (1) environmental problems caused by exploiting groundwater such as land subsidence, water exhausting, water quality deterioration due to sea water intrusion; (2) environmental problems caused by digging at sub-constructions such as land subsidence, landslides; (3) environmental problems caused by urban waste disposal such as water and land pollution, destruction of landscape, upsilting of the water body, air pollution, slides and rockfall. So the aim of the geological environmental quality assessment in an urban area is to solve these problems. The most convenient method for geological environmental quality assessment in an urban area is weighting, which means awarding scores for different assessment parameters according to a preset standard for the assessment unit and obtaining an accumulative total value. The higher the value, the poorer the geological environmental quality, and vice versa.

3. STATUS OF EIA FOR GEOTHERMAL FIELDS IN HEBEI PROVINCE

3.1 Geothermal resources

Geothermal resources are quite abundant and distributed over almost every region in Hebei province. There are 11 geothermal fields and 13 geothermally anomalous areas in the flatlands and 43 hot springs in the mountainous areas. The total area of geothermal fields in the flatlands is 15,000 km^2. All are low- to moderate-temperature geothermal fields with temperatures ranging from 30 to 100°C. Geothermal reservoir formations are classified as one of three types: tectonic-fractural, karst-fractural and voids.

Generally, tectonic-fractural geothermal reservoirs are located in mountainous areas; their main expression is in hot springs, chemical types are Na-SO_4, Na-HCO_3-SO_4 and Na-Cl-SO_4. Karst-fractural and void geothermal reservoirs are located in the flatlands. The majority of the reservoirs are of Tertiary age, but a few are from the Cambrian and Ordovician periods. The main expressions are from drillholes. The chemical types are Na-HCO_3 and Na-Cl.

1) Tectonic-fractural geothermal reservoirs are located in mountainous areas, formed in gneiss of Archean magma and bedrock and fractural zones. Their extent is small. Water flows are mostly from 3 m^3/h to 60 m^3/h. Most manifestations are hot springs. The average temperature is about 50°C, pH values are mostly 7.5, TDS 0.62-1.06 g/l. Houhaoyao geothermal field is typical of this kind of reservoir. The major chemical type is Na-SO_4, low-TDS water. Its hardness is also low, but its F^- concentration is quite high and needs to be treated when the water is utilized.

2) Karst-fractural geothermal reservoirs are located in areas such as Yongqing county, Gu'an county, Xiong county, Gaoyang county, Hejian county, etc. The reservoir formations are mostly Proterozoic limestones. Permeability and thermal conductivity of this kind of rock are relatively high. The thickness of the sediments varies from 800 to 2000 m; wellhead temperatures are 50-60°C. They are generally of medium extent. Hydraulic discharge varies from 150 to 1500 m^3/d. The water chemical types are Na-Cl, Na-HCO_3-Cl, Na-HCO_3, Na-SO_4-Cl. They are brines. Hardness is very high, and all are fluoride waters.

3) Void geothermal reservoirs are located widely in the flatlands. The reservoirs are Tertiary sedimentary formations. Their permeability and thermal conductivity are relatively high; the highest permeability is 2778 mD. Temperatures vary from 43 to 79°C. Because of the thickness of the reservoirs, thin cover fomations, high temperatures and large hydraulic discharges, this kind of reservoir is the main type economically exploited in Hebei province. The representative reservoirs are in the Niutuo town geothermal fields and Hengshui geothermal fields. The major chemical types are Na-HCO_3 and Na-HCO_3-Cl, low TDS water, with low F^- concentrations.

The 24 geothermal fields are divided into 11 large, 7 medium and 6 small fields according to the extent of the geothermal energy. Detailed statistics are shown in Table 2.

3.2 History of geothermal utilization in Hebei province

Geothermal utilization in the mountainous areas in Hebei province can be traced back 2000 years. The ancient generations utilized geothermal water for bathing and the treatment of diseases. There are 285 beds for treating rheumatism and mange in Zunhua geothermal sanitorium. Two geothermal springs in Chi Cheng county, Zhang Jiakou city, have been utilized from the Sui-Tang dynasty till the present. Development and utilization of geothermal resources in the mountainous areas are still on a small scale, being limited by conditions of their location and the quantity of the geothermal water. Although development and utilization of geothermal resources started late in the flatlands, the potential prospects are great. From the end of the 1980s, geothermal energy has created a high social and economic status as a major important member of renewable energy resources. At present, Niutuo town, Huanghua and Hengshui geothermal fields are extensively developed .

Geothermal fields in the flatlands are mostly low- to moderate-temperature fields, hence they can be utilized directly. Now geothermal resources are utilized for bathing, sanitoria, space heating, flax processing, leather processing, vegetable dehydration, greenhouses, cultivation, mineral drinking water, swimming pools, accommodation and recreation, chicken hatching, fish farming, etc. A good example of cascading utilization of geothermal energy is the develpoment and exploitation of Niutuo town geothermal field which is located in Xiong county, Baoding city.

TABLE 2: Geothermal resources in the flatlands in Hebei province
(Zhang and Huang, 1999)

No.	**Geothermal field**	**Area (km^2)**	**Lithologic age**	**Geothermal resources, total reserve (10^{16} J)**	**Hot water resources**			**Extent of field**
					Volume mass (10^8 m^3)	**Mineable energy (10^{16} J)**	**Temp. (°C)**	
1	Changli	284	Ar	111	1.7	0.53	45	S
2	Langfang *	190	N	880	219	24	48	M
3	Baigezhuang *	2725	N	3576	818	55	47	L
4	Rongcheng	178	N	244	80	5.3	47	M
		178	Pt	1425	13.3	7.1	67	
5	Niutuo town	970	N	3101	1047	115	47	L
		460	Pt	3271	92	49	67	
6	Wen-an *	762.5	N	5139	1542	225	62	L
7	Gaoyang	1150	N	6845	1713	226	54	L
8	Suning *	437.5	N	4054	676	194	62	L
9	Renqiu	212.5	N	1028	189	28	58	M
10	Hejian-Shenzhou	1475	N	6969	1918	197	45	L
		175	Pz_1	1235	26	12.7	61	
11	Dacheng *	550	N	1407	497	28	43	L
		375	Pz_1	2647	56	27	61	
12	Huanghua	331.5	N	1997	507	1.3	58	S
13	Xianxian	550	N	1072	398	37	42	L
		285	Pz_1	2059	43	20	62	
14	Cangzhou	104	N	190	52	3.7	46	S
15	Mengcun *	575	N	1216	345	18.7	41	M
16	Qingfeng village *	290	N	64	17	1.5	58	S
17	Shulu-Ningjin	750	N	2268	670	35	40	L
		360	C+O	1823	33	21	78	
18	Hengshui	1351	N	2918	1151	101	41	L
		833	C+O	5754	186	95	65	
19	Sunhu *	187.5	N	1003	213	25	50	M
20	Qincun *	300	N	285	72	4.4	44	S
21	Zaoqiang *	647	N	1801	685	62	43	L
		120	C+O	709	17	7.3	57	
22	Gucheng *	600	N	665	257	23	40	M
		150	C+O	882	18	9.2	65	
23	Weixian *	50	N	96	21	1.5	49	S
24	Linxi *	336.3	N	2003	160	14.9	60	M
	Total	**15006**		**68735**	**13733**	**1698**		

* Abnormal geothermal area; L: large, M: medium, S: small;
Ar: Archean, N: Neogene period, Pt: Proterozoic era, Pz: Palaeozoic era,
C+O: Cambrian + Ordovician period

Niutuo town geothermal field is located in the middle of Jizhong plain, across Xiong county, Yongqing county, Bazhou county and Guan county, which belong to the Baoding and Langfang administrative regions. The total area is 970 km^2 and geothermal reserves are 3100×10^{16} J. The population of this area is 1,320,000. This area is also the main oil production area of the North-China oil field. Several hundred oil production wells are within it.

During the seventh Five year plan the prospecting of Niutuo town geothermal field was carried out and in 1990 the prospecting report for Niutuo town geothermal field was completed. Ten geothermal drillholes were drilled in this field (Figure 3) and drilling results proved the existence of this field (Table 3).

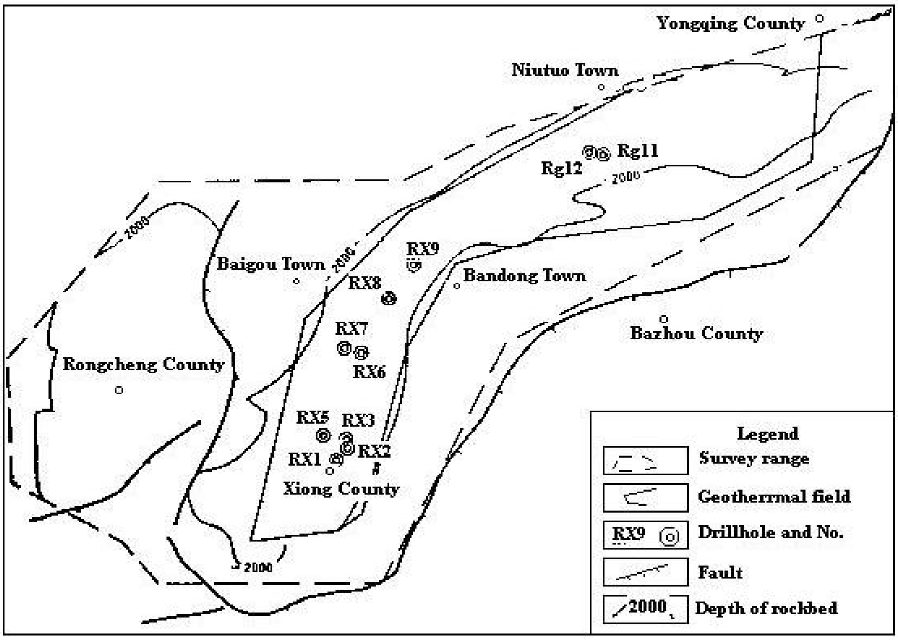

FIGURE 3: Map of Niutuo town geothermal field

TABLE 3: Geothermal drilling projects (Source: Zhang, 1990)

Well no.	Depth (m)	Formation	Water flow (m^3/h)	Temperature (°C)	TDS (g/l)
RX1	1054.18	J_{XW}	43.92	70	2.92
RX2	994.02	Nm	57.89	54.5	1.06
RX3	550.46	Q	69.0	29.5	0.41
RX5	1168.74	J_{XW}	64.1	65	2.93
RX6	527.93	J_{XW}	112.68	73	2.98
RX7	1016.56	J_{XW}	36.96	68	2.86
RX8	661.95	Nm	18.44	58	1.08
RX9	818.84	J_{XW}	25.14	73.5	2.88
Rg11	1302.35	Jxt-w	57.89	75.2	2.85
Rg12	1263.64	Jxt-w	74.69	81.5	2.87
Total	**9358.67**				

J_{XW}: Proterozoic era, Jixian system, Wumishan formation;
Nm: Neogene system, Minghuazhen formation;
Q: Quaternary system;
Jxt-w: Proterozoic era, Jixian system, Tieling and Wumishan formation.

Xiong county is located in the centre of Niutuo town geothermal field with a population of 314,000 and total area of 524 km^2. Oil, methane, mineral water, geothermal, and tourist resources are abundant in this area. Over 600 oil production wells produce 500 tons of oil and 200,000 m^3 of methane per day. Geothermal prospecting wells and some abandoned oil wells have been used by local industries for house heating, chicken hatching, leather processing, etc., since 1989. After more than two decades of development, cascading utilization of geothermal resources has been realized. The total area for space heating by geothermal resources is 200,000 m^2, 30% of the total construction area within the district. The annual amount of coal saved is approximately 6450 tons, reducing emissions of coal dust by 120 tons, and reducing combined emissions of CO_2 and SO_2 by 57.5 tons (Liu and Li, 2000). The waste heating water, with temperatures of 30-40°C, is used for greenhouses, and fish farming. The temperature of the final discharge is less than 20°C.

Other utilization of geothermal energy in Hebei province includes house heating, such as in Hengshui City where it extends to 40,000 m^2, and two bathing pools that create ¥600,000 of production value. The largest Nile tropical fish farm in North China was built by Zhong-Jie farm in 1980 and utilized geothermal energy for parent fish and shrimp feeding and surviving the winter; heating a 20,000 m^2 area in Cangzhou Military Subarea saves 1000 tons of coal per year, and so on.

3.3 Previous EIA work on geothermal fields in Hebei province

Geothermal utilization started much earlier than EIA work in Hebei province. However, the scale of most geothermal utilization is much smaller than that of projects requiring EIA, and most of the geothermal wells used were abandoned oil wells, except for geological prospecting wells in Niutuo town geothermal field. So EIA work has not been directed to geothermal utilization in Hebei province. However, in recent years following greater uses of geothermal energy and some responsible national environmental policies, geothermal development and utilization has become more and more widespread and at the same time attracted more and more governmental attention. Although so far no complete geothermal EIA project has been carried out, some geological work which is related to an environmental impact assessment was carried out when developers applied for mining licences for geothermal exploitation according to the law of mineral resources, e.g. reports of the feasibility of geothermal resource exploitation and utilization, schemes for geothermal utilization, etc. These reports or schemes deal with environmental aspects although they are not real EIAs; they can be regarded as rudimentary EIA work in the geothermal field.

4. EIA IN ICELAND

4.1 General introduction

EIA in Iceland has been executed since May 1994. The basic law is *EC Directive 1985-11/1997*, i.e. *Law on environmental impact assessment in Iceland (English version)*. The Ministry for the Environment is the principal authority in the field covered by this Act, and the Planning Agency consults the Minister and is responsible for the supervision of the implementation of the act and providing guidelines. The Planning Agency decides on the EIA and also decides if developments should be made subject to EIA.

In this 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. The following projects should be subject to EIAs:

- Hydropower > 10 MW, 3 km^2
- Geothermal > 50 MWt installed power, or > 10 MWe
- Power lines > 66 kV
- Roads > 10 km
- Gravel mines > 50,000 m^2 or > 150,000 m^3
- Chemical plants
- Disposal of hazard waste and household waste, etc.

It is also stipulated that the developer should carry all the costs of the EIA as well as advertisements and publicity. An EIA of one project and its operating license are processed at the same time; however, developmental permission should be in accordance with the EIA decision. The generalized EIA process is: screening → scoping → baseline studies → impact prediction → impact evaluation → reporting → review → decision → monitoring.

The geothermal projects in Iceland that have been subject to EIA are drilling at Ölkelduháls, Hengill area, which was granted; utilization at Reykjanes, which was granted with restrictions on drilling area that has been challenged; drilling in Graendalur which was granted with restrictions on road construction and drilling area, that has also been challenged; a power plant in Bjarnarflag, which has been recommended for additional EIA; and additional plants at Krafla and Nesjavellir which are in the EIA process. Furthermore the granting of a permission to drill at Trölladyngja, Reykjanes Peninsula without EIA has been challenged, and the decision of the Minister for the Environment was to grant this permission.

4.2 EIA methods and techniques

Various techniques have been developed such as checklists, matrices, networks and overlay maps. Matrices are the most commonly used technique for impact identification and are often associated with checklists.

4.2.1 Matrices

Matrices of various kinds are used for impact identification. A simple two-dimensional matrix is shown in Table 4. Such matrices where environmental components are on one axis and project stages on the other are quite common. They are essentially expansions of checklists that acknowledge the fact that different components of a developmental project (e.g. construction, operation, decommissioning; buildings, access road) have different impacts.

TABLE 4: Components of an environmental matrix

Environmental issues/components	**Project stages**		
	Construction	**Operation**	**Demobilization**
Flora			
Fauna			
Soil and geology			
Air/water quality			
Housing			
Community structure			

4.2.2 Weighted matrices

Weighted matrices are developed in an attempt to better identify the significance of impacts. Importance weightings are assigned to environmental components, and sometimes to project components. The impact of the project on the environmental component is then assessed and multiplied by the appropriate weighting, to obtain an overall total for the project. Table 5 shows a small weighted matrix that compares three alternative project sites.

Each environmental component is assigned an importance weighting (a) relative to other environmental components: for example, air quality is weighted 21% of the total of the environmental components. The magnitude (c) of the impact of each project on each environmental component is then assessed on a scale of 0-10, and multiplied by (a) to obtain a weighted impact (a*c). For instance, site A has an impact of 3 out of 10 on air quality, which is multiplied by 21 to give the weighted impact. For each site, the weighted impacts can then be added up to give a project total. The site with the lowest total, in this case site B, is the least environmentally harmful.

4.2.3 Magnitude matrices

Magnitude matrices go beyond the mere identification of impacts by describing the impacts according to their magnitude, importance and/or time frame, for instance short-, medium, or long-term matrices.

TABLE 5: Alternative sites compared

Environmental component	(a)	Alternative sites					
		Site A		Site B		Site C	
		(c)	(a*c)	(c)	(a*c)	(c)	(a*c)
Air quality	21	3	63	5	105	3	63
Water quality	42	6	252	2	84	5	210
Noise	9	5	45	7	63	9	81
Ecosystem	28	5	140	4	112	3	84
Total	**100**		**500**		**364**		**438**

(a) = Relative weighting of environmental component (total 100);
(c) = Impact of project at particular site on environmental component (0-10).

4.2.4 Checklists

Most checklists are based on a list of special biophysical, environmental, social and economic factors that may be affected by development. The simple checklist can help identify impacts and ensure that impacts are not overlooked. An environmental review checklist that outlines an environmental analysis in the United States constitutes the Appendix.

4.3 EIA in geothermal fields in Iceland

4.3.1 Geothermal resources of Iceland

The geothermal resources of Iceland are closely associated with the country's volcanism and its location on the Mid-Atlantic Ridge. The high-temperature resources are located within an 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. About two thirds of a population of 279,000 live in the southwest part of the country, where geothermal resources are abundant.

There are about 250 separate low-temperature areas with over 600 hot springs (temperature over 20ºC) and at least 26 high-temperature areas with steam fields in Iceland. The high-temperature areas are directly linked to the active volcanic systems (Figure 4).

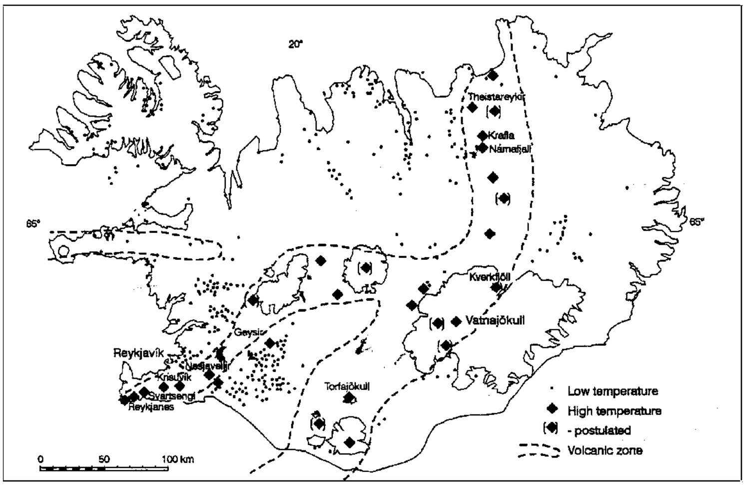

FIGURE 4: Geothermal areas in Iceland

The annual primary energy supply in Iceland, is 121 PJ or 434 GJ per capita, which is higher than in any other country. Geothermal energy provides about 50% of the total primary energy supply while the share of hydropower is 18%, oil 30% and coal 2%. Thus, about two thirds of the energy supply of the country come from indigenous renewable energy sources. It is estimated that the total direct heat use of geothermal energy in Iceland in 1999 was 20170 TJ and the corresponding installed capacity 1469 MWt (Ragnarsson, 2000).

The availability of geothermal energy has strongly influenced the standard of living in Iceland. The economic benefits of using geothermal energy for space heating instead of fossil fuels are significant, as it saves annually about 100 million US$ in imported oil. Besides financial savings the environmental benefits are of great importance.

The main use of geothermal energy in Iceland is for space heating; about 86% of the space heating is by geothermal energy, the rest is by electricity (12%) and oil (2%). The total geothermal energy used for space heating in Iceland is about 15600 TJ per year.

Other utilizations of geothermal resources in Iceland are (Ragnarsson, 2000):

1. *Swimming pools.* There are about 100 public swimming pools and about 30 pools in schools and other institutions with a combined surface area of 27,000 m^2 heated by geothermal energy. The annual water consumption is about 220 m^3 of water or 40,000 MJ of energy are needed annually for heating one m^2 pool surface area. The total annual water consumption in geothermally heated swimming pools in Iceland is estimated as 6,000,000 m^3 which corresponds to an energy use of 1100 TJ per year.

2. *Snow melting.* The use of geothermal energy for snow melting has been widespread for the past 15-20 years. Spent water from houses, at about 35ºC, is used for deicing sidewalks and parking spaces. The total area covered by snow melting systems in Iceland is estimated to be 350,000 m^2, of which about 250,000 m^2 are in Reykjavik. The annual energy consumption is estimated to be 325 kWh/m^2. Of that, about two thirds comes from return water from the houses and one third from 80ºC hot water. The total geothermal energy used for snow melting is estimated to be 410 TJ per year.

3. *Industrial uses.* Industrial uses of geothermal steam on a large scale started in Iceland in 1967 by the establishment of Kísilidjan, the diatomite plant at Mývatn near the Námafjall high-temperature field. The plant is one of the world's largest industrial users of geothermal steam and produces annually some 20-30 thousand tonnes of diatomite filter aids for export. The geothermal steam is mainly used for drying, but also for other purposes such as preheating of fuel oil and diatomite slurry, space heating, deicing of holding ponds and loading areas and for dust elimination. Other industrial uses are in a seaweed processing plant, a salt plant, a hardwood drying company and so on. The total geothermal energy used as industrial processing heat in Iceland is estimated to be 1600 TJ per year.

4. *Fish farming.* There are about 50 fish farms in operation in the country. Salmon is the main species with about 70% of the production, but arctic char, trout and halibut are also raised. Geothermal water is used mainly at the hatchery stage. The total production in fish farms in Iceland has been slowly increasing to about 4000 tonnes per year. The total geothermal energy used in the fish farming sector in Iceland is estimated to be 650 TJ per year.

5. *Geothermal electric power generation.* The total capacity of geothermal power plants in the country was 170 MWt in 1999. Of the total electricity generation of 7185 GWh in 1999, 1138 GWh or 15.8% came from geothermal energy, 84.1% from hydro and 0.05% from fuels.

4.3.2 Status of EIA in geothermal fields in Iceland

By Icelandic law, it is required to assess the environmental impact of energy production and select the most favourable option concerning environmental effects. The most important environmental changes brought about by geothermal utilization are: *Surface disturbances, physical effects due to fluid withdrawal, noise, thermal effects, emissions of chemicals, both gas emissions and liquid discharge, and social and economic effects on the communities concerned* (Ármannsson and Kristmannsdóttir, 1992)

The work of studying environmental impact of geothermal exploitation was started in 1991, and since then five high-temperature geothermal production areas in Iceland have been assessed, then several priority projects to be carried out within the scope of the larger project were defined. One of the priority projects was aimed at the exploration of unexploited geothermal areas (Kristmannsdóttir and Ármannsson, 1995).

1. *Project scope.* For the purpose of defining and initiating monitoring schemes for natural features in unexploited geothermal areas, and developing investigative methods, the status of environmental knowledge for Iceland's unexploited high-temperature geothermal areas was defined. To carry out an EIA for a 20 MW power plant in each unexploited Icelandic geothermal area, methods were tested to measure the mass flow of steam in fumarole outlets, and for monitoring geothermal areas by remote sensing using aerial thermography. Concentrations of sulphur gases and mercury in the atmosphere were determined in four unexploited geothermal areas.

2. *Status of unexploited geothermal areas.* Results of the present-status environmental examination (non-biological) of Iceland's unexploited geothermal areas are summarized in Table 6. Of the 28 high-temperature areas, seven are developed to some degree, three are ready for production drilling, eight are at the beginning stage of exploration drilling, four are in the first stages of surface exploration, and six are virtually unexplored. The 20 MW size was selected for assessment because it is a standard size for steam turbines and a minimum size for initiation of a geothermal power plant developmental project.

3. *Studies of selected geothermal areas.* Four unexploited areas were selected as the localities for the project in Iceland: Theistareykir, Krýsuvík, Kverkfjöll and Torfajökull. Surface manifestations in the areas were mapped every year, steam flow valued, and samples for chemical analysis collected from 2-4 fumaroles in each area for several years.

TABLE 6: The status of environmental investigation in 28 high-temperature geothermal areas in Iceland. The numbers refer to how many areas are at a specific stage of investigative techniques (Ármannsson et al., 2000)

Stage	Reference list	Prelim. EIA	Geol. map	Natural steam flow	Gas % in steam	Gas % in air	Ground-water map	Gravity measured	Natural activity changes
Ready	15	8	17	10	11	10	15	14	9
Partly	0	0	5	6	9	3	2	2	8
Missing	13	20	6	12	8	15	11	12	11

Although the status of environmental knowledge of the exploited high-temperature geothermal areas in Iceland is known, background data on some unexploited areas, information on specific effects such as gravity and microearthquakes, comparable monitoring methods and network establishment, and information on noise and weather conditions are scarce. Few biological studies have been performed except in Nesjavellir, and decisions on the protection of the areas and effective public relations have not been made.

5. EIA IN OTHER COUNTRIES

Most countries have embodied their environmental concerns in legislation. Although the actual legislation varies in detail from country to country, the overall requirements, and the purpose and need for the legislation are recognized worldwide. The countries discussed here - UK, the United States (U.S.), the Philippines, New Zealand and Italy - all 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.

5.1 EIA in UK

Since *EC Directive 85/337* on EIA was adopted in 1985, the individual EC (now EU) member states have implemented the directive through their own regulations. In the UK, the production of the resulting environmental impact statements (EISs) increased more than tenfold from the early 1980s into the early 1990s as a result of the directive; more than 350 EISs are now prepared annually in the UK.

In the UK, the directive is implemented through 20 regulations, the core of which are the *Town and country planning (Assessment of environmental effects) regulations* of 1988. The requirements of each regulation differ slightly, but all are essentially variants of these core regulations. The regulations divide the contents required by the *EC Directive* into two lists, one mandatory and the other discretionary. In essence, the consideration of the use of natural resources, the emission of pollutants, alternatives to the project and difficulties encountered are discretionary.

According to the *Town and country planning (Assessment of environmental effects) regulations* of 1988, the likely significant effects on the environment of the development would be considered with reference to its possible impacts on human beings; flora; fauna; soil; water; air; climate; the landscape; the interaction between any of these; material assets; and the cultural heritage. Also included is how to assess these effects (including direct and indirect, secondary, cumulative, short, medium and long-term, permanent and temporary, positive and negative effects of the project), to estimate and forecast the potential effects, to carry out some suitable mitigating measures to avoid, reduce or remedy those effects, and to assess the probable effectiveness of mitigating measures. Impacts to health and safety or risk analysis are not considered in an EIA. Monitoring is not strictly part of the EIA process and is not statutory in the UK, but lack of monitoring is realized as a serious deficiency in current EIA practice (Morris and Therivel, 1995).

5.2 Regulations of the United States

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 (national), 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.

5.2.1 Environmental laws

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

- *National environmental policy act*;
- *Geothermal resources operational orders*;
- *Specific resources 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 impacts statement* (EIS) is intended to provide an objective analysis of any significant or potential environmental impacts 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 their major action. However, the needs of economic growth are expressly recognized in the congressional declaration of policy under NEPA.

NEPA requires the preparation of an *Environmental assessment* (EA) of proposed projects to determine whether a project would have a significant effect on the quality of the human environment. If no significant impacts are identified in the environmental analysis of the project, and those impacts that have been identified can be mitigated to levels that are not significant, a Finding agency can issue the appropriate permit or approval for the project.

If a project might have significant environmental effects, then an *Environmental impact statement* (EIS) must be prepared. Preparation of an EIS is required when a proposed action would have, or has the potential to have, a significant impact on the quality of the environment. The NEPA process is outlined in Figure 5.

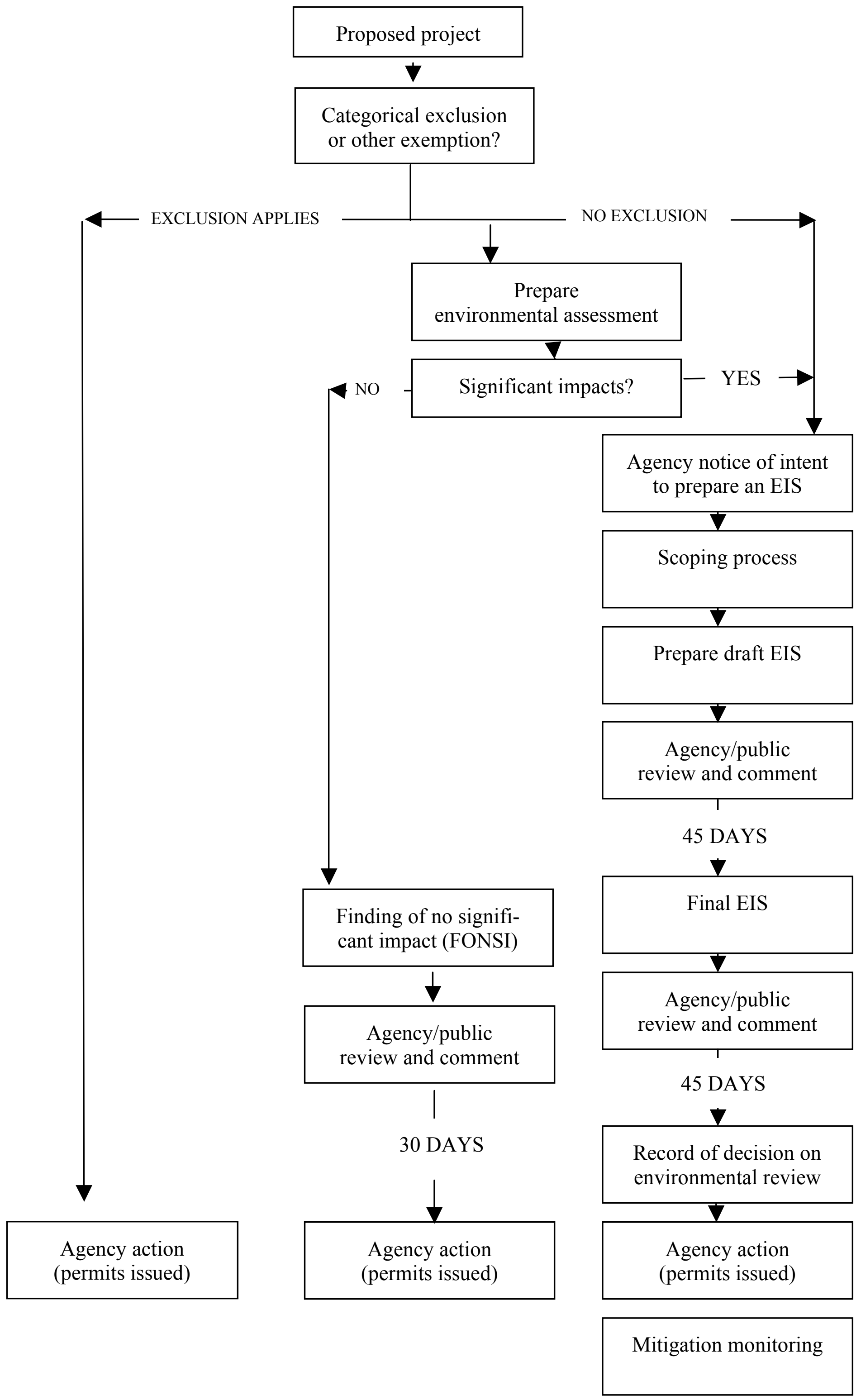

FIGURE 5: U.S. NEPA environmental review process (Bass and Herson, 1993)

In addition to the broad requirements of NEPA, there are a series of federal, state, and local regulations that address protection of the environment for specific parameters, such as air quality, water resources, fish and wildlife, vegetation, cultural and archaeological resources, and public health and safety. Specific environmental laws include the:

- *Clean air act*;
- *Clean water act*;
- *Endangered specific act*;
- *Archaeological resources protection act*;
- *Occupational health and safety act.*

5.2.2 Geothermal laws and guidelines

Geothermal development in the U.S. was on a very small scale and at scattered, remote locations until development increased at the Geysers in the 1960s. As geothermal development accelerated, a distinct set of regulations was developed to address the particular requirements of geothermal development. The *Geothermal steam act* of 1970 was enacted to provide for the leasing of federal lands for geothermal exploration and development. Lands within national parks were excluded from geothermal leasing.

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

GRO no. 1: *Exploratory operations*
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 impacts of geothermal development would vary with the location, size, depth, temperature, and chemical composition of the geothermal resources. The type of development, whether power generation or direct use, also affects the level of environmental effects. The GROs therefore are written to allow the agency the option to adjust requirements to fit each specific geothermal project.

The lead, or primary permitting agency for geothermal development in the U.S. depends on the ownership of the land to be developed. The U.S. Department of the Interior, Bureau of Land Management (BLM) has been designated as the federal agency that has the primary responsibility to lease federal lands for geothermal development, to conduct the environmental review, and to approve the plans for developing the geothermal resources. For geothermal resources on federal lands, the BLM is the leading federal agency and is responsible for the final approval of the project.

In the U.S. the identified geothermal resources may be located on lands managed by an agency other than the BLM, such as a national forest managed by the U.S. Department of Agriculture - Forest Service (such as the Newberry geothermal resources in Oregon and the Glass Mountain resource in North California). In these cases, where BLM has the responsibility for the development of the resource, but the lands are managed by a different agency, the environmental review and permitting is often conducted under the terms of one or more *Memoranda of understanding* (MOUs) between the agencies. These agreements define methods for cooperation between the agencies to avoid duplication of environmental review, but allow for the land managing agency to participate in decisions about the development of the subsurface geothermal resources.

Because state agencies usually must issue a permit for a geothermal project (for air emissions, waste disposal, or fluid discharge), there may also be several state agencies involved in permitting the project. MOUs may also be developed to define cooperation between the federal and state agencies. State agencies may include water quality control boards, air pollution control districts, departments of fish and wildlife, and archaeological and historic resource preservation offices.

In addition to compliance monitoring for the NEPA document, each of the permitting agencies has their own programme for monitoring compliance with permit conditions. The number of agencies involved can result in a complex web of permits and compliance (Hietter, 1995).

5.3 Regulations in New Zealand

5.3.1 Environmental laws

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 applicant must follow a resource consent process. The process is outlined in Figure 6. The five types of consents are:

1. *Land use consents;*
2. *Subdivision consents;*
3. *Coastal permits;*
4. *Water permits;*
5. *Discharge permits*.

Some consents are called permits, there is no technical distinction between the two terms.

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 analysed. The term "effects" is considered to be much broader than impacts.

5.3.2 Geothermal laws and guidelines

Geothermal drilling activities in New Zealand are 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 temperatures and pressures encountered in drilling in geothermal reservoir areas. The code of practice is very similar to the U.S. GROs (Hietter, 1995).

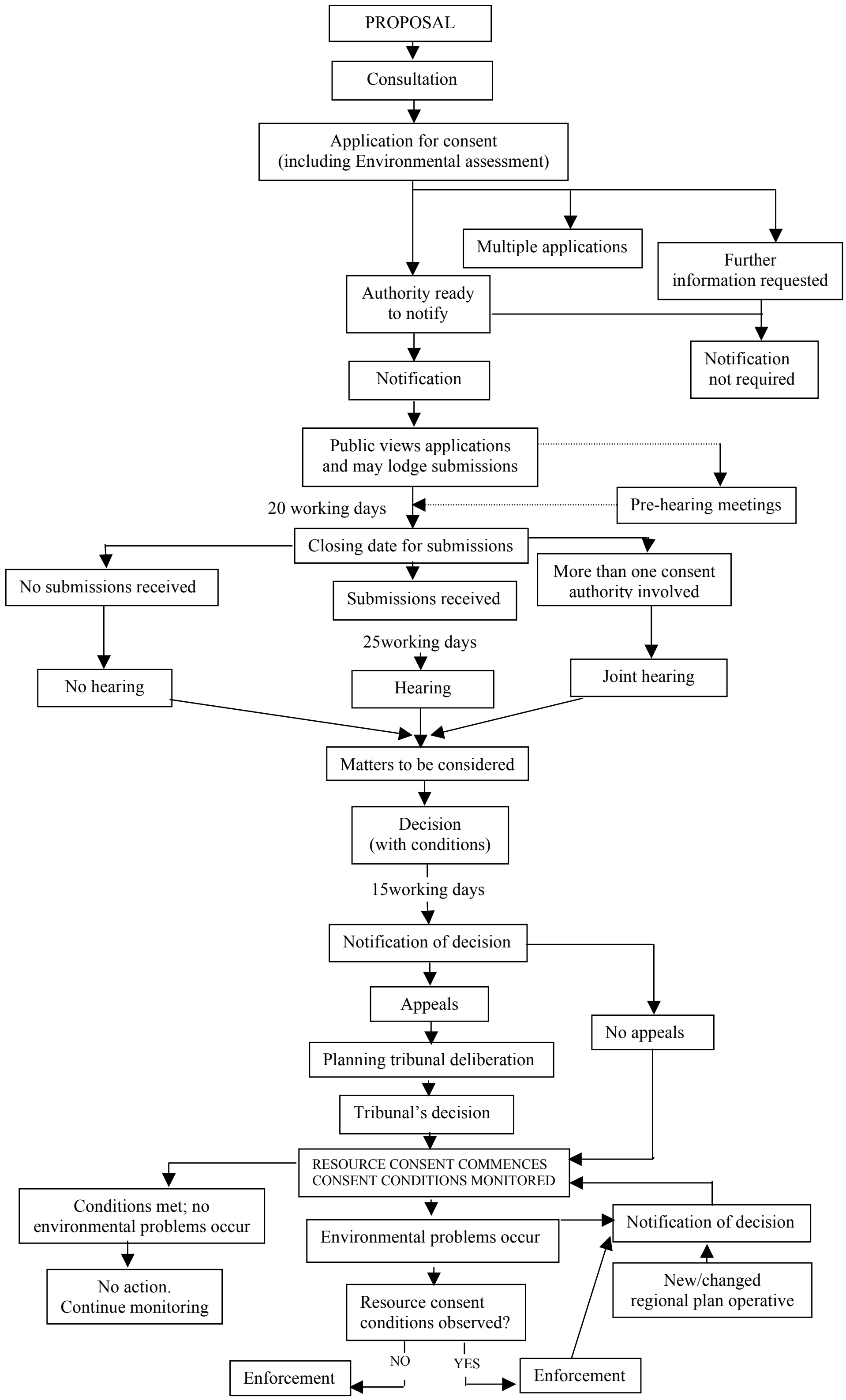

FIGURE 6: New Zealand resource consent process (after Milne, 1992)

5.4 Regulations in Italy

5.4.1 Environmental laws

Environmental regulations in Italy are based on the European Community (EC - now EU) directive 85/337 to the *Environmental impact assessment* (EIA). The EC 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 environmental impacts* (EIS). The EIA procedure requires the Ministry for the Environment to consult with the ministries 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 a harmony between the regulations and the requirements of development. The EIA focuses on the environmental compatibility of the project. The EC directive does not apply to geothermal developmental activities. The legislature modified the approach for energy production activities.

In Italy the EIS is prepared by the applicant based on the expected project activities. The activity plan may be modified at any time; the EIS 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 EIS must be prepared and the approval procedure followed. Each modification to the original EIS should be approved by the National Mining Bureau for Hydrocarbons and Geothermal Activities (UNMIG), according to DPR 395/91 (pertaining to geothermal development).

For exploration permits and mining leases the Ministry for Industry, Commerce and Handicraft (MICA) is the primary authority for coordinating the environmental protection process. During the exploration process, the mining authority starts a new environmental procedure in the area of the wells, in cooperation with other state and regional administrations.

5.4.2 Geothermal laws and guidelines

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 the exploration is successful. Developmental activities are classified as surface exploration, deep exploration, and development and exploitation (Hietter, 1995).

5.5 Regulations in the Philippines

5.5.1 Environmental laws

The environmental and geothermal laws in the Philippines are based on key *Presidential decrees* (PD):

- 1982 *PD 1586* – Established an *Environmental impact statement* EIS system;
- 1992 *Amendment of PD 1586* – Amendments to the EIS System.

The Philippines *Environmental impact statement* (EIS) system, resulting from *Presidential decree* (PD) 1586, is similar to that of 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 EIS system includes a compliance review where the impacts predicted in the EIS are compared with the impacts that actually occurred after the implementation of the proposed project. The EIS process requires *Compliance monitoring* to determine the level of compliance with the conditions stipulation in the EIS and in the project approval. The project approval is called the *Environmental compliance certificate* and is issued by the Secretary of the Department of Environment and Natural Resources.

The Philippines also have several specific laws for protection of the air, water, and natural environment, such as *Revised air quality standards and rules*, *Air quality regulations for geothermal projects*, *Pollution control decree*, *Environmentally critical projects and areas*, etc.

5.5.2 Geothermal laws and guidelines

In the Philippines, the Philippine National Oil Company (PNOC) has developed a set of guidelines for geothermal operations. *Presidential decree 1442* was issued in 1978. The decree sets out 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 lands or private lands (with appropriate authorization); holders of existing geothermal permits and leases may enter into service contracts and revoked existing permits; the Bureau of Energy Development issues development and exploitation 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).

6. COMPARISON OF EIA WORK IN DIFFERENT COUNTRIES

From comprehensive analysis of EIA work developed in the above countries, we come to the following conclusions:

a. EIA work is widespread in the world. It is regarded as an important part of most types of project proposals. This indicates that environmental problems are already quite serious and need more and more consideration. EIA is mainly embodied in the environmental legislations in each country, and many relevant standards or regulations ensure the operation of environmental laws, special organizations for management of environment, and stipulations of authorities and responsibility.

b. Development of EIA is not balanced in different countries due to economical and technical reasons. The United States was the first country to legislate for EIA; its regulations and legislation are probably the most complete. On the other hand, EIA standards differ between countries because natural conditions and emphases are different, but generally they are based on the U.S. model. The general procedure is: submit application for a proposed project ? lead agency determines adequacy of plan ? pre-EIA ? public participation ? lead agency permits ? permits issued ? monitoring. In methods of environmental impact assessment, one of the best known is the magnitude matrix called the Leopold matrix, which was developed for the US Geological Survey (Leopold et al., 1971). This matrix is based on a horizontal list of 100 project actions, and a vertical list of 88 environmental components, meaning that there are 8800 possible interactions between project action and environmental components. Another well known method is the environmental impacts checklist, which often lists 20 kinds of environmental impacts for checking direct/indirect, short-term/long term, reversible/irreversible, significant environmental impacts and their mitigation. Thus, the US model has already become a standard for EIA worldwide. The EC/EU directive has added secondary, cumulative, permanent/temporary, possitive/negative effects assessment.

c. At present most EIAs study physical impacts, socio-economic impacts, chemical impacts and biological impacts, i.e. impacts on human beings, flora, fauna, soil, water, air, climate, landscape, cultural heritage, etc. Development of the occupational safety and health aspect are different between countries. Generally speaking, this work has not been developed to the same extent as other work. For example, in the UK impacts to health and safety or risk analysis are not considered in an EIA.

d. Monitoring is important for checking the results of an EIA, but is very difficult to develop for economical and technical reasons. Even if it is developed, some factors can be done satisfactorily, such as meteorological monitoring, water monitoring and noise monitoring, but others such as monitoring of impacts on flora and fauna are still very difficult. So far, good methods for monitoring these aspects have not been developed.

e. Public participation is an important procedure in an EIA. As people have different values, interests, and worldviews, information from the public is helpful for decision-makers, developers, public interest groups and planning regulators. The quality of the information is gauged by its accessibility, accuracy, completeness, timeliness, and relevance.

f. The above discussed countries attach importance to geothermal development and utilization; they have already developed EIA work in the geothermal field. For example, in the U.S. in the late 1970s the U.S. Geological Survey developed the *Geothermal resources operational orders* (GROs). The GROs address all phases of geothermal development, the technical aspects of exploration and developmental drilling, as well as outlining specific environmental protection procedures that generally need to be taken to minimize the environmental effects of drilling and utilization. In New Zealand in 1991, the Deep Geothermal Wells Committee of the Standard Association established the *Code of practice for deep geothermal wells*, which is very similar to the U.S. GROs. Development of EIA in Iceland came later or in 1993 when the *Law on environmental impact assessment in Iceland* was passed, therefore no EIAs were carried out for most geothermal projects already in operation, although five geothermal fields have now been subjected to EIAs. However, its fundamental monitoring baseline data are relatively complete, and are a good basis for preparing the gathering data for new projects.

7. SUITABLE EIA METHODS FOR GEOTHERMAL DEVELOPMENT IN HEBEI PROVINCE

7.1 Several points of attention regarding geothermal development

There is a huge potential in the use of renewable energy and a large contribution of geothermal resources in Hebei province to be realised, indicating the importance of this natural resource in local economical construction and the necessity of strengthening the management of its exploitation and utilization.

EIA for projects becomes unavoidable following the continuous strengthening of environmental requirements in economical construction as well as because of problems that have occurred during geothermal exploitation and harnessing. Since such work is still non-existent, its possible development is discussed here. With reference to experience in the geological environmental field, the author sets forth the following points:

a. *Certain decrees or regulations should be put forward to strengthen the management of EIA in the geothermal field.* In certain respects geothermal resources are not only a kind of "green energy" but also a renewable energy; this is the difference between it and other mineral resources. Its lifetime can be extended with proper management. Meanwhile, its environmental efficiency makes it enormously beneficial to the human environment. Hence, it should be regarded as a special resource to be managed and protected. At present, the *Law for the protection of the environment* and the *Law of mineral resources* in force in Hebei directs that all mineral resources and environmental actions, exploitation and utilization of geothermal resources should comply with these two laws. Meanwhile there should be a special decree or regulation such as "ordinance of management of geothermal resources" that details rules on the management of the whole process of exploration, development and monitoring of geothermal resources with reference to EIA, as well as providing a strict determination of the relationship between the principal executive department and relevant departments when functions overlap.

b. *Strengthening of preliminary EIA work on development and exploitation of geothermal resources to minimise concealment.* For a proposed project, if a preliminary assessment and prediction can be made, i.e. if a correct estimation of its possible consequences, especially adverse operational impacts, can be made and suitable mitigation measures can be put into effect, this is much more useful than remediation of the problems after adverse consequences occur. Therefore, pre-EIA work has a pretty important practical significance. A complete EIA should include assessment of the natural, social and economical environment. Efficiency and benefits of development and exploitation of geothermal resources are obvious. Still, some problems and adverse effects may result, so it is necessary to strengthen the EIA work for development and exploitation of geothermal resources.

c. *Strengthening the study of mitigation measures for environmental problems known to occur during development and exploitation of geothermal resources.* Although EIA for geothermal development has not been carried out in Hebei district, some problems have been discovered from geological work and the process of development and utilization, some of which are so serious that they cannot be ignored. Hence, it is not only very important for solving problems that have already come up in existing projects but also significant for proposed projects to strengthen the study of mitigation measures for potential environmental problems during development and exploitation of geothermal resources. The major problems are:
   1) *Overdrawing of geothermal water* can cause continued lowering of the water level and temperature. Several geothermal wells that were abandoned oil exploitation wells utilized in the Niutuo town geothermal field, used to be artesian several years ago, but now they must be pumped due to lowering of the water level. The normal water level is 30-40 m or so. The temperature has declined by 2-4°C according to long-term observation results. A geothermal well in Zhongying village (originally utilized for heating a flower greenhouse) was rejected due to lowering of the water level and a water pump could not be inserted because the diameter of the well was small and another well had to be drilled. The same problems are now occurring in other geothermal fields.
   2) *Chemical components* destroy production wells and pipelines. The concentrations of chemicals such as TDS, Na^+, Ca^{2+}, Fe^{2+}, F^-, Cl^-, SO_4^{2-}, etc. in geothermal water are normally high in the flatlands. The present equipment utilized for production wells and pipelines was designed according to requirements for fresh water, so it could not withstand geothermal utilization and was destroyed by calcite scaling, corrosion, sand obstruction and so on. A geothermal well (depth >3000 m utilized for house heating, fish breeding and vegetable planting) in Jinzhuang Village, Gaoyang County is a typical example of well that has suffered calcite scaling. The thickness could reach 1 cm during the heating season (five months) and seriously affected water effluent. Another geothermal well in Xiong County hospital has an obvious corrosion problem. Many geothermal wells have had to be shut down because of usage of unsuitable de-sanding and anti-corrosion equipment.
   3) *Thermal pollution* causes biological impact. Since utilization of geothermal energy is not complete, temperatures of the water effluent are normally 30-40°C and the effluent drained to a ditch. This temperature is suitable for the growth of some bacteria and insects. Therefore, pests such as flies, mosquitoes and midges in the effluent zone are much greater than they are in other areas. For instance, waste geothermal water discharge in Hot Spring in Xiong County has this impact when it is discharged to Baiyang Lake.
   4) *Impact on the soil.* Several years ago, some geothermal water discharge was utilized for watering farmland. Some soil hardening and alkalinization manifestations caused by high concentrations of Ca^{2+}, Mg^{2+} and F^-, Cl^-, etc., have been discovered even if abnormal chemical components have not been discovered in plants. Topography of Xiong County is low, its elevation being below 20

m a.s.l., and it is in the regional groundwater discharge zone. Groundwater in soil tends to be saturated and the soil's self-cleaning ability is low, hence chemicals in geothermal water discharge concentrate relatively easily and cause problems.

5) *Impact of noise.* Operation and production noise affects surrounding dwellings and residents. However, when compared with the noise from a coal-fired boiler heating system, it is small.

7.2 Suitable EIA methods for geothermal development

7.2.1 Suggested methods for Hebei geothermal fields

In recent years, the momentum of development of new energy sources has increased progressively. Geothermal development and utilization projects have become an important aspect of resource management in Hebei province. Expansion of the developed resources is sought for wider economical and environmental profits. Known but undeveloped geothermal fields are lined up for development. Some areas where no geothermal resources have been discovered are putting effort into geothermal exploration with development in mind. It is necessary to find suitable EIA methods or modes for developing EIA work. A comprehensive study of EIA methods in some countries, connection with domestic EIA on other projects, and expansion of the actual state of geothermal resources in Hebei province, lead the author to suggest the following EIA methods for Hebei geothermal fields:

1. Ascertain the purpose, foundation, content, range and emphasis of an EIA. The purpose of an EIA is to assess and predict the consequences of a proposed project through existing data and experience, to carry out a feasibility study and suggest mitigating measurements, to ensure maximum utilization and minimum damage of a proposed project, to provide a scientific foundation for the decision-maker, developer and public interest groups. The implementing national standards can be the basis for implementation; local government can formulate rules or policies according to local practice. Ascertain content, emphasis and range of the assessment.

2. The collection of existing data of the highest quality, especially regional environmental background data such as meteorological, hydrological, geological, social, ecological, agricultural, industrial, transportation, and economical aspects, should serve as the basis for calculation, analysis, assessment, and prediction.

3. Engineering analysis of the proposed project, including technological analysis, economical efficiency analysis, impact analysis especially pollution analysis, and risk analysis, etc., should be undertaken.

4. Make sure that a proper method of assessment is used for analysis and assessment of each component. Generally, assessment concerns four components, i.e. physical impact, chemical impact, biological impact, and socio-economic impact.

   a. *Physical impact: Landscape, subsidence, air, natural features, earthquakes, thermal effluents, solid waste, etc.* Since geothermal energy must be utilized relatively close to the source in order to reduce heat losses, the disruption to the landscape is concentrated into one area. Often the land's use for road construction, pipelines, and drilling pads during geothermal development will be in conflict with other uses such as agriculture, housing, etc. Suitable solutions should be suggested in an EIA.

   Withdrawal of fluid from geothermal wells will normally result in a reduction of pressure in the formation pore space that can lead to subsidence. Although so far significant subsidence caused by geothermal utilization hasn't been observed in Hebei province, drawdown of fluid is obvious. A bowl caused by drawdown has formed in Niutuo town geothermal field. Since the local government tends to expand geothermal utilization for house heating, the planned increase being 500,000 m^2 from the original 200,000 m^2, drawdown of geothermal fluid will definitely become more serious, so the possible effects and likelihood of subsidence must be addressed in the EIA.

Noise is lower in geothermal utilization works than in fossil fuel-fired or coal-fired boiler systems since it is caused by pumps running. However, it will directly affect the health of workers as well as local inhabitants. Therefore, noise should be controlled within the range permitted by the *Standard of environmental noise in urban areas*. If conditions or techniques are limited, compensation should be considered.

Natural features in mountainous areas should be considered since most geothermal manifestations in mountainous areas are hot springs and are at present developed as tourist attractions. However, these hot springs are mostly fracture-dominated, their flows are limited and cannot be over-developed for sustainable development for further uses such as house heating, bathing and fishing, etc.

Two geothermal wells have been used for many years for seismic observation as part of a seismic study in Gaoyang county. Although no earthquake observed was caused by geothermal utilization, the seismic factor should be considered during exploration or exploitation of geothermal resources in fracture zones such as the Tangshan and Chengde areas.

Thermal effluents have a small effect on the atmosphere since they reduce numerous gas emissions such as CO_2, S-gases, dust, etc., compared with coal or oil-fired boilers and have high economical and environmental efficiency. However, since thermal energy cannot be utilized completely, relatively high temperature thermal effluents (nearly 30-40°C) can have some biological impacts on the surroundings. Flies, mosquitoes and midges are rife in waste geothermal water drainages.

Solid waste disposal should be particularly considered in binary heating systems, or geothermal and coal fired boiler co-generation systems.

b. *Chemical impact:* Geothermal fields in Hebei province are mostly low- to moderate- temperature geothermal fields. During exploitation, gas emissions to the atmosphere such as CO_2, H_2S are negligible and are not considered an adverse impact. On the other hand, in some hot springs, for example in Chicheng hot spring, radon, which may have a curative effect, has been developed as a beneficial gas.

Concentrations of some chemical elements such as Fe^{2+}, Ca^{2+}, Mg^{2+}, Si^{2+}, Cl^-, SO_4^{2-}, etc should be considered. High concentrations of Fe^{2+} suggest corrosion of well and pipeline equipment. Problems of calcite scaling due to rapid pressure reductions after geothermal water is pumped to the wellhead are very common in Hebei province. High salt content of NaCl water will cause eye irritation, and it is astringent and harmful to the skin.

Chemicals in discharge will affect surface water and groundwater. Wastewater is normally drained directly to the ocean in coastal areas. The self-cleaning action of ocean water can act well on the relatively dilute waste geothermal water. But in the inland areas of the North Plain, especially in the Baiyang Lake area whose environment is quite vulnerable (i.e. where Niutuo town geothermal field is located), waste discharge has a serious adverse impact on the water quality of Baiyang Lake water. Hence, quantitative analysis of discharge chemicals should be considered and mitigation measures should be suggested in these areas in order to reduce the amount of direct waste discharge and strengthen waste disposal.

c. *Biological impacts:* Population density is very high in Hebei province (330/km^2). Human activity affects animal life and vegetation seriously, while biological impact is a manifestation of a relatively small long-term change, which cannot be assessed by present technology. Therefore, impacts on soil and crops when geothermal water is used to irrigate farmland, impacts on livestock and aqua-products where aquatic and livestock are bred, and the effects on natural vegetation and wildlife need not be considered in too great a detail.

d. *Socio-economic impacts:* Social impact is an abstract concept; it includes population forms, social system, history and culture, educational level, religion and traditions and so on. At least a ten-year or two five-year comprehensive reports and public participation results are required for basic data to do impact analysis.

   Economic impact includes local economical status, tax and income, source of project fee, increasing price levels, etc. so economical impact analysis should include two aspects: risk estimation of proposed project, self-economical efficiency and its contribution to local economics.

The above impacts considered during assessment should be selected as suitable parameters with reference to the expected use of the proposed project. It is not necessary to consider every parameter. For instance, if geothermal energy is used for space heating, to heat maximum areas with a minimum amount of geothermal water should be considered. Hence, emphasis should be on its physical impacts on drawdown of the water level, land use, etc.

7.2.2 Selection of assessment techniques

At present techniques such as matrices, checklists, networks, overlay maps, etc. are adopted for environmental impact assessment in the world. Matrices and checklists are used widely because they are simple and direct and descriptive. In Hebei province pollution index models are normally used for quantitative analysis assessment of pollution factors, i.e.

$$P_i = \frac{C_1}{C_{oi}}$$

where P_i = Pollution index of assessed water;
C_i = Average concentration of pollutant;
C_{oi} = Standard value for pollutant (Zhou and Cai, 1998).

Assessed water is considered polluted if $P_i > 1$ but not polluted if $P_i \leq 1$. The advantage of this method is that it is a quantitative analysis of pollution factors and the results are accurate, reliable and transparent; the shortcomings of this method are that the data required must be complete. This method is suitable for quantitative analysis assessment. For some qualitative analysis such as landscape, climate change, and biological impacts, so far no convenient methods can be chosen as a standard for EIA in Hebei province. But the methods introduced above can be selected for EIA for geothermal production in Hebei province. Progress in science and technology, however, provides methods that are applicable to environmental assessment, and thus optional assessment methods for each project proposed.

1. *Prediction and mitigating measures:* The purpose of assessment is to predict consequences especially adverse consequences of a proposed project, to predict its direct/indirect, long/short term, reversible/irreversible, permanent/temporary, cumulative, and secondary impacts, in order to provide mitigating measures for predicted results. Two aspects should be noted: the agency of assessment should predict objectively and realistically, not be interfered with by the developer's economical benefits; on the other hand, it shouldn't over-emphasize adverse impacts of the proposed project so as to affect the decision-maker's decision, and hence obstruct development of the project. Also mitigation measures that take into account technological progress should be adopted if possible.

2. *Public participation* should be an obligatory step in an EIA. The mode of public participation should be representative, of extensive rationality and righteousness. To encourage public groups as many people as possible should participate in surveys. A good comparison between public survey results and results of expert consultation will be of benefit to the decision-maker and make it easy to make correct judgements, for solving conflicts between developer and benefit loser, for minimising damages and maximising benefits to developers and the local interested public.

3. *Monitoring* is getting more and more recognition as an important measure for judging the correctness of an EIA. However, there are still some difficulties for developing this work which is constrained by economics and technology. For further consideration, a complete EIA report should include a monitoring plan. Development of Niutuo town geothermal field provides a serious lesson. People have known that the geothermal water level has been decreasing for many years, but as there are not any actual monitoring results to prove this, the relationship between drawdown of the water level and recharge of water cannot be measured. Nobody dares challenge a project for expanding development of geothermal resources in this area, and thereby hamper development of local economics and environment.

All in all, EIA is getting more and more publicity because of its objectivity and practicality. This work will become more and more optimal following accumulation of experience, technical progress, and change in people's attitudes and increase in environmental investment.

8. CONCLUSIONS

Accompanying technical progress, and economic development, impacts on the environment caused by human activities become more and more serious and obvious. How to utilize available natural resources and minimise destruction of the environment becomes a problem to which people give increasing attention. At present many countries are seeking solutions to it. EIA is a result. It is becoming progressively better received by the decision-maker, developer and interested public because of its objectivity, practicality and importance.

Geothermal resources are quite abundant in Hebei province. Their development history is ages long and has a wide background. But for reasons, such as management, technology, economics etc, EIA work hasn't yet been developed for geothermal fields in Hebei province although EIA work has been undertaken in China for many years. From now on it is on the working agenda for resource management in Hebei province. For coordinating development of this work, suitable EIA methods are needed.

At present, many techniques have been developed for EIA in the world, such as matrices, checklists, overlay maps, networks and so on. A suitable EIA method should be selected for geothermal development in Hebei province. During comparison, matrices can be used for impact identification; it can also be associated with checklists. A checklist is good as a guide to potential impacts. Pollution factors index method, which is often used in EIA of other projects in Hebei province, can be used for quantitative analysis of pollutant components and the degree of pollution. Prediction and mitigating measures can be improved beyond the present local technical level.

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APPENDIX: ENVIRONMENTAL IMPACTS CHECKLIST

ENVIRONMENTAL IMPACTS CHECKLIST

Project name:
Project location:
Description of project:

Subjects	*Direct/ Indirect (D/I)*	*Short-term*	*Long-term*	*Reversible/ Irreversible (R/I)*	*Significant (Y/N)*	*Mitigating*
1. Earth. Will the proposal result in:						
a. Unstable earth conditions or in changes in geologic substructures ?						
b. Disruptions, displacements, compaction or over covering of the soil ?						
c. Change in topography or ground surface relief features ?						
d. The destruction, covering or modification of any unique geologic or physical features ?						
e. Any increase in wind or water erosion of soils, either on or off the site ?						
f. Changes in deposition or erosion of beach sands, or changes in siltation, deposition or erosion which may modify the channel of a river or stream or the bed of the ocean or any bay, inlet or lake ?						
g. Exposure of people or property to geologic hazards such as earthquakes, landslides, mudslides, ground failure, or similar hazards ?						
2. Air. Will the proposal result in:						
a. Substantial air emissions or deterioration of ambient air quality ?						
b. The creation of objectionable odours ?						
c. Alteration of air movement, moisture, or temperature, or any change in climate, either locally or regionally ?						
3. Water. Will the proposal result in:						
a. Changes in currents, or the course of direction of water movements, in either marine or fresh waters ?						
b. Changes in absorption rates, drainage patterns, or the rate and amount of surface runoff ?						
c. Alteration to the course or flow of flood waters ?						

Subjects	*Direct/ Indirect (D/I)*	*Short-term*	*Long-term*	*Reversible/ Irreversible (R/I)*	*Significant (Y/N)*	*Mitigating*
d. Change in the amount of surface water in any water body ?						
e. Discharge into surface waters, or in any alteration of surface water quality, including, but not limited to, temperature, dissolved oxygen or turbidity ?						
f. Alteration of the direction or rate of flow of ground waters ?						
g. Change in the quantity or quality of ground water, either through direct additions or withdrawals, or through interception of an aquifer by cuts or excavations ?						
h. Substantial reduction in the amount of water otherwise available for public water supplies ?						
i. Exposure of people or property to water-related hazards such as flooding or tidal waves ?						
4. Plant life. Will the proposal result in:						
a. Changes in the diversity of species, or number of any species of plants (including trees, shrubs, grass, crops, and aquatic plants) ?						
b. Reduction of the numbers of any unique, rare or endangered species of plants ?						
c. Introduction of new species of plants into an area, or in a barrier to the normal replenishment of existing species ?						
d. Reduction in acreage of any agricultural crop ?						
5. Animal life. Will the proposal result in:						
a. Change in the diversity of species, or number of any species of animals (birds, land animals such as reptiles, fish and shellfish, benthic organism or insects) ?						
b. Reduction of the number of any unique, rare or endangered species of animals ?						
c. Introduction of new species of animals into an area, or a barrier to the migration or movement of animals ?						
d. Deterioration to existing fish or wildlife habitat ?						
6. Noise. Will the proposal result in:						
a. Increases in existing noise levels ?						
b. Exposure of people or noise-sensitive receptors to severe noise levels ?						
7. Light and glare. Will the proposal produce new substantial source of light or glare?						

Subjects	*Direct/ Indirect (D/I)*	*Short-term*	*Long-term*	*Reversible/ Irreversible (R/I)*	*Significant (Y/N)*	*Mitigating*
8. Land use. Will the proposal result in a substantial alteration of the present or planned land use of an area ?						
Present :						
Planned :						
9. Natural resources. Will the proposal result in:						
a. Increases in rate of use of any natural resources ?						
b. Substantial depletion of any nonrenewable natural resources ?						
10. Risk of upset. Will the proposal involve:						
a. A risk of an explosion or the release of hazardous substance (including, but not limited to, oil accident, chemical or radiation) in the event of an accident or upset conditions ?						
b. Possible interference with an emergency response plan or emergency evacuation plan						
11. Population. Will the proposal alter the location, distribution, density, or growth rate of the human population of an area ?						
12. Housing. Will the proposal affect the existing housing, or create a demand for additional housing ?						
13. Transportation/circulation. Will the proposal result in:						
a. Generation of substantial additional vehicular movement ?						
b. Effects on existing parking facilities, or demand for new parking ?						
c. Substantial impact upon existing transportation systems ?						
d. Alteration to present patterns of circulation or movement of people and/or goods ?						
e. Alteration to waterborne, rail or air traffic ?						
f. Increase in traffic hazards to motor vehicles, bicyclists or pedestrians ?						
14. Public services. Will the proposal have an effect upon, or result in a need for new or altered governmental services in any of the following areas:						
a. Fire protection ?						
b. Police protection ?						
c. Schools ?						
d. Parks or other recreational facilities ?						
e. Maintenance of public facilities, including roads ?						
f. Other governmental services ?						

Subjects	***Direct/ Indirect (D/I)***	***Short-term***	***Long-term***	***Reversible/ Irreversible (R/I)***	***Significant (Y/N)***	***Mitigating***
15. Energy. Will the proposal result in:						
a. Use of substantial amounts of fuel or energy ?						
b. Substantial increase in demand upon existing sources of energy, or require the development of new sources of energy ?						
16. Utilities and service systems. Will the proposal result in a need for new systems, or substantial alterations to the following utilities:						
a. Power or natural gas ?						
b. Communications systems ?						
c. Water ?						
d. Sewer or septic tanks ?						
e. Storm water drainage ?						
f. Solid waste and disposal ?						
17. Human health. Will the proposal result in:						
a. Creation of any health hazard or potential health hazard (excluding mental health)						
b. Exposure of people to potential health hazards ?						
18. Aesthetics. Will the proposal result in:						
a. The obstruction of any scenic vista or view open to the public ?						
b. The creation of an aesthetically offensive site open to public view ?						
19. Recreation. Will the proposal result in an impact upon the quality or quantity of existing recreational opportunities ?						
20. Cultural resources. Will the proposal:						
a. Result in the alteration of or the destruction of a prehistoric or historic archaeological site ?						
b. Result in adverse physical or aesthetic effects to a prehistoric or historic building structure, or object ?						
c. Have the potential to cause a physical change which would effect unique ethnic cultural values ?						
d. Restrict existing religious or sacred use within the potential impact area ?						

Subjects	***Direct/ Indirect (D/I)***	***Short-term***	***Long-term***	***Reversible/ Irreversible (R/I)***	***Significant (Y/N)***	***Mitigating***
21. Mandatory finding of significance.						
a. Does the project have the potential to degrade the quality of the environment, substantially reduce the habitat of a fish or wildlife species, cause a fish or wildlife population to drop below self-sustaining levels, threaten to eliminate a plant or animal community, reduce the number or restrict the range of a rate or endangered plant or animal or eliminate important examples of the major periods of history or prehistory ?						
b. Does the project have the potential to achieve short-term, to the disadvantage of long-term, environmental goals ? (A short-term impact on the environment is one which occurs in a relatively brief, definitive period of time while long-term impacts will endure well into the future.)						
c. Does the project have impacts which are individually limited, but cumulatively considerable ? (A project may have a relatively small impact on each resource, but the effect of the total of those impacts on the environment is significant.)						
d. Does the project have environmental effects which will cause substantial adverse effects on human beings, either directly or indirectly ?						