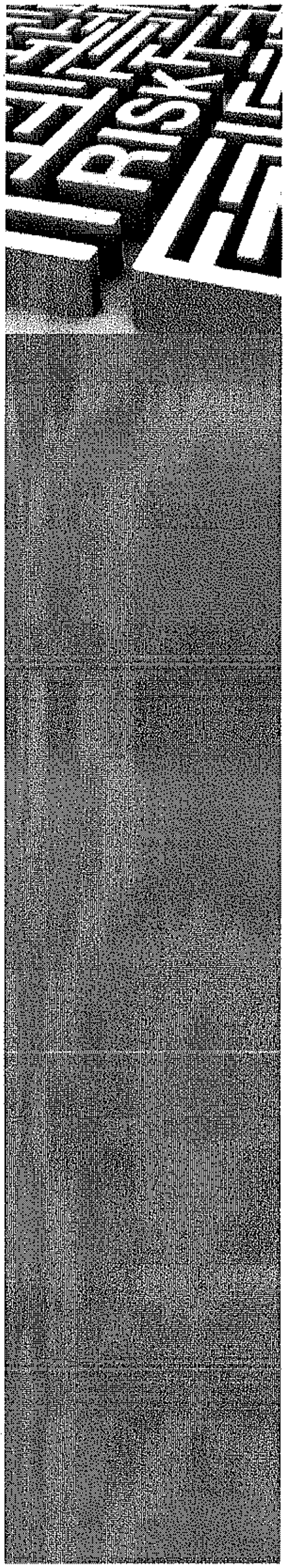

ENVIRONMENTAL DAMAGES VALUATION

Texpet-Ecuador Concession Area

September 2010

DOUGLAS C. ALLEN, P.A.
Managing Risk. Moving Business Forward.

September 11, 2010

Douglas C. Allen

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

1.0 INTRODUCTION

From 1964 through June 1990, Texaco Petroleum Company (Texpet) conducted petroleum exploration and production operations in an area known as the Concession area located in the Oriente District of eastern Ecuador. Through a series of agreements, Texpet conducted its activities as part of a consortium beginning with Gulf Oil in 1964. In 1974, the Corporacion Estatal Petrolera Ecuatoriana (CEPE), now known as Petroecuador joined the consortium. Throughout this time period, Texpet acted as the oil field operator for the consortium.

In 1993, a group of Ecuadorian plaintiffs filed a class action lawsuit against Texaco in the United States District Court, Southern District of New York (*Maria Aguinda , et. al. v. Texaco, Inc.*). In the *Aguinda* litigation, the plaintiffs, a class of persons residing in the Oriente region of Ecuador, sought to recover individual personal injury and property damages from Texaco (SDNY, 2010). The *Aguinda* case was dismissed by the Court in May 2001. However, in May 2003, a group of Ecuadorians asserting the same or similar claims filed the *Lago Agrio* litigation against Chevron in the Superior Court of Neuva Loja, Ecuador. In the *Lago Agrio* case, plaintiffs are asserting claims against Chevron for environmental remediation costs (SDNY, 2010).

In March 2007, the President of the Court in Neuva Loja appointed Engineer Richard Stalin Cabrera Vega (Cabrera) to provide expert technical assistance to the Superior Court in the *Maria Aguinda et al.* case (Case No. 002-2003). In March 2008, Cabrera produced an expert report documenting his study of the environmental damage caused in the Concession area and his estimate of the costs for remediating contaminated soil, groundwater, and sediment and for restoring the ecosystem. Cabrera's total estimate for remediating environmental damages in his March 2008 report was $2.4 billion (Cabrera, 3/2008).[1] In November 2008, he issued a revised report in which he increased his estimate to remediate environmental damages to $7.7 billion (Cabrera, 11/2008).[2]

On August 2, 2010, the Neuva Loja Court issued an order directing the parties in the litigation to submit independent damages assessments within six weeks. The order asks the parties to 'assess the "economic cost" of the environmental damages documented by more than 100 expert reports and the tens of thousands of chemical sampling results now before the court' (Energy & Ecology Business, 2010).

1.1 SCOPE OF ENGAGEMENT

DOUGLAS C. ALLEN, P.A. (DCA) was retained on behalf of plaintiffs' counsel in the Aguinda litigation to assist in developing an independent evaluation and estimate of the potential costs for the remediation of environmental damages in the Concession area in the Oriente region of Ecuador.

DCA's task was limited to the development of potential costs for the remediation of contaminated soil and groundwater at well sites and production stations, and sediments in waterways (e.g., rivers, streams,

---

[1] Cabrera's cost estimate in his March 2008 report was for remediating contaminated soil at the oil well platforms and production stations to a cleanup level of 1,000 ppm total petroleum hydrocarbons (TPH), and compensation for loss of ecosystem.

[2] Cabrera's cost estimate in his November 2008 revised report was for remediating contaminated soil at the oil well platforms and production stations to a cleanup level of 100 ppm TPH, remediating groundwater, and compensation for loss of ecosystem.

marshes, etc.) associated with the oil exploration and production operations conducted by the Texpet-Petroecuador Consortium in the Concession area.

1.2 FRAMEWORK FOR VALUATION

DCA utilized a rational and objective framework in order to develop a credible and conservative valuation. This framework integrates three components: (1) Ecuador's current quality standards for contaminated environmental media, (2) U.S. environmental legislation and programmatic guidance for investigating and remediating contaminated sites under the Comprehensive Environmental Reclamation, Compensation and Liability Act (CERCLA, also known as "Superfund"), and (3) standard guidance for estimating environmental costs and liabilities developed by the American Society for Testing and Materials (ASTM). Each of these framework components is discussed in the following paragraphs.

Ecuador's Environmental Quality Standards. Ecuador's environmental legislation and standards have been discussed in detail previously (Cabrera, 3/2008, Appendix D; Fugro-McCelland, 1992; HBT Agra, 1993).

The primary focus for this valuation was the Ecuador standards for the protection of soil and water from contamination by petroleum hydrocarbons associated with crude oil. Although sampling data from the Concession area has indicated the presence of numerous other contaminants associated with crude oil, (including metals, benzene-toluene-xylenes (BTEX), and polyaromatic hydrocarbons (PAHs)), to date the target cleanup levels for soil and groundwater have focused on total petroleum hydrocarbons (TPH) as the primary contaminant of concern (COC).

Ecuador's soil quality standards for TPH as set forth in Decree No. 1215, Annex 2, Table 6. Decree No. 1215 allows three permissible TPH soil concentrations: 1,000 ppm for the protection of sensitive ecosystems, 2,500 ppm for agricultural soils, and 4,000 ppm for industrial soils. The Concession area is located in the tropical Amazon forest and is likely to be considered as a sensitive ecosystem (Cabrera, 3/2008, pp. 11-13; Annex D). For the purpose of this valuation, DCA assumed a 1,000 ppm TPH cleanup level in developing its environmental damages valuation.

It has been suggested that a TPH cleanup level of 100 ppm would afford greater protection of human health and the environment (Cabrera, 11/2008, pp. 16). Support for a 100 ppm level may be found in two places. First, Petroecuador's Project for the Remediation of Pits in the Amazon Region (PEPDA) establishes a TPH level of 100 ppm when cleanup of TPH contamination in soils achieves 100% environmental quality (Cabrera, 3/2008, p. 13; Cabrera, 11/2008, p. 16). Second, although many U.S. states are moving toward chemical-specific risk-based cleanup standards, there are a few states where TPH soil cleanup standards of 100 ppm (or less) have been established.[3] For the purpose of this valuation, DCA assumed 100 ppm as a possible alternative TPH cleanup level.

---

[3] Table 5 in Cabrera's Annex D (A Review of Ecuador's Environmental Quality Standards) provided a list of 13 U.S. states of which 6 established TPH soil standards of 100 ppm or lower. This list was based on a survey conducted in 2008 and reflected TPH regulations in effect in 2003. A review of this list by DCA indicated 3 of these states have since moved to risk-based cleanup standards. DCA also found that Washington has a cleanup standard <100 ppm where gasoline is involved, and North Dakota has a 100 ppm TPH soil cleanup standard.

Ecuador's water quality standards for TPH are set forth in Decree No. 1215, Annex 3, Table 5 which establishes a standard of 0.325 mg/l for TPH in water (Cabrera, 3/2008, p. 12; Annex D). For the purpose of this valuation, DCA evaluated groundwater remediation necessary to achieve the 0.325 mg/l standard.

U.S. CERCLA "Superfund" Program. While Ecuadorian environmental laws and policy may not incorporate an equivalent of the U.S. Superfund program, it is nevertheless instructive and useful to consider the programmatic guidance and knowledge base of information and data that has been developed for the Superfund program in any valuation of environmental damages. For this valuation, DCA drew upon the wealth of Superfund information and data on remedial treatment technologies and used the Superfund evaluation framework of criteria and factors in considering the overall effectiveness, ability to implement and costs of remediating contaminated soil, groundwater and sediments at the Concession area.

ASTM 2137-06. Selection of an appropriate cost estimation method for environmental valuations depends on a number of factors including the quality and quantity (i.e., the value) of the information available or obtainable, the intended use of the estimate, and the estimator's judgment based on their knowledge and experience. DCA considered the value of the information it reviewed as the primary determinant in selecting an appropriate estimation method. For the purpose of this valuation, DCA developed its remedial cost estimates as a range of values from low cost to high cost, based on reasonable assumptions. This method of cost estimation is one of five methods prescribed in ASTM E 2137-06, *Standard Guide for Estimating Monetary Costs and Liabilities for Environmental Matters,* for estimating environmental costs and liabilities.[4] The range of values method is best used where there is insufficient information for more robust estimation methods and/or where the probabilities for various scenarios cannot be accurately predicted.

1.3 SOURCES OF INFORMATION RELIED ON

The primary information and data used by DCA for this valuation was obtained from plaintiffs' counsel and included: (1) the expert reports and associated annexes of Richard Cabrera; (2) technical reports cited in the Cabrera reports; and (3) other information and data submitted to the Court for the Aguinda litigation. In addition, DCA obtained information and data from internet sources including: media releases, U.S. EPA CERCLA legislation and guidance, and environmental remedial technology databases. Finally, DCA relied on its own knowledge and experience in the investigation and remediation of petroleum-contaminated sites. A list of the documents used by DCA for this valuation is presented in **Section** 7 (Bibliography).

1.4 LIMITATIONS AND UNCERTAINTIES OF VALUATION

The Aguinda litigation has generated more than 100 expert reports and tens of thousands of chemical sampling results (Energy and Ecology Business, 2010). The time constraints under which this valuation was prepared did not permit an exhaustive analysis of the voluminous record of evidence that has been presented to the Court. The documents reviewed and relied on by DCA represent a small percentage of the documents cited in the Cabrera reports and annexes and an even smaller percentage of the documents submitted to the Court during the litigation. DCA based its valuation on the information made available

---

[4] ASTM E 2137-06 is the current version which was approved in November 1, 2006 and published in December 2006. The five cost estimating methods are: Quoted Price, Expected Value, Most Likely Value, Range of Values, and Known Minimum Value. Descriptions of the five cost estimating methods are provided in E 2137-06.

during the period of engagement. The assumptions made by DCA and the resulting estimated potential costs developed for this valuation are subject to change as a result of further review and analysis of existing information and data, and/or the generation of additional information and data from future investigations. Although standard cost estimating practices and unit cost data have been used to the extent practicable, the remedial cost estimates developed by DCA for this valuation should be viewed as potential, conceptual-level estimates only. Finally, these costs are based on a generic approach; when a final remedial action plan (RAP) has been developed and Concession area-wide remedial activities have commenced the costs to remediate the soils and groundwater at the Concession area will likely vary significantly among individual sites.

1.5 REPORT ORGANIZATION

DCA's valuation is presented in Sections 2 through 6. Section 2 provides a concise summary of the Site organized into the following subsections:

- Site Setting — provides a brief physical description of the Site and the development of the oil fields within the Site;
- Site Chronology — summarizes highlights of the operational, investigative and remedial history of the Site; and
- Nature and Extent of Contamination— summarizes the general findings of environmental site assessments, characterizations and investigations that have been conducted at the Site.

Sections 3 through 5 discuss the remediation of soil, groundwater, and sediment, respectively, organized into the following subsections:

- Valuation Assumptions and Analysis — presents DCA's assumptions and evaluation of the remedial actions, and the associated costs for cleaning up environmental media at the Site; and;
- Results of Cost Estimation – summarizes the estimated remedial costs.

Section 6 presents a summary of the valuation of environmental damages.

2.0 SITE SUMMARY

2.1 SITE SETTING

The Concession area (Site) is located east of the Andes Mountain range within the Amazon Region, Oriente District, of northeastern Ecuador (**Figure 1**). The Site encompasses approximately 400,000 hectares (ha) (HBT Agra, 10/1993, p. 2-1; Fugro-McClelland, 10/1992, p. 2-2).

Topography and Climate. The general topography of this region is composed of gently sloping land and flat valleys that stretch eastward toward the headwaters of the Amazon River. The surface elevation varies from approximately 300 to 275 meters above mean sea level, sloping to the east. The vegetation of the Site can generally be categorized as primary forest, secondary forest, cultivated fields, wetlands and cleared areas covered with grass. The climate of the Oriente District of Ecuador is tropical characterized by high temperatures and heavy rainfall. Rainfall in the Oriente ranges from 2,000 mm to 5,000 mm annually. There is no dry season in the Oriente; soils are dry for less than three consecutive months (Woodard-Clyde, 5/2000, p. 1-3; HBT Agra, 10/1993, p. 2-1; Fugro-McClelland, 10/1992, p. 2-2).

Surface Water. The Site is drained by one main river system, the Rio Napo, which is a tributary of the Rio Amazonas. Major tributaries of the Rio Napo are the Rio Coca and the Rio Aguarico. Tributaries of the Rio Aguarico which cross the Concession area include the Rio Teteye, Rio Eno, Rio Dureno, and Rio Shushufindi. Tributaries of the Rio Coca which cross the Concession area are the Rio Yanayacu, Rio Jivino, Rio Curiyacu, Rio Rumijacu, Rio Tiputini and Rio Tivacuno. All of the rivers generally flow in an easterly or southeasterly direction. The size of these rivers varies considerably. The Rio Napo and Rio Aguarico are the largest rivers and are about 150 to 200 m wide. The Rio Eno, Rio Tiputini and Rio Shiripuro are about 30 m wide. Most of the other rivers are less than 10 m wide. The rivers serve a wide range of domestic and industrial uses including: habitat for terrestrial and aquatic wildlife, drinking water supply, fishing, bathing, discharge points for effluents from petroleum operations, withdrawals for industrial uses, and transportation (HBT Agra, 10/1993, p. 2-6, p. 7-2).

Soils. An environmental assessment conducted by HBT Agra indicate soils in the Oriente are formed on alluvium volcanic and sedimentary materials. Soils in the alluvial plains are characterized as recent volcanic ash deposited over older deposits of ash with stratified mud and sand. Soils in the floodplains, hills, and hilly plateaus are characterized as sedimentary with high clay content; these soils are poorly drained. Fractured clay layers as well as discontinuous lenses or layers of sand or silt are encountered throughout the Site (HBT Agra, 10/1993, pp. 2-2 to 2-4, Table 2-1, p. 8-2; Section 8.4).

Groundwater. Environmental assessments conducted by HBT Agra and Fugro-McClelland indicate shallow groundwater occurs within the unconfined and perched conditions within the Oriente Basin. Groundwater depths vary throughout the Site ranging from less than 1 meter below ground surface (bgs) to 8 meters bgs (HBT Agra, 10/1993, Section 8.4; Fugro-McClelland, 10/1992, p. 6-22). Domestic water wells hand dug to depths less than 5 meters are common south of the Aguarico River and north of the Napo River. Springs are common in the upland areas to the south of the Napo River, and north of the Napo River in the Lago Agrio and Guanta Field areas and are partly controlled by perched aquifers, fractures and faults. Because of the occurrence of clayey soils of low permeability, the rate of recharge to the shallow aquifers is relatively low to moderate, and surface runoff to rivers is high. Typically, streams in humid tropical regions receive groundwater discharge, and the water table slopes towards the streams. Most vertical and lateral groundwater flow occurs along fractures within the clay or within silt or sand units (HBT Agra, 10/1993, p. 8-2).

Oil Well Field Development. Petroleum exploration and production operations at the Site began in 1967. The exploration operations between 1967 and 1972 resulted in the discovery of nine large oil fields. Seven smaller additional fields were discovered between 1972 and 1990 (Woodward-Clyde, 5/2000, p. 1-1; Fugro-McClelland, 10/1992, pp. 1-1 to 1-2). **Figure 2** shows the production field locations.

Each of the larger oil fields that were developed consists of multiple well sites; one or more production stations; camps and supply depots; and pipelines. **Figure 3** shows an aerial view of the Shushufindi South Production Station Site. The well site output from the smaller oil fields is sent to production stations in larger fields (Woodard-Clyde, 5/2000, Table 1-1; HBT Agra, 10/1993, pp. 6-6 to 6-12).

Well sites are generally equipped with a single well head and control equipment for the flow system. The average well site gravel pad area is approximately 5,600 square meters [60,000 square feet] with a range of approximately 1,900 square meters [20,000 square feet] to 16,700 square meters [180,000 square feet], excluding the area occupied by the reserve and production pits (HBT Agra, 10/1993, p. 6-8; Fugro-McClelland, 10/1992, p. 6-8). **Figure 4** shows an aerial view of oil well sites around the Shushufindi North Production Station.

Production stations contain equipment necessary to separate water from oil, store crude oil and dispose of produced water to the environment. Most of the production stations contain storage tanks for crude oil and fuel, surge tanks, wash tanks, oil-water separators, manifolds and pumps, metering stations, produced water pits and natural gas flares. Selected facilities contain water treatment and water injection pumps, hydraulic life pumps, gas lift compressors, power generation turbines and chemical storage. The commonly used chemicals in all fields include demulsifiers, descalers, anticorrosives, antifoaming agents, antiparaffin and acid treatment chemicals. The area occupied by the production stations range in size from 2.5 ha (6 acres) to 50 ha (125 acres) (HBT Agra, 10/1993, Sections 5.4 and 5.5; Fugro-McClelland, 10/1992, p. 6-12).

Associated with each of the well sites and production stations were one or more pits (Fugro-McClelland, 10/1992, Section 6.3.3). Unlined, on-site pits were used at the well sites and production stations for the management of drilling muds, evaporation and storage of produced water, management of workover or completion fluids and for emergency containment of produced fluids. The pits were typically excavated to a depth of approximately 1 to 2 or 2.5 meters (Cabrera, 3/2008, Annex H, p. 4; Woodard-Clyde, 5/2000, p. 3-4; HBT Agra, 10/1993, p. 72). The pits contain a variety of materials (debris, crude oil, rainwater, and sludges) depending on their primary use (reserve pits, flare pits, water pits, test pits, production pits and trash pits). Reserve and production pits vary in size from approximately 3 meters by 3 meters [10 feet by 10 feet] to approximately 60 by 60 meters [200 by 200 feet]. The reserve pits, usually larger than 900 square meters (10,000 square feet), are used for the collection and disposal of drilling muds and cuttings (Woodward-Clyde, 5/2000, p. 3-4; Fugro-McClelland, 10/1992, pp. 6-8 to 6-9).

Camps and supply depots are located in larger oil fields usually adjacent to the production facilities. The camps have living and recreational facilities for workers and guests, vehicle maintenance shops, fuel storage, and airstrips. Some have administrative/operations offices. Supply depots store pipe and other equipment necessary to maintain and develop the oil field. Used pipe, empty drums and unusable vehicles are often stored in these depots (HBT Agra, 10/1993, p. 6-12; Fugro-McClelland, 10/1992, p. 6-5 to 6-6).

The well sites and production stations are accessible via a network of primary, secondary and access roads which provide access to the oil well fields, oil well sites, and individual well sites, respectively. By

1990, approximately 310 km of primary roadway were in use. The roads were constructed by cut and fill methods and using granular materials extracted from river beds. Primary and secondary roads are often coated with residual crude oil as a dust control measure and to limit the erosion of granular materials used in their construction (HBT Agra, 10/1993, p. 6-6; Fugro-McClelland, 10/1992, p. 6-5).

A series of flowlines convey produced fluids from the well sites to the production stations while secondary pipelines deliver crude oil between stations. The majority of these flowlines are located in narrow corridors immediately adjacent to roadways thus minimizing the need for additional right-of-way construction. Generally, well site access road corridors contain a single flowline, secondary roads up to 9 flowlines, and primary roads up to 14 flowlines. The majority of these pipelines are located aboveground supported by steel racks or concrete stands. The remaining pipeline either lies on the ground or is buried (HBT Agra, 1993, p. 6-12; Fugro-McClelland, 10/1992, p. 6-27).

2.2 SITE CHRONOLOGY

The following summarizes some highlights of the Site operational, investigative, and remedial history:

3/1964	The Government of Ecuador (GOE), Texpet and Gulf Oil signed a Concession Agreement which allowed Texpet and Gulf to begin petroleum exploration and production operations in Ecuador. Each company had 50 percent participation interest in the concession (Woodard-Clyde, 5/2000, p. 1-1; Fugro-McClelland, 10/1992, p. 1-1).
1972	A 318-mile-long trans-Ecuadorian pipeline was built to transport oil from Lago Agrio across the Andes Mountain Range to the oil terminal at Esmeraldes on the Pacific Coast (Woodard-Clyde, 5/2000, p. 1-1; Fugro-McClelland, 10/1992, p. 1-4).
1973	The [1964] Agreement was renegotiated and a new contract was signed between Texpet, Gulf Oil and the GOE (Woodward-Clyde, 5/2000, p. 1-1).
6/1974	The Corporacion Estatal Petrolera Ecuatoriana (CEPE), the predecessor to Petroecuador, acquired a 25 percent interest in the producing assets of the 1973 contracts. Texaco retained a 37.5% interest and Gulf retained a 37.5% interest (Woodward-Clyde, 5/2000, p. 1-1; HBT Agra, 10/1993, p. 1-3).
1977	CEPE purchased Gulf's remaining shares making CEPE the majority holder with a 62.5 percent share and Texaco with a minority share of 37.5 percent (Woodward-Clyde, 5/2000, p. 1-1).
1986	Texpet ended its exploration activities at the Site (Woodward-Clyde, 5/2000, p. 1-1).
6/1990	Texpet turned over the operation of the Oriente fields to Petroecuador (HBT Agra, 10/1003, p. 1-3; Fugro-McClelland, 1-/1992, ES-1).
6/1992	Texpet's portion (37.5 percent) of the ownership of the oil fields was transferred to Petroecuador (Woodard-Clyde, 5/2000, p. 1-1).

4-5/1992	Fugro McClelland conducted an environmental field audit for Texpet as part of the transfer of ownership of the oil fields from Texaco to Petroecuador in June 1992. This audit was conducted independently of and parallel to the environmental assessment conducted by HBT Agra on behalf of both Texaco and Petroecuador. Fugro audited 158 wells, 18 production stations, 6 camps, and approximately 30 miles of pipeline. The audit included: site condition documentation, produced water, stream, and groundwater sampling and analysis, crude oil and spill sampling and analysis, soil permeability and percolation testing, and noise measurement. (The results of this audit discussed in Section 2.3) (Fugro-McClelland, 10/1992, p. E-1, p. 1-5).
5-6/1993	HBT Agra conducted an environmental assessment of the Oriente oil fields on behalf of Texpet and Petroecuador as part of the transfer of ownership of the oil fields from Texaco to Petroecuador in June 1992. HBT Agra conducted a two-phase scope: Phase I involved a biophysical survey, historical review, regulatory review, facility audit and site reconnaissance to all 22 production stations, 163 well sites, and 66 flowlines. Phase II involved surface water, groundwater and subsurface investigations on those sites where contamination or a high potential for contamination was identified during Phase I (The results of this audit and assessment are briefly summarized in Section 2.3) (HBT Agra, 10/1993, pp. 1-3, 6-1).
12/1994	A Memorandum of Understanding (MOU) was executed by the Government of Ecuador, Petroecuador, and Texpet in which Texpet agreed to implement environmental work at the Site (Woodard-Clyde, 5/2000, p. 1-3).
3/1995	A Scope of Environmental Remedial Work (SOW) was executed by the Government of Ecuador, Petroecuador and Texpet. Texpet was responsible for: (1) remediation of all existing pits and spills at 108 well sites that had been drilled prior to 1990 and at 26 well sites abandoned prior to June 30, 1990; (2) review and abandonment of the 26 wells that had been abandoned prior to June 30, 1990; (3) remediation of hydrocarbon-impacted soil at the 26 sites and at an additional 27 well sites where the surface soil had potentially been impacted as a result of operations prior to June 30, 1990; and (4) implementing the required modifications to the production water treatment and discharge systems at nine production stations and at four well locations where production water used to be discharged (Woodard-Clyde, 5/2000, p. 1-4).
1995-1998	Woodard-Clyde reported on environmental investigation and remediation/reclamation work conducted in 1995-1998 in accordance with the 1994 MOU and the 1995 SOW. According to Woodard-Clyde, a total of 250 pits and 7 spill areas located at 133 well sites were remediated through a combination of traditional oil field and innovative remediation technologies and/or certified as requiring no further action based on confirmation soil sample results. Only 13 of the pits could not be remediated because of site conditions (i.e. ongoing activities by Petroecuador) (Woodard-Clyde, 5/2000, p. ES-1; p. 1-5). Texpet claimed to have spent $40 million on this remedial program (Texaco, Undated).[5]

---

[5] DCA was unable to obtain any supporting documentation for Texaco's claimed expenditures of $40 million.

2004-2009	A series of Judicial Inspections were conducted by Chevron's and plaintiffs' experts. Soil and water samples were collected from 34 well sites and 11 production stations. (The results of this field study are discussed in Section 2.3) (Cabrera, 3/2008, pp. 16-17; Annex E).
2007	Cabrera collected soil, surface water and groundwater samples from 48 production wells and one production station as part of his scope and role as the Court-appointed Expert. (The results of this field study are discussed in Section 2.3) (Cabrera, 3/2008, pp. 16-17).

2.3 NATURE & EXTENT OF CONTAMINATION

This section presents a brief overview of the nature and extent of environmental contamination that has been documented by numerous assessments and investigations conducted at the Site.

Field audits conducted by Fugro-McClelland of operations at the Site well fields in 1992 documented widespread hydrocarbon contamination. Audit findings included:

- Hydrocarbon contamination requiring remediation at all [18] production facilities and a majority of the drill sites (Fugro-McClelland, 10/1992, p. E-1);

- Approximately 70 percent of the well sites audited had drilling or production pits. Almost 50 percent of the pits audited were empty or contained water. A majority of the remaining pits had 100 percent crude oil cover. Contamination beyond the pits was observed at some areas. The contamination usually occurred as a result of pit overflow, berm failure or releases through the siphon (Fugro-McClelland, 10/1992, pp. 6-9, 6-10);

- Four production facilities had final stage pits (pits that discharge directly to a surface water feature) with little to no accumulation of hydrocarbons (less than 5 percent); nine production facilities were observed to have final stage pits with a large accumulation of crude oil (greater than 95%); discharge pits at the remaining facilities had crude oil cover which ranged from 20 to 50 percent (Fugro-McClelland, 10/1992, p. 6-14);

- Evidence of petroleum releases beyond the final stage pit into a surface drainage feature was observed at five of the production stations. Drainage channels at two of the stations were heavily contaminated and contained free-standing crude oil which was slightly degraded. In all instances hydrocarbon contamination was limited to the immediate vicinity of the stream discharge point or tributary (Fugro-McClelland, 10/1992, p. 6-23);

- Spills of hydrocarbons and chemicals at the production stations and well sites were often not cleaned up. Instead they were covered with sand. Contaminant migration from the well site spills into the highly plastic red clay was generally observed to be minimal (HBT Agra, 10/1993, p. 6-13; Fugro-McClelland, 10/1992, p. 6-25); and

- Evidence of pipeline leaks were observed along 11 of the 28 transects. Ten of the spills identified along four transects would be considered major, i.e., greater than a few hundred square feet in area (Fugro-McClelland, 10/1992, p. 6-28).

Field audits conducted by HBT Agra of operations at the Site well fields in 1993 documented widespread hydrocarbon contamination. Audit findings included:

- Contamination of soil and water was observed at well sites, production stations and along roadways, flowlines and secondary pipelines (HBT Agra, 10/1993, p. 6-12);

- Spills were noted at 158 of the 163 well sites assessed. Most of these spills were confined to the well site. Contaminant migration from these well site spills into the highly plastic red clays was generally observed to be minimal (HBT Agra, 10/1993, p. 6-13);

- Waste pits were found at 125 of the well sites assessed. A total of 126 open or closed pits contained oily waste which was confined within 50 of the pits and was found to be migrating in 76 of the pits (HBT Agra, 10/1993, p. 6-15);

- Seepage was noted at 69 of the well site pits as evidenced by the presence of oily soil lateral to the pits. Seepage or pit discharge to streams was observed to have occurred at 28 pit locations (HBT Agra, 10/1993, p. 6-15);

- Both well site pits and production pits contained oily sludges. The thickness of the sludges in the well site pits was estimated to be less than one meter on average (HBT Agra, 10/1993, p. 6-15 and 6-20); and

- Spills of produced fluids, used oil, chemicals or fuel were observed at the production stations including: manifolds and separators, pumps and compressors, process area drains and sumps, and vehicle maintenance areas and pits (HBT Agra, 10/1993, p. 6-16).

Sampling and analysis of soil, surface water, groundwater and sediment has been conducted at the Site by numerous parties. Details on these sampling events have been reported elsewhere (Cabrera, 3/2008, Section 3.2.10; Annexes A and C; HBT Agra, 10/1993, Section 6.4).

Sampling of environmental media at the Site conducted by experts for the defendant and plaintiffs as part of the Judicial Inspections, and by Cabrera as part of his 2007 field investigation indicates:

- Soils at the Site contain TPH concentrations in well pits, production pits and surrounding soils exceeding the Ecuadorian standard of 1,000 ppm. Soil samples within the pits had average TPH concentrations of 19,586 ppm (defendant/plaintiff data) and 22,219 ppm (Cabrera data), and maximum TPH concentrations of >900,000 ppm (defendant/plaintiff data) and 414,414 ppm (Cabrera data). Soil samples outside of the pits had average TPH concentrations of 5,028 ppm (defendant/plaintiff data) and 7,500 ppm (Cabrera data), and maximum TPH concentrations of 333,262 ppm (defendant/plaintiff data) and 175,095 ppm (Cabrera data) (Cabrera, 3/2008, pp. 19-20);

- Soils at the Site contain oil production-related metal concentrations exceeding Ecuadorian standards in soil with copper, barium, vanadium and chromium VI most frequently exceeding the standards (Cabrera, 3/2008, pp. 20-21);

  - Copper, with a standard of 63 mg/kg, was found at average and maximum concentrations of 44 ppm and 130 ppm (defendant/plaintiff data), respectively;

  - Barium, with a standard of 750 ppm, was found at average and maximum concentrations of 595 and 1,736 ppm (Cabrera data) and 490 ppm and 10,100 ppm (defendant/plaintiff data), respectively;
  - Vanadium, with a standard of 130 ppm, was found at average and maximum concentrations of 99 and 290 ppm (Cabrera data) and 92 ppm and 290 ppm (defendant/plaintiff data), respectively; and
  - Chromium VI, with a standard of 0.4 ppm, was found at average and maximum concentrations of 0.52 ppm and 87 ppm (defendant/plaintiff data), respectively.
- Groundwater sampling by both Cabrera and experts for the defendant/plaintiffs indicates TPH concentrations exceeding the Ecuadorian standard of 0.325 mg/l (Cabrera, 3/2008, pp. 21);
- Groundwater at the Site contains metals, notably barium and cadmium, in concentrations that exceed Ecuadorian standards in only a small percentage of the samples collected (Cabrera, 3/2008, pp. 22);
- Surface water sampling of streams, rivers, and marshes located near oil field sites by experts for the defendant generally shows no contamination above applicable standards (Cabrera, 3/2008, p. 23); and
- Sediment sampling of streams and marshes or swamps indicates TPH concentrations exceeding the Ecuadorian standard of 1,000 ppm at a limited number of Site locations sampled (Cabrera, 3/2008, Annex E; Sampling data collected during the Judicial Inspections).

3.0 REMEDIATION OF SOIL

This section discusses the analysis and underlying assumptions used by DCA to develop an estimate of the potential costs to remediate contaminated soils associated with the well sites and production stations.

3.1 VALUATION ASSUMPTIONS AND ANALYSIS

Cabrera's approach for estimating the potential costs to remediate contaminated pits and soils at the Site was based on his determination that there were 917 pits at 356 well sites and 22 production stations with 80 percent of the pits at the wells and 100 percent of the pits at the production stations being remediated to target cleanup levels of 1,000 ppm and 100 ppm TPH (Cabrera, 3/2008, pp. 8, 43, Annexes H and N; Cabrera, 11/2008, pp. 16-18). Cabrera calculated the total surface area of the pits and soils requiring remediation and assumed excavation depths of 4 meters and 5 meters to calculate remedial volumes for the 1,000 ppm and 100 ppm TPH cleanup levels, respectively. Finally, he assumed that the contaminated soils would be remediated using bioremediation technology at an estimated cost of US\$489 m^3 (Cabrera, 11/2008, pp. 16-18). Cabrera's approach resulted in estimated costs of \$2.03 billion and \$2.74 billion to remediate pits and soils to the 1,000 ppm and 100 ppm TPH levels, respectively (Cabrera, 11/2008, pp. 16-18).[6]

DCA's approach for estimating potential costs to remediate contaminated pits and soils at the Site was based on: (1) a conceptual remedial framework for determining the need for and extent of remediating the contaminated pits and associated soils, and (2) a set of assumptions for applying that framework to derive a potential low cost and a potential high cost estimate.

<u>Conceptual Remedial Framework</u>. Based on DCA's understanding of the operational, investigative, and remedial history of the Site, DCA believes that not all of the contaminated pits and soils at the Site would necessarily require the same degree of remediation.

As part of their 1993 environmental assessment of the Oriente oil fields on behalf of Texpet and Petroecuador, HBT Agra developed a scoring system to rate potential environmental impacts from the environmental risks they had identified. HBT's scoring system consisted of the following three tiers (HBT Agra, 1993. p. 6-24):

- **Low** – Environmental damage that can be naturally corrected or cleaned up on the scale of hours to days. Spills, regardless of size, are confined to the [well] site. No oil containing pit is present;

- **Medium** – Environmental damage that even after mitigative action will take days or weeks to regain pre-event conditions. Spills, regardless of size, have migrated off-site. Pit containing oil is present. Contaminant appears confined within the pit; and

- **High** – Environmental damage that may require extensive mitigative action or may be of long-term duration before recovery. Pit containing oil is present. Contaminants appear to have migrated out of the pit.

---

[6] Cabrera's initial estimated cost to remediate the pits and soils to 1,000 ppm TPH was reported as \$1.7 billion in his March, 2008 report. Subsequently, because of errors made by Cabrera and his responses to comments made by the plaintiffs, Cabrera increased his estimate to \$2.03 billion in a revised expert report issued in November 2008.

HBT assessed 163 well sites and determined that the environmental risks were rated as having low impact at 31% (51) of the sites, medium impact at 18% (29) of the sites, and high impact at 41% (66) of the sites. Ten percent of the sites (16) were reported as having no impact (HBT Agra, 1993, p. 6-24).

DCA believes HBT's framework is a reasonable and appropriate method to characterize environmental impacts and the subsequent need for and level of remediation for well pit soils. Accordingly, for the purpose of this valuation, DCA utilized the basic framework of HBT's scoring system but modified it with respect to the degree of remedial action that might be required for each tier of the ranking or scoring system. One modification was that since little documentation was provided by HBT Agra to demonstrate the reported no-impact sites, DCA grouped those sites into the low impact category. Accordingly, for the purposes of estimating costs, three categories were created using the HBT Agra percentages: low impact sites and wells (which include the report no-impact sites) (41%); medium impact sites and wells (18%); and high impact sites and wells (41%). This modified framework is shown in **Figure 5**. Because of the operational history and the nature and extent of contamination documented at the production stations, DCA assumed that 100% (22) of the production stations will require remediation and therefore grouped all 22 production stations into the high TPH-impact category.

Assumptions Regarding the Number of Well Sites and Pits. DCA's review of the available technical and expert reports indicated numerous discrepancies in the number of well sites and pits, production stations and pits, and ambiguities in their status (i.e., open/closed/covered, badly remediated/well remediated, dry pit/water pit/floating crude oil pit, pits with seepage/no seepage, etc.). However, it is DCA's understanding from counsel that the inventory of well sites/pits, and production stations/pits that was conducted by Cabrera represents the most recent information available. Accordingly, DCA based its valuation of environmental damages on the number of well sites/pits and production stations/pits reported in Cabrera's inventory (Cabrera, 3/2008, Annex N) to support the estimation of a potential low cost and a potential high cost range (See **Appendix A, Table A-1**; Details on how the other Table A-1 assumptions for a low cost/high cost range were derived are presented in **Tables A-2** and **Table A-3**).

Assumptions Regarding Remedial Volumes. DCA reviewed the assumptions and underlying data (i.e., sampling data from the Judicial Inspections) used by Cabrera in determining the depth of contaminated soils and subsequently the volume of contaminated soils requiring remediation to achieve TPH cleanup levels of 1,000 ppm and 100 ppm. (Cabrera, 3/2008, p. 43-44, Annex N; Cabrera, 11/2008, pp. 17).

The Judicial Inspection soil sampling data were used by DCA to create a plot of TPH concentrations versus depth beneath pit surface (see **Figure 6**). This plot is similar to the data plot presented by Cabrera (Cabrera, 3/20808, Annex N, p. 3). The two plots are not identical, which may be the result of DCA only using data that were linked to specific pits in the database provided to DCA to ensure that subsurface samples from outside the pits were not inadvertently used in the plot. A detailed statistical analysis of these data was not performed due to time constraints but a general assessment of the distribution of the data points suggests that a majority of the TPH data points greater than 100 ppm are above a 5 meter depth, and a majority of TPH data points greater than 1,000 ppm are above a 3 meter depth. A more rigorous review of the data (e.g., TPH depth profiles at the same sampling locations, concentrations at the deepest sample at each location (i.e., did the sampler get to the bottom of the contamination), the number and type of pits sampled), and the sampling methods and procedures (e.g., could contamination been inadvertently carried down from shallow zones to deeper sampling locations as a result of the sampling methods) should be completed to refined the required remediation depths. However, for the purposes of this valuation, excavation depths of 3 and 5 meters (below ground surface) for the pits were assumed for the 1,000 ppm and 100 ppm TPH clean-up levels.

In calculating the volume of soil to be remediated, DCA assumed that there is 1 meter of freeboard currently present in all pits, i.e., the previously existing liquids in the pits have either been removed, have evaporated/volatilized, or seeped to lower depths leaving only residual oil, drilling cuttings/muds, and debris. Where pits have been previously covered, it was assumed that this 1 meter of freeboard was filled with soil that meets the clean-up standards and does not require remediation (only removal and replacement to access the deeper soils). Therefore, the net soil depths used to calculate soil volumes at each pit were 2 and 4 meters for the 1,000 ppm and 100 ppm TPH cleanup levels, respectively.

DCA also recognizes that a certain amount of soil surrounding each pit is likely to have been impacted by TPH during the many years of operation. This would have been the result of spillage, overtopping, etc., and likely impacted the soils immediately surrounding the pits (which were unlined) and the berms that may have been present on the surface to further contain the liquids. For the purpose of this valuation, DCA assumed that soils within 1 meter of the perimeter of the pit, and to a depth of 2 meters (to the bottom of the original pit), would require excavation and remediation.

Lastly, based on experience and literature, DCA assumed that the soils surrounding each well head are likely contaminated and require remediation. This contamination would have been the result of decades of spillage, leaks, etc. during well drilling, operations, and rehabilitation over the several decades of operation. The assumed volume of soil around each well head that will require remediation was calculated based on an assumed depth of 1 meter over a radius of 15 meters around each well head.

Assumptions Regarding Treatment of Contaminated Soils. Cabrera's remedial cost estimates assumed contaminated soils would be remediated to either the 1,000 or 100 ppm TPH cleanup levels using bioremediation technology (Cabrera also evaluated other remedial technologies). Cabrera's unit cost of US\$489/m^3 was based on an average of costs for bioremediation systems used at several U.S. Superfund sites (Cabrera, 3/2008, p. 43, Annex N).

DCA conducted an independent preliminary screening of remedial technologies to determine what would be the most appropriate remedial technologies to achieve the 1,000 ppm and 100 ppm TPH cleanup levels. The results of the technology screening are presented in **Table A-4**. Based on this screening, DCA selected composting and thermal desorption as the treatment technologies of choice for both the low cost and high cost estimates to clean up the soils to the 1,000 ppm TPH level and the 100 ppm TPH level, respectively. DCA assumed unit costs of US\$118/m^3 and US\$304/m^3 for composting and thermal desorption, respectively. The unit costs for treatment technologies reflect a discount to account for overall economies of scale, clustering of pits at individual well sites and production stations, and lower labor and energy costs in Ecuador. Details on how these unit costs were derived are presented in **Tables A-5** and **A-6**.

As described above, DCA accounted for the expected variability of levels of contamination from pit to pit by grouping them into low, medium and high level contamination sites and wells based on HBT Agra's assessment of the level of contamination of well sites they assessed. DCA assumed that composting technology would be used to remediate contaminated soils at low level impact sites where the TPH concentrations were low enough to allow for reduction of the soil TPH concentrations in a reasonable timeframe. For the medium level and high level sites, where TPH soil concentrations were higher, DCA believes thermal desorption would be a more time-efficient and reliable technology to reduce concentrations to the target cleanup levels. While it is possible that composting could achieved the target cleanup levels even for the medium and high impact sites, the extended timeframe for this to occur would likely not make this a time-efficient or cost-effective remedial technology. Thermal desorption is a proven and effective technology for soils and sludges with high levels of oil contamination. This technology has the following advantages over other potentially applicable technologies such as solidification, surfactant washing, *in-situ* steam injection: it will achieve the clean-up goals in a relatively short time frame; it removes the contaminants from the media and therefore results in a permanent clean-up; and it does not require on-going monitoring to document performance.

DCA also assumed that the implementation of both composting and thermal desorption would be conducted at multiple centralized treatment centers instead of having mobile or trailer-based treatment equipment transported to every well site and production station. Contaminated soil from the well sites and production stations would be excavated and transported by truck from each site to the centralized treatment center. In this way, remediation of the individual well site/production station would be accomplished more efficiently (taking advantage of the economy of scale) and would facilitate the return of these sites to beneficial use more quickly.

3.2 RESULTS OF COST ESTIMATION

The result of DCA's valuation for the remediation of contaminated soil at the Site is presented in **Tables A-7 and A-8**. Based on the assumptions and analysis discussed above, DCA estimated potential costs to remediate contaminated soils at the well sites and production stations could range from a low of $487 million for a 1,000 ppm TPH cleanup to a high of $949 million for a 100 ppm TPH cleanup. The cost estimates are adjusted to 2010 dollars, but are undiscounted (i.e., no net present value analysis was done for the time value of money).

4.0 REMEDIATION OF GROUNDWATER

This section discusses the analysis and underlying assumptions used by DCA to develop an estimate of the potential costs to remediate contaminated groundwater associated with the well sites and production stations.

4.1 VALUATION ASSUMPTIONS AND ANALYSIS

Cabrera's approach for estimating the potential costs to remediate contaminated groundwater at the Site appears to be based on the assumption that contaminated groundwater beneath 356 well sites and 22 production stations would need to be remediated to achieve the Ecuador standard of 0.325 mg/l for TPH in groundwater. Cabrera assumed the average cost to remediate groundwater at each site would be $7.8 million. This was based on his review of four U.S. groundwater remediation projects which employ active pumping and treatment of groundwater contaminated with BTEX, VOCs and oil. The range of estimated costs for these systems was $3.5 million to $13.5 million. The remedial timeframe for all four projects was estimated to be 20 years (Cabrera, 11/2008, pp. 12-14). Using this information, Cabrera estimated the total potential costs of groundwater remediation to be $3.24 billion (Cabrera, 11/2008; Table: Overview of Environmental Remediation Costs).[7]

DCA's approach to estimating the potential costs for groundwater remediation at the Site was similar to the approach used for soil remediation and is discussed in the following paragraphs.

Conceptual Remedial Framework. DCA's cost estimate to remediate contaminated groundwater is based on the assumption that free petroleum product, or light non-aqueous phase liquid (LNAPL) is present in the subsurface trapped within silt/sand stringers, clay fractures, and root channels. Free product is also likely to be present in anthropogenic features such as subsurface drains, sumps and trenches. This assumption is consistent with the spill history at the Site as well as what is known about the operations at both the well sites and the production stations. Observations made by HBT Agra during their 1992 field audit confirmed the presence of LNAPL in the subsurface (HBT Agra, 1993, pp. 8-7, 8-8). The LNAPL serves as a continuous source of TPH contamination to the groundwater. Therefore the removal of the LNAPL would remove the hydrocarbon source material thereby reducing TPH in the dissolved phase, which limited groundwater sampling data indicates is currently above the Ecuadorian standard of 0.325 mg/l in many instances. This conceptual model also assumes that dissolved phase groundwater contamination is not widespread or migrating significantly such that off-site risks are present. Although this can be argued by the fact that the Site soils have generally been characterized as having a high clay content which would limit the vertical and horizontal migration of contaminants from their source, additional groundwater sampling data would be needed to delineate the extent of any off-site groundwater migration.

Assumptions Regarding Production Stations and Well Sites Requiring Remediation. For the purpose of this valuation, DCA assumed that all 22 of the production stations would require some form of groundwater remediation. However, since DCA believes that not all production stations would require groundwater remediation to the same extent, DCA also assumed that the extent of any groundwater remediation at the production stations would be proportional to the volume of liquids (i.e., oil and

---

[7] It is not clear how Cabrera derived this total cost. Assuming $7.8 million per site x (356 well sites + 22 production sites) results in a total potential cost of $2.95 billion.

production water) that was processed at each production station. Therefore, DCA categorized the production sites based on volume throughput and the expected magnitude (level) of resulting groundwater contamination. The results of this categorization are shown in **Figure 7**. For example, this analysis assumes that Level 4 production stations, with a total throughput ranging from 187,048,695 to 249,106,260 barrels, would have four times the magnitude of groundwater contamination as would a Level 1 production station, with a total throughput ranging from 1,592,128 to 16,555,798 barrels.

DCA also considered the need for remediating the groundwater beneath well sites. For the purpose of this valuation, DCA assumed that 210 well sites out of 356 well sites (59%) would require groundwater remediation. This represents 64 sites in the Moderate Impact Level (18%) and 146 sites in the High Impact Level (See Figure 5 and Section 3.1.1).

Assumptions Regarding Treatment of Contaminated Groundwater. For the purpose of this valuation, DCA considered two options for groundwater remediation at production stations and well sites. Option 1, which DCA assumed as a viable low cost option, is the containment and recovery of the LNAPL using a horizontal recovery trench with a vertical sump (**Figure 8**). The sump would include a low-flow (less than 5 gallons per minute (gpm)) groundwater pump and a floating oil skimmer pump to recover the LNAPL. For the Level 1 production stations/well sites, DCA assumed that the trench dimensions would be approximately 100 meters long by 2 meters wide by 5 meters deep. Trench dimensions for a Level 4 production station/well site would be four times those of a Level 1 system. The operation and maintenance (O&M) periods for the Option 1 system was assumed to be 10, 15, 20 and 30 years for Levels 1, 2, 3, and 4, respectively.

DCA recognizes that this containment and recovery option alone may not result in the remedial goal of 0.325 mg/l being met. However, long-term natural attenuation processes (e.g., biodegradation, sorption, dispersion and dilution, chemical reactions, and volatilization) of residual dissolved groundwater contamination following the active remediation period may achieve the remedial goal. Monitored natural attenuation (MNA) (in conjunction with source control) is recognized by U.S. EPA as a viable remedial measure for petroleum-contaminated groundwater and has been selected as a groundwater remedy at an increasing number of Superfund sites (U.S. EPA, 5/1999, U.S. EPA, 1/2002). Accordingly, DCA assumed that MNA would begin following the end of the active remediation and would continue for 20 years.

Option 2, which DCA assumed as a viable high cost option, consists of the LNAPL containment and recovery system described in Option 1, plus an active groundwater pumping and treatment system. For a Level 1 site, this system would consist of 5 groundwater extraction wells yielding an assumed 5 gpm per well. A 25 gpm treatment train consisting of multi-media pre-filter and carbon adsorption units would also be installed. A remedial system installed for a Level 4 site would be four times larger. The O&M periods for the Option 2 system were assumed to be 15, 20, 30 and 50 years for Levels 1, 2, 3 and 4, respectively. The O&M periods were increased over the O&M periods for Option 1 based on longer anticipated time frames to achieve a remedial goal of reaching the 0.325 mg/l standard and the operation period of the product recovery and containment system was also increased to the same duration since they were assumed to operate in tandem. No MNA was assumed for Option 2 since the groundwater pumping and treatment system would be expected to achieve the 0.325 mg/l standard.

4.2 RESULTS OF COST ESTIMATION

The result of DCA's valuation for the remediation of contaminated groundwater at the Site is presented in **Tables B-1 through B-10** in Appendix B. Based on the assumptions and analysis discussed above, DCA estimated potential costs to remediate contaminated groundwater at the production sites and well sites to the Ecuadorian standard of 0.325 mg/l for TPH could range from a low of $396 million to a high of $911 million. The cost estimates are undiscounted (i.e., no net present value analysis was done for the time value of money) and adjusted to 2010 dollars.