

## SECTION B: BASELINE ASSESSMENT

### CHAPTER B5: TOPOGRAPHY, GEOLOGY & TOPSOILS

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## 5 TOPOGRAPHY, GEOLOGY & SOILS

### 5.1 INTRODUCTION

This Chapter of the ESIA describes the topography, landscape, geological setting and key geological features within the Project area. It also describes the main soil types which occur within the Project area, and discusses their vulnerability to impacts such as wind and water erosion as well as herd animals and traffic. This information is provided for the Oyu Tolgoi Mine Licence Area, Gunii Hooloi valley which includes the water supply network and the airport, and the infrastructure corridor to the Chinese border, which crosses the Galbyn Gobi and Small Gobi Strictly Protected Area (SGSPA). This Chapter also includes a description of the Project's seismic setting and the historical record of seismic activity in the area.

The Oyu Tolgoi Project area lies within the southern desert zone of Mongolia and is characterised by areas of gently rolling plains with an average elevation of over 1,000 m above sea level (m a.s.l.) which contain small (15 to 50 m) Gobian hills and higher mountains (e.g. Khanbogd Mountain at 1,350 m a.s.l.). Oyu Tolgoi is the name of the Gobian hill in the southern part of the Mine Licence Area. Oyu Tolgoi (1,172 m a.s.l.) means 'turquoise hill' and Bronze Age inhabitants in the area excavated semi-precious turquoise stones from the hill for jewellery and bronze production (see *Section B12.7.2*).

The geology of the Oyu Tolgoi Area of Influence comprises a Palaeozoic (circa 300-370 million years old) basement, with adjacent elongate deep Mesozoic (circa 75-145 million years old) sedimentary basins. The Palaeozoic basement is made up of a structurally-deformed sequence of igneous and sedimentary rocks, which have been heavily mineralised in parts, while the sedimentary basins comprise thick sequences of Mesozoic clastic sediments. These Mesozoic clastic sediments form the main aquifers which will be used to provide the operational water supply for the Project, while local weather Palaeozoic bedrock aquifer on the Mine Licence Area is in use for the construction phase water supply.

The soils of Mongolia typically change from north to south following latitudinal and altitude zones. From north to south, these zones comprise:

- Mountain taiga zone with cryomorpho-taiga and derno taiga soils;
- Mountain forest steppe-steppe zone with chernozem, dark kastanozem, forest dark coloured and derno taiga zones;
- Dry steppe zone with kastanozem soils;
- Brown semi desert soils;
- Grey-brown desert soils; and
- Extra arid desert "borzon" soils.

Oyu Tolgoi is located within the brown semi-desert and grey-brown desert soils region.

### 5.2 SOURCES OF DATA

#### 5.2.1 Topography

A description of topographic conditions in the Oyu Tolgoi Project area is given in the Oyu Tolgoi Project Environmental Impact Assessment, Volume 3 Mining and Processing, Eco-Trade LLC 2006 (*Chapter 1*)<sup>1</sup>. Topographic data on the road and power corridor is provided in Volume I: Report of Oyu Tolgoi to Gashuun Sukhait Road and Infrastructure Corridor, Environmental Protection Plan and Environmental Monitoring Plan, Eco-Trade LLC, 2004<sup>2</sup>; data on the potential borefield areas (Gunii Hooloi and Galbyn Gobi) is provided in the report: Oyu Tolgoi Project Groundwater Resource Use from the Gunii Hooloi and

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<sup>1</sup> Eco Trade LLC (2006), Oyu Tolgoi Project Detailed Environmental Impact Assessment, Volume 3 – Report for the Oyu Tolgoi Project Mining and Processing, May 2006

<sup>2</sup> Eco Trade LLC (2004), Oyu Tolgoi Project Environmental Impact Assessment, Volume 1 – Report of Oyu Tolgoi to Gashuun Sukhait Road and Infrastructure Corridor, April 2004.

Galbyn Gobi Regional Aquifers, Eco-Trade LLC, 2005<sup>3</sup>. These reports provide detailed information on topographic conditions across the Project area. Further data on the topography of the Gunii Hooloi and Infrastructure is included in the later work by Aquaterra (2008)<sup>4</sup> and the Supplementary EIA for the infrastructure corridor prepared by Eco-Trade in 2006<sup>5</sup>.

## 5.2.2 Geology

The baseline geology data for this chapter has been obtained from a wealth of reports covering various aspects of the area's geology. These include the initial DEIAs undertaken by Eco-Trade<sup>6,7</sup>, which covered the superficial geology, the main aquifers and the host rock for the ore. The aquifer modelling reports prepared by Aquaterra<sup>4</sup> provide greater detail and interpretation of the geology of the Gunii Hooloi aquifer, and the Technical Reports produced by Ivanhoe such as the Integrated Development Plan IDP10 provide detail on the geology and structure of the ore bodies. The chapter also draws upon additional data gathered in the design phase such as seismic risks for which references are provided as appropriate.

## 5.2.3 Soils

Baseline data for soils has been obtained from the Environmental Impact Assessment and Groundwater Resource Use reports by Eco Trade LLC<sup>1,2,3</sup> along with the Environmental and Social Impact Assessment UHG Phase 11<sup>8</sup>, the Oyu Tolgoi Project Social, Economic Subset<sup>9</sup> and the Integrated Development Plan (Section 8) prepared by Ivanhoe. Additional detail on the soil in the Tailings Storage Facility (TSF) has been provided by the KCB 2010 Feasibility Study<sup>10</sup>.

No additional sampling has been undertaken as part of this ESIA, however the baseline data has been reviewed against the observations from ESIA field visits and the current views of Oyu Tolgoi's Environment Department based on the lessons learnt from the soil rehabilitations trials<sup>11</sup> underway within the Mine Licence Area. The soil and its preservation are intimately linked to the behaviour and type of fauna and flora in the area and reference should be made to the appropriate Chapters within the Baseline Section of this ESIA (see *Chapter B7A: Biodiversity Baseline* and *B7B: Ecosystem Services*).

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<sup>3</sup> Eco Trade LLC (2005), Oyu Tolgoi Project Groundwater Resource Use from the Gunii Hooloi and Galbyn Gobi Regional Aquifers, 2005

<sup>4</sup> Aquaterra (2008), Gunii Hooloi Aquifer, Groundwater Investigation and Resource Assessment - 2007 (Revised Water Demand), March 2008

<sup>5</sup> Eco-Trade 2006: Supplementary Environmental Impact Assessment Report for Oyu Tolgoi to Gashuun Sukhait Infrastructure Corridor

<sup>6</sup> Eco Trade LLC (2006), Oyu Tolgoi Project Detailed Environmental Impact Assessment, Volume 3 – Report for the Oyu Tolgoi Project Mining and Processing, May 2006

<sup>7</sup> Eco Trade LLC (2004), Oyu Tolgoi Project Environmental Impact Assessment, Volume 1 – Report of Oyu Tolgoi to Gashuun Sukhait Road and Infrastructure Corridor, April 2004

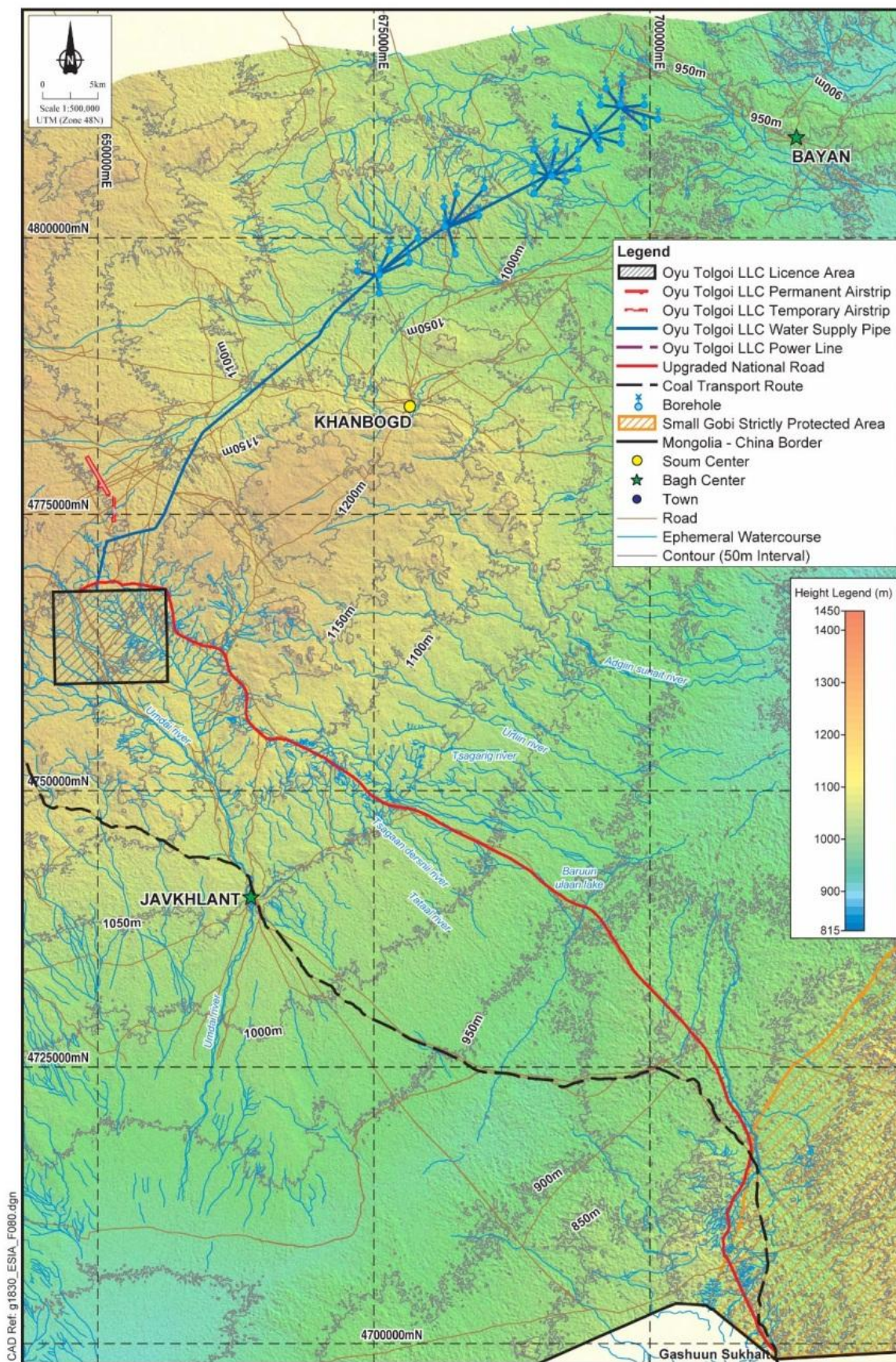
<sup>8</sup> Environmental and Social Impact Assessment: UHG Phase II, Energy Resources LLC, ERM and Sustainability, 2009

<sup>9</sup> Oyu Tolgoi Project Social, Economic and Environmental Subset, Centre for Policy Research, Population Training and Research Centre, 2009

<sup>10</sup> Klohn Crippenut Berger 2011, Tailings Storage Facility 2010 Feasibility Study Update, 5<sup>th</sup> August 2011

<sup>11</sup> Oyu Tolgoi Report on the Implementation of Environmental Plan 2009.

Figure 5.1: Topography of the Area of Influence



## 5.3 TOPOGRAPHY

### 5.3.1 Overall Topography in Area of Influence

The topography in the Area of Influence is illustrated in *Figure 5.1*. The main topographic elements are the broad Gunii Hooloi north easterly trending valley within which is the sedimentary basin that the Project's operational water supply will be sourced, the elevated dome of the Khanbogd Massif to the east of the Mine Licence Area, and the general fall of the land south towards the Galbyn Gobi plains which the infrastructure corridor crosses. The hills of the SGSPA in the south are slightly elevated compared to the adjacent Galbyn Gobi and form the southern boundary to the Galbyn Gobi plains.

### 5.3.2 Oyu Tolgoi Mine Licence Area and its Environs

The Mine Licence Area and immediate environs comprises a semi-plain at an elevation of between 1,120 and 1,220 m a.s.l with small hills between 15 and 50 m above the surrounding semi-plain with elevations of between 1170 and 1180 m a.s.l and surrounding mountains. These mountains are of high scenic value for the area as these are relatively high mountains for the Gobi region including: Khanbogd (1,350 m above sea level (m a.s.l.) in the Khanbogd Massif which is a large elevated granitic area (see *Figure 5.2* and *Figure 5.7*), Bumbat Zadgain Khyar (1,233 m a.s.l.), Javkhlant Uul (1,295 m a.s.l.) and Dalain Duulga Uul (1,240 m a.s.l). Some of these upland areas also have a cultural heritage value and are the site of cultural rituals, termed 'ovoos'; these are described further in *Chapter B12: Cultural Heritage*.

**Figure 5.2: Khanbogd Mountain and surrounding Khanbogd Massif viewed from Gunii Hooloi Basin (after summer rains)**

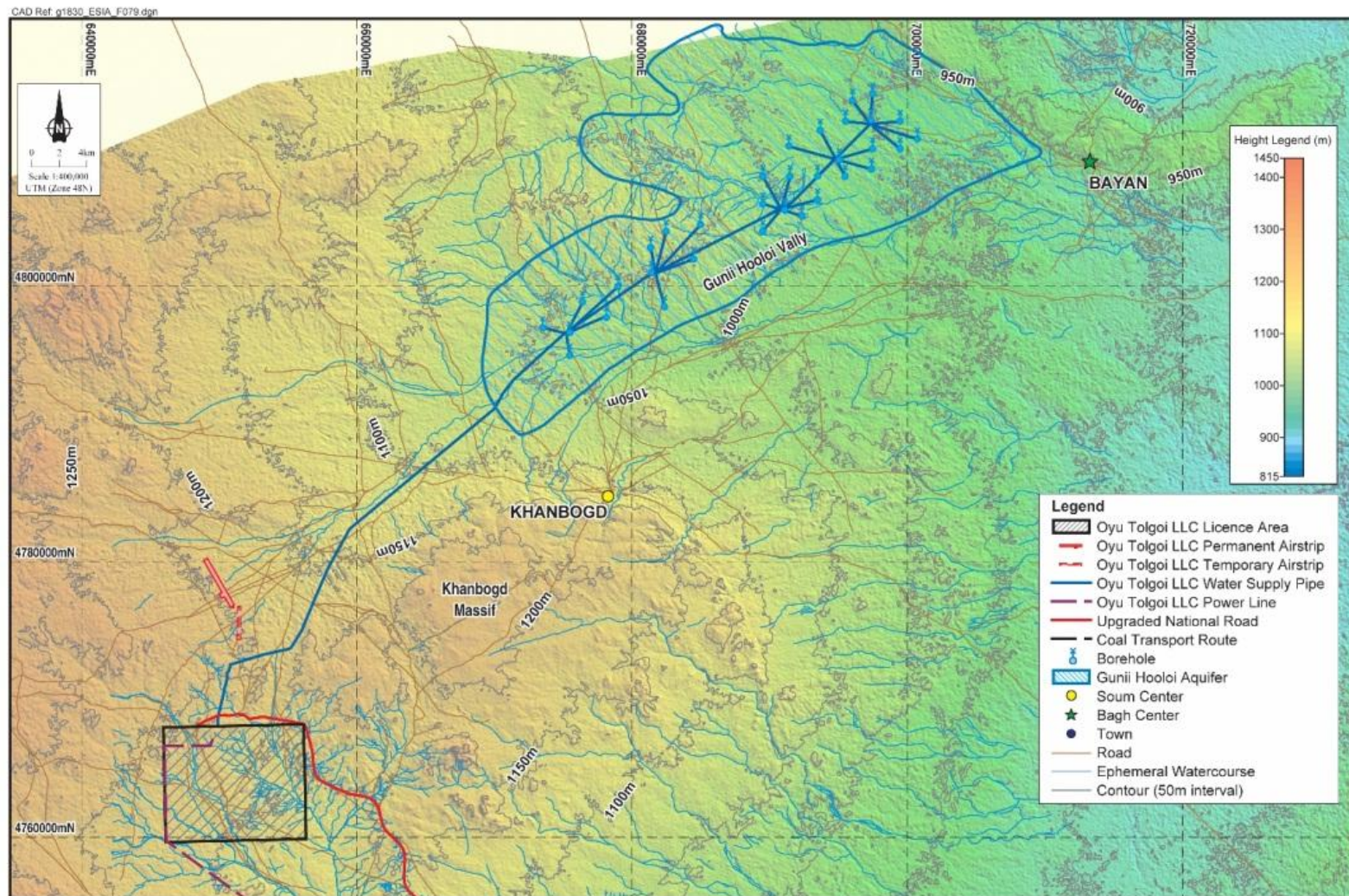


Along the western side of the Mine Licence Area lies the ephemeral Undai watercourse. The Undai is generally dry with occasional short periods of surface flows after summer rainfall events, historically these have occurred 4-6 times per year. The Undai is the main watercourse within the regional watershed in which the Project is located and flow events in the Undai at Oyu Tolgoi may reflect rainfall many kilometres away higher in the catchment.

### 5.3.3 Gunii Hooloi Valley

The water supply for the Oyu Tolgoi Project will be taken from the Cretaceous aquifers within the Gunii Hooloi sedimentary basin, beneath the central eastern part of the Gunii Hooloi valley, 35-75 km north of the Oyu Tolgoi site. The Gunii Hooloi valley is a wide, gently undulating plain extending east from the Temporary Domestic Airport, with the Khanbogd Massif to the south and low hills defining the other sides of the overall valley. The Khanbogd *soum* centre is located on the southern side of this valley. Overall the valley slopes towards the east falling from approximately 1,150 m to 900 m with the main ephemeral streams along the periphery of the valley and a broad easterly trending dome crossed by a few minor ephemeral streams running through the central area of the valley as illustrated in *Figure 5.3*.

**Figure 5.3: Regional Topography from the Mine Licence Area into the Gunii Hooloi Valley**



Note: Higher mapping density in Gunii Hooloi area and around Mine Licence Area

A small depression is present in the eastern part of the Gunii Hooloi valley which collects some of flows from the main ephemeral watercourse, and supports some vegetation, overall the surface waters from the Gunii Hooloi valley flow southeast into the Galbyn Gobi valley. No topography with religious significance has been identified within the Gunii Hooloi valley although there are a number of graves in the area (see *Chapter B12: Cultural Heritage*).

### 5.3.4 Infrastructure Corridor

The road and power corridor runs from the Oyu Tolgoi Mine Licence Area south to the Galbyn Gobi desert area and then into the low hills making up the eastern part of the SGSPA (see *Figure 5.1*).

The Galbyn Gobi comprises semi-flat terrain with the lowest altitude in Mongolia. The general altitude of the infrastructure corridor area ranges from between 937 m (Bulan Sukhai) to 1,202 m a.s.l. (Zagaliin Khuren Ovoo) near the Mine Licence Area. Topography falls south-westwards towards the Chinese border with the lowest point around 878.5 m a.s.l. in the central part of the Galbyn Gobi. This low area in the Galbyn Gobi area comprises playa areas such as the Baruun ulaan lake located to the east of the Oyu Tolgoi to Gashuun Sukhait road (see *Figure 5.5*) and the terminus of several ephemeral water courses including, further to the southwest, the terminus of the Undai.

## 5.4 LANDSCAPE

### 5.4.1 Oyu Tolgoi Mine Licence Area and Gunii Hooloi Valley

The landscape around the Mine Licence Area can be separated into four distinct landscape types:

#### **Gobian small hills**

This type of landscape is distributed in the Turquoise Hill (South Oyu), Vandan Hill (Central Oyu), Bor Ovoo and the small hills to the south east, and to the south of Dugat Khets Hills (presently known as Hugo North). These hills rise 15-50 m above the surrounding gently rolling plain and are capped with rocky outcrops. The little vegetation that occurs on the exposed hills are dominantly small and sparse desert shrubs.

**Figure 5.4: Typical Desert Plain Landscape in central Galbyn Gobi Valley**



#### **Wide valley terrace and desert plain**

This landscape is characterised by an extensive valley between the Bor Ovoo and Vandan Hill, and also forms the broad desert plain (see *Figure 5.4*) of western Gunii Hooloi valley which has the Temporary Domestic Airport at its western end and extends over the area of the Cretaceous Aquifer in the east from which the Project's operational water supply will be drawn. The ground surface of this landscape is generally flat with low long amplitude hills and ephemeral valleys.

The surface cover is gravelly with small and sparse desert plants and shrubs. These areas, outside of the Mine Licence Area, are used as pasture for camels and goats, with vegetation in the autumn and spring time being more developed in the broad depressions and minor ephemeral streams, where soil moisture is higher.

### ***Ephemeral Watercourses***

This landscape predominantly follows the Undai and its tributaries, which transect the Project area and flow south, and other drainage features to the east in the Gunii Hooloi valley and south in the Galbyn Gobi. These ephemeral watercourses are characterised by meandering channels within a narrow linear flood plain, the boundaries of which being defined by low hills or rocky outcrops. These ephemeral river bed landscapes such as the Undai, are associated with alluvial sediments which retain groundwater and can support substantial vegetation along the river banks. The occasional elm trees that grow along the ephemeral watercourses are the only substantial trees in the area and therefore form distinctive landscape features (see *Figure 5.5*).

### ***Gobian meadow with springs and temporary surface water***

The south of the Project area and the eastern part of the Gunii Hooloi contains flat wide depressions or playas which fill with surface run-off after significant rainfall events. This seasonal and intermittent surface water is subsequently lost through seepage and evaporation. Elsewhere along the main ephemeral watercourses are a number of springs such as the Bor Ovoo and Maanit springs, which are located along the Undai, and springs in and around the edge of the Khanbogd Massif (see *Chapter B6*). Both the permanent springs and temporary wetlands are significant landscape features supporting seasonal and permanent vegetation which can be visible for some distance.

## **5.4.2 Infrastructure Corridor**

The Oyu Tolgoi to Gashuun Sukhait infrastructure corridor is typical of Central Asian semi-desert and desert steppe habitat types. The open flat desert plains and low hills are sparsely covered with small (<0.5 m) drought tolerant shrub species. The ephemeral river beds, creek beds and playas support some larger species of trees and tall shrubs associated with shallow underground water (see *Figure 5.5*). The key landscape types along the infrastructure corridor can be summarized as follows:

### ***Javkhlant semi-desert plain***

The section of road corridor from Oyu Tolgoi to Javkhlant *Bagh* centre slopes gently southwards and comprises open rolling hills with some ephemeral water courses with a typical semi-desert steppe vegetation type. The vegetation type comprises drought- and salt-tolerant species, less than 10 cm in height and sparsely distributed.

### ***Galbyn Gobi desert plain***

The Galbyn Gobi desert plains occur south of Javkhlant *Bagh* centre; the broad area of the plain is constrained by the hills of the SGSPA to the south and the Khanbogd Massif to the north. Small playa areas are present, although overall the area slopes gently towards a broad depression to the southwest. These arid plains have sparse low (< 20 cm) shrubs with typical plant densities between 20 to 25 plants per 10 m<sup>2</sup>.

### ***Galbyn Gobi low hills***

The low hills south east of Oyu Tolgoi and near the Chinese border in the SGSPA, have a distinctive topography with hard rock creating low steep sided hills (see *Figure 5.5*). Overall the area has a sparse plant coverage dominated by low arid shrubs less than 20 cm in height.

### ***Ephemeral Watercourses***

The landscape of these is the same as described for the Mine Licence Area and Gunii Hooloi valley. Along the infrastructure corridor the vegetation density increases near these southerly flowing ephemeral watercourses. Surface vegetation cover is an average of 50% and the shrub species are generally between 50 and 80 cm in height. Elm trees (*Ulmus pumila*) which grow to 4 m in height occur along the stream beds in the northern sector of the infrastructure corridor (see *Figure 5.5*) between Oyu Tolgoi and Javkhlant Bag centre and in the Galbyn Gobi low hills towards the Chinese border.

**Figure 5.5: Landscape Features along Infrastructure Corridor showing an ephemeral water course within the plains, with Galbyn low hills in the background**



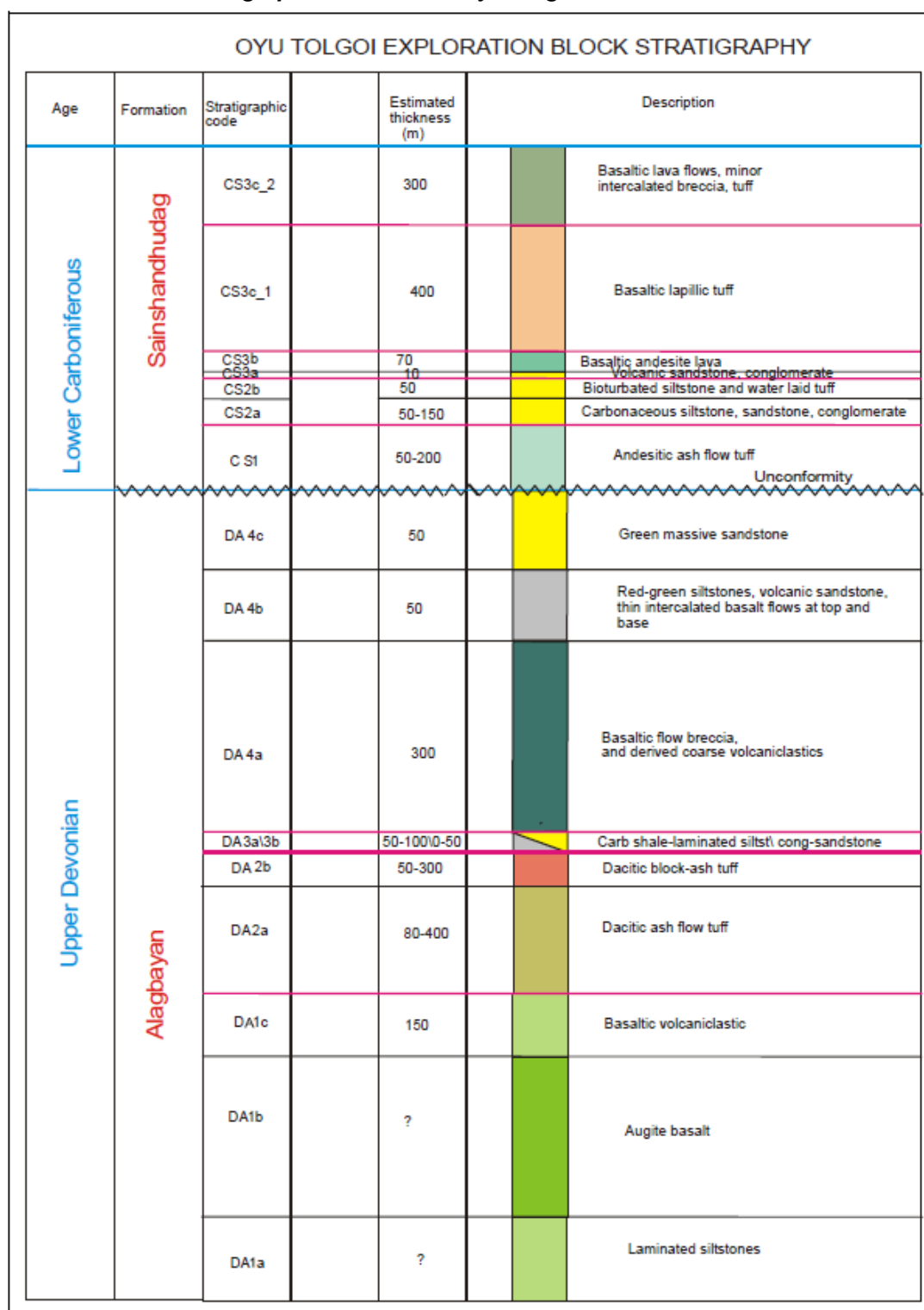
**Galbyn Gobi playa**

A large playa (dry lake bed) locally named Bulan Sukhait is present in the infrastructure corridor. This area is one of the lowest areas of the Galbyn Gobi and a significant number of the ephemeral watercourses flowing in the Galbyn Gobi terminate within this low-lying saline basin. The availability of shallow groundwater within the playa results in the establishment of sufficient vegetation to stabilize soils and allows the accumulation of organic material resulting in larger plant species and higher densities of large plants than are found in surrounding areas. A smaller playa associated with an ephemeral water course is illustrated in the foreground of *Figure 5.5* and in *Figure 5.19*.

**5.5 OYU TOLGOI GEOLOGY**

The geology of Oyu Tolgoi comprises a thin covering of gently-dipping to horizontal Cretaceous to Quaternary clay, sands and gravels across the majority of the Mine Licence Area. These sediments overly a structurally complex sequence of Palaeozoic rocks which host the mineralisation. These two units (Palaeozoic basement and overlying sediments) are described in further detail in the following sections.

Figure 5.6: Palaeozoic Stratigraphic Column for Oyu Tolgoi Mine Licence Area



Source: IDP05<sup>12</sup> Figure 3-2. Section 3, Page 3

<sup>12</sup> AMEC AUSENCO Joint Venture (2005), Oyu Tolgoi Integrated Development Plan, August 2005

### 5.5.1 Palaeozoic Geology

The Palaeozoic geology of the Oyu Tolgoi Mine Licence is relatively complex due to the interbedded nature of the host rocks combined with phases of structural movement, mineralisation and igneous intrusions. The Project lies within an east-west-trending belt of Devonian-to-Carboniferous volcanic and sedimentary rocks of continental margin and island arc affinities (similar to the present day Andean Arc in South America), constituting what is termed the ‘South Mongolia Volcanic Belt’<sup>13</sup>. Two major stratigraphic Palaeozoic sequences are recognised:

- Tuffs, basaltic rocks, and sedimentary strata, probably associated with island arc activity (Upper Devonian Alagbayan Formation); and
- An overlying succession containing conglomerates, fossiliferous marine siltstones, sandstones, waterlain tuffs, and basaltic to andesitic flows and volcanoclastic rocks (Carboniferous Sainshandhudag Formation).

The two sequences are separated by a regional unconformity that, in the Oyu Tolgoi area, is associated with a time gap of 10 to 15 Million Years (Ma).

The Palaeozoic stratigraphic column for the Oyu Tolgoi area is illustrated in *Figure 5.6*. The upper part of this Palaeozoic sequence is variably weathered and it is this weathered section which is exploited by Oyu Tolgoi for its construction phase water supply.

#### ***Intrusive Rocks/Copper-Gold Deposit***

Intrusive volcanic rocks are widely distributed through the Oyu Tolgoi area and range from large batholithic intrusions to narrow discontinuous dykes and sills. At least seven classes of intrusive rocks can be defined on the basis of compositional and textural characteristics.

***Figure 5.7: Khanbogd Mountain to the south of Gunii Hooloi Valley illustrating Granitic Outcrop***



The copper-gold porphyry mineralisation that the Oyu Tolgoi Project will exploit is related to the oldest recognised intrusive suite (large Devonian quartz monzodiorite intrusions). Many of the older intrusive units found on the Project are strongly to intensely altered.

As well as affecting and influencing the Oyu Tolgoi mineable resources, the intrusive rocks form some of the distinctive topographic features in the area. The dykes are often more resistant to erosion than the

<sup>13</sup> Ivanhoe Mines Integrated Development Plan IDP10

surrounding formation forming linear surface outcrops. In addition, and where they intersect the river beds, they can cause the base-flow in the river bed sediments to rise to the surface and form permanent to semi-permanent springs. The Bor Ovoo spring is one such example.

The igneous intrusions typically form the higher hills such as the large early Permian Khanbogd alkaline granite complex also referred to as the Khanbogd Massif (see *Figure 5.2* and *Figure 5.7*). This distinctive surface feature forms the circular intrusion to the east of the Project, and its margins also form the recharge zone for the springs and shallow aquifers used by the Khanbogd community to its north.

### **Oyu Tolgoi Structural Geology**

The Project area is underlain by a complex network of faults, folds, and shear zones. Most of these structures are poorly exposed on the surface and can only be defined through the integration of detailed exploration data (primarily drill hole data), property-scale geological mapping, and geophysical data.

Oyu Tolgoi has made extensive use of oriented core drilling which has been essential in determining the subsurface morphology and structural history of the Project area. The major structures strongly influence the distribution of mineralisation, both by controlling the original position and form of mineralised bodies, and by modifying them during post-mineralisation deformation events. The significance of the faulting on the position and extent of the ore bodies is illustrated in *Figure 5.8*.

The most significant structure in the Oyu Tolgoi mining license is the Solongo Fault which is an east- to east-northeast-striking, sub-vertical structure that cuts across the Oyu Tolgoi property just south of the Southwest Oyu and South Oyu deposits (see *Figure 5.8*). All of the significant mineralisation first discovered on the Oyu Tolgoi property is on the northern block of this fault. There is a minimum throw of 1,600 m on this fault resulting in the mineralised basalt of the South Oyu deposit being juxtaposed with much younger sediments of the Upper Alagbayan Formation.

### **Mineralisation**

Within the Mine Licence Area, four separate mineralisation zones have been identified with porphyry-style gold, copper and molybdenum. These zones are termed the Central, Far North, South and Southwest Oyu zones and are all contained within an 8 km<sup>2</sup> area, the main zones are shown on *Figure 5.8*.

The main host rock types in the area are:

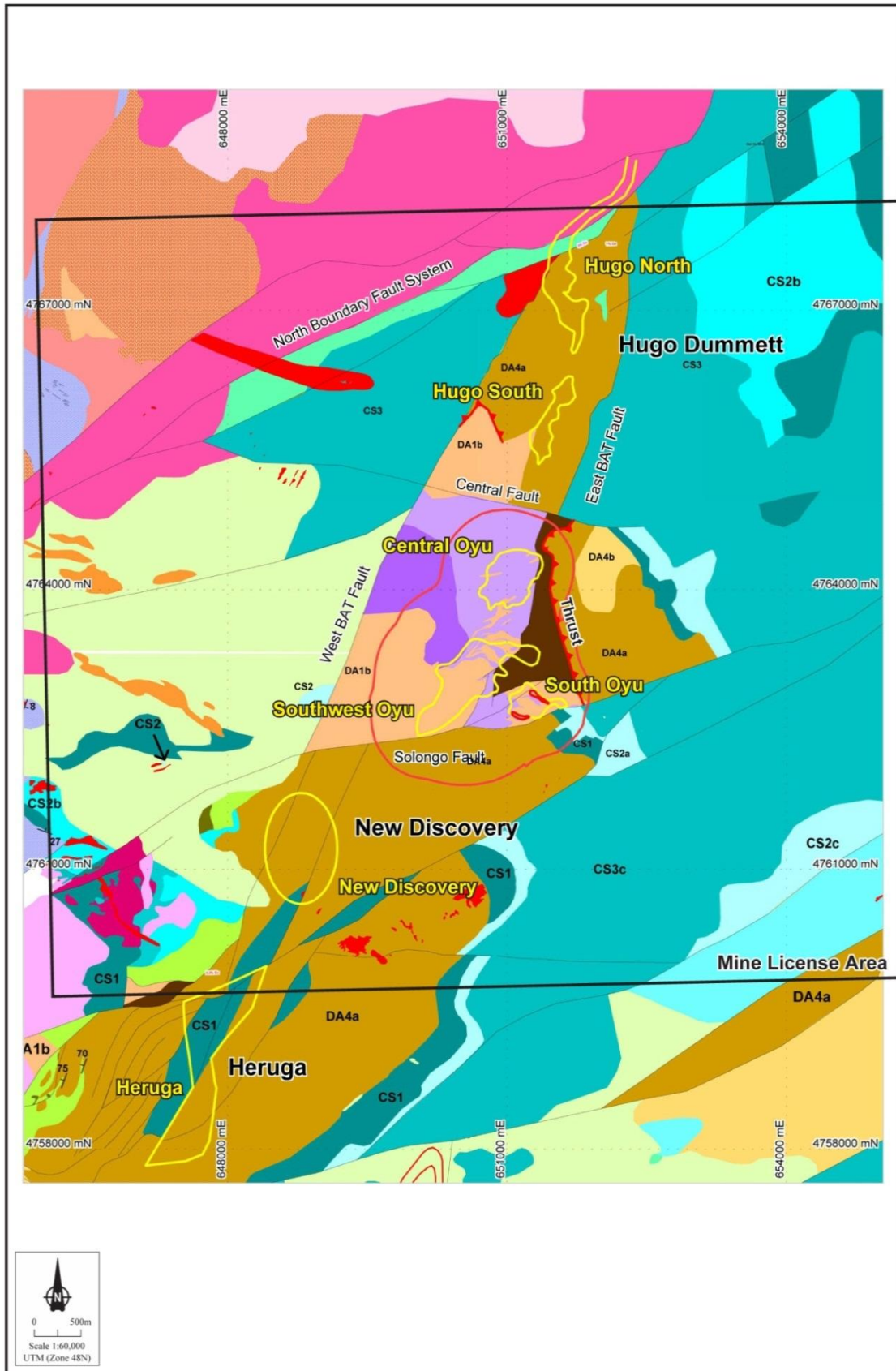
- Basaltic volcanics;
- Andesitic tuff;
- Quartz monzodiorite;
- Oyu Tolgoi quartz monzodiorite; and
- Quartz monzonite.

The basaltic volcanic rocks host the bulk of mineralisation in South West Oyu (80%) and chalcopyrite-gold mineralisation in Central Oyu. Quartz Monzodiorite is the most common intrusive rock in the area. Post mineralisation intrusive deposits include:

- Hornblende-biotite andesite;
- Rhyolite;
- Biotite granodiorite; and
- Basalt.

The extensive drilling has resulted in the ore bodies being relatively well defined (see *Chapter A4.2*), although the full extent of these at depth and outside the mining license is still being assessed.

**Figure 5.8: Simplified Geological Map and Main Ore Deposits of Oyu Tolgoi Licence Area**



Source: Aquaterra (2010), Oyu Tolgoi Mine Site Hydrological Assessment

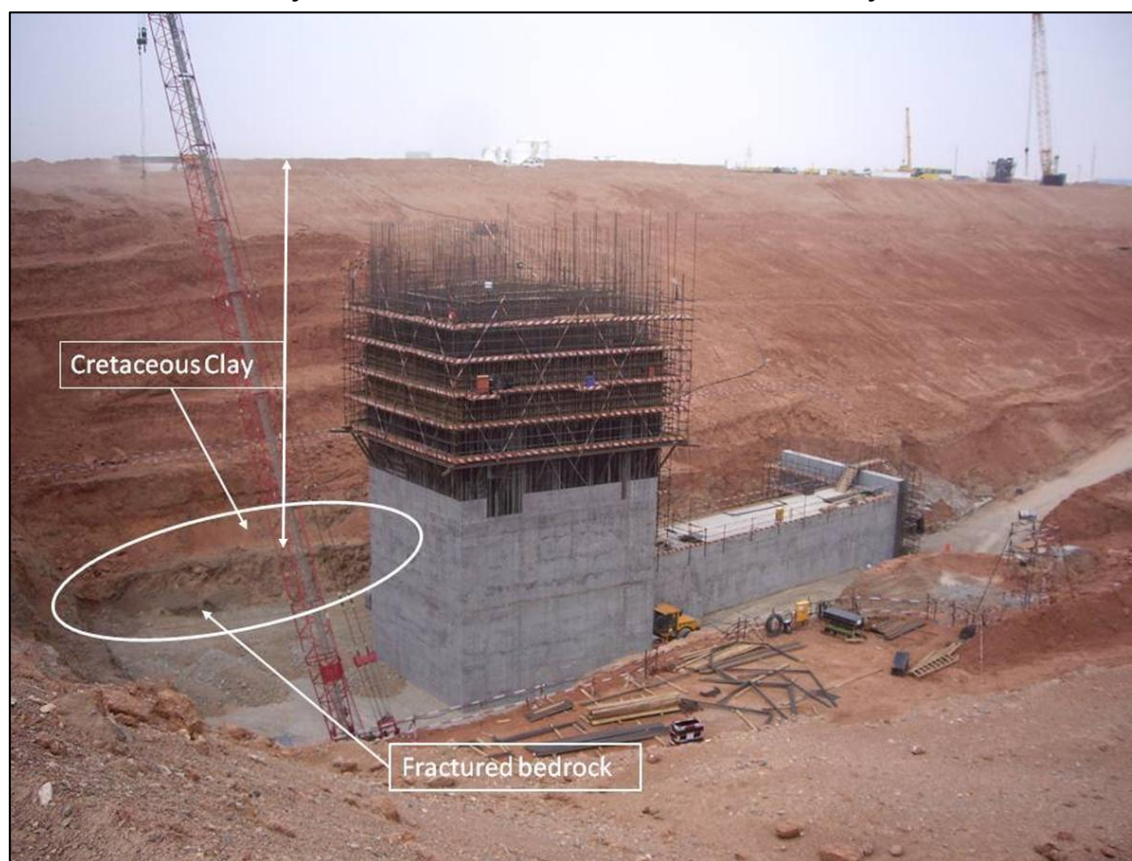
Note: Refer to Figure 5.6 for explanation of symbols.

## 5.5.2 Shallow Geology (sediments overlying Palaeozoic basement)

Overlying the Palaeozoic bedrock is a sequence of gently-dipping to horizontal Cretaceous stratified clays and Quaternary sand/gravels, infilling palaeochannels and small fault-controlled basins (see *Figure 5.11*). Across the north-eastern half of the Mine Licence Area these sediments comprising Cretaceous stiff clays which rest on the weathered Palaeozoic bedrock (see *Figure 5.9* which illustrated the significant thickness of clay over parts of the Mine Licence Area)) overlain with weathered clays and minor alluvial sediments (termed the 'East Colluvial Domain' (see *Figure 5.10*).

The weathered bedrock, which occurs throughout the Mine Licence Area to a depth of up to 30 m, provides the main source of groundwater in the Mine Licence Area. This weathered bedrock outcrops within the north-western and southern parts of the Mine Licence Area, and is covered to various degrees by Cretaceous and other sediments through the rest of the Mine Licence Area. Construction phase groundwater supply boreholes have yields ranging from 0.7 – 8 L/s with flow inferred to be primarily from enhanced secondary permeability due to the weathering and fracturing which is often associated with intrusive igneous bodies<sup>14</sup>.

**Figure 5.9: Cretaceous Clay cover around Excavation around the Primary Crusher**



To the southwest of this area of clay the shallow geology is dominated by Quaternary alluvial deposits associated with the Undai and its tributaries (termed the 'West Alluvial Domain'). The alluvial sediments associated with the Undai which are in contact with the underlying Palaeozoic bedrock can be over 5 m thick in the main Undai channel. Outside of the Undai the alluvial sediments associated with its tributaries, such as the Buda, are typically less than 2 m thick and discontinuous, which results in them being less significant with respect to shallow groundwater flow in the area (see *Figure 5.12*).

<sup>14</sup> Aquaterra 2010, Oyu Tolgoi Mine Site Hydrogeological Assessment, Ref: U25D/111c, 9<sup>th</sup> December 2010

**Figure 5.10: Surface Geology sequence within the Mine Licence Area**

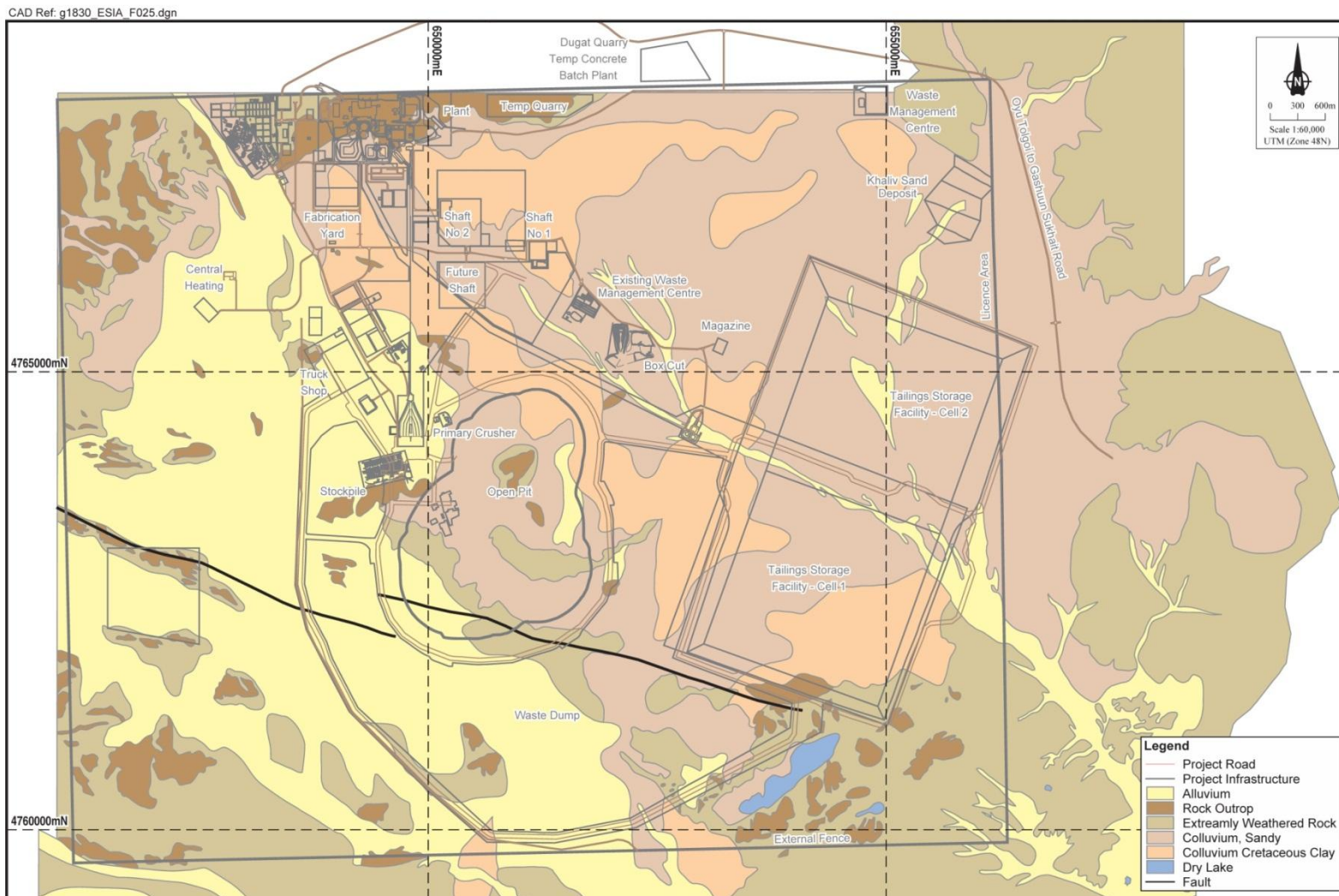
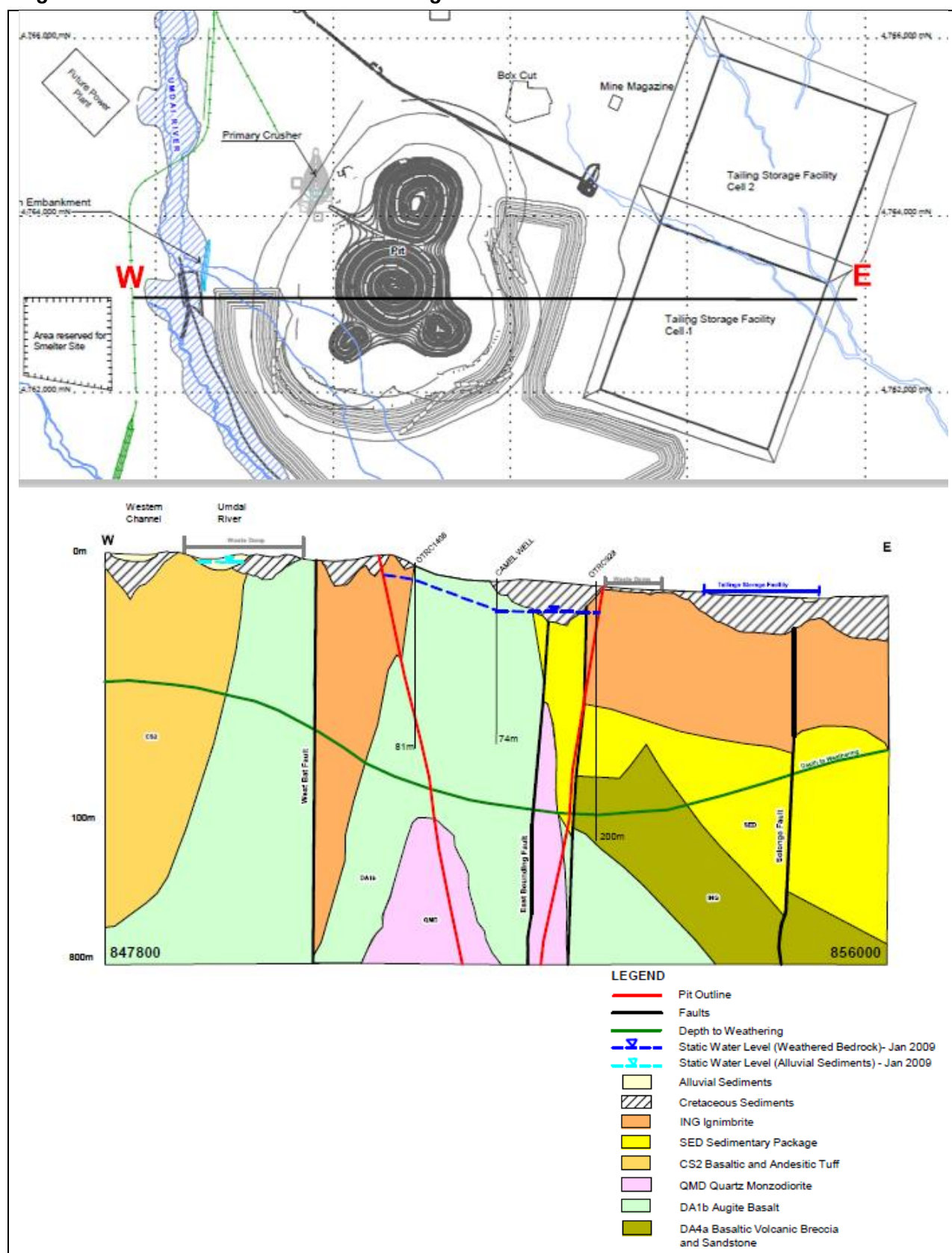


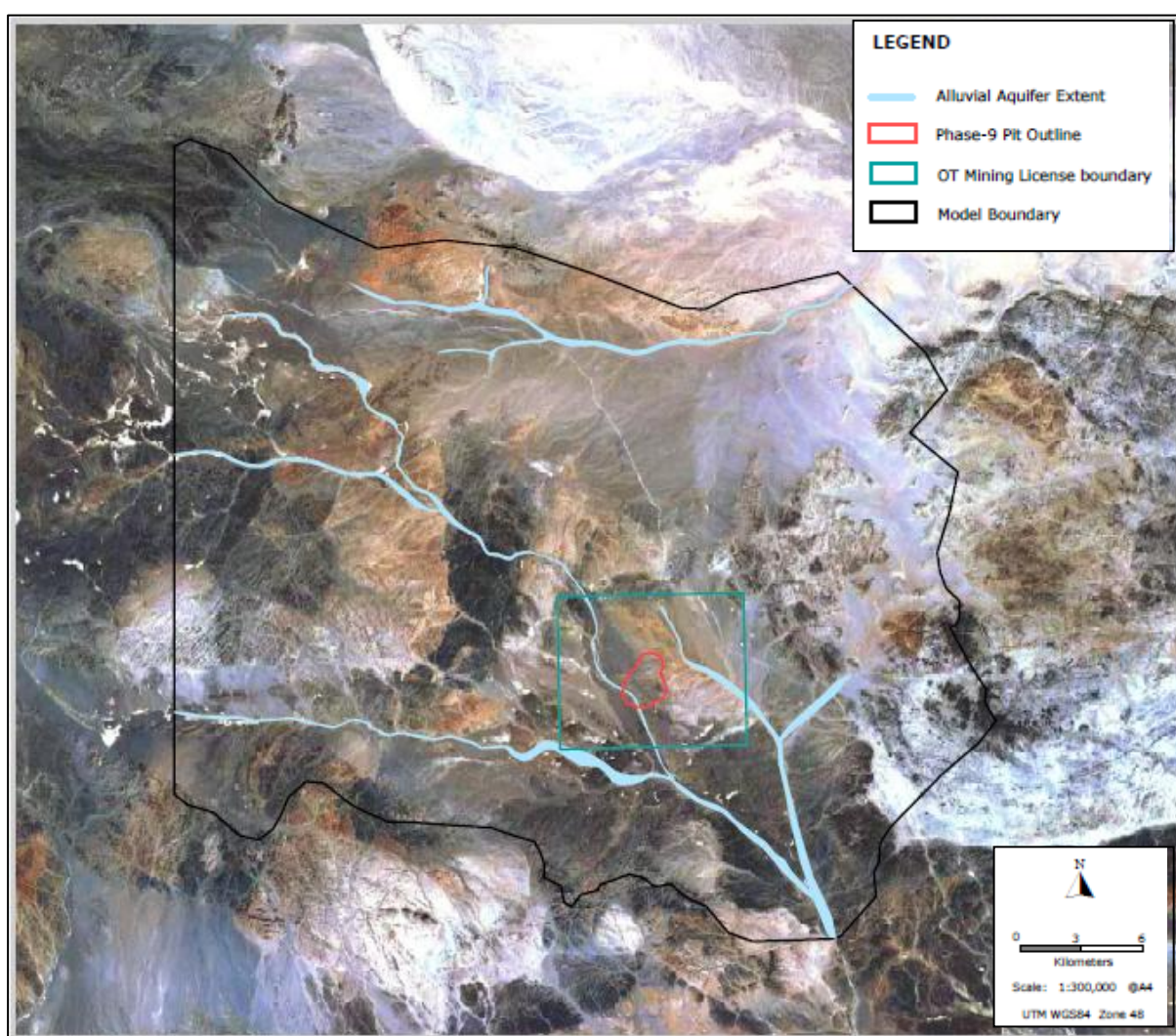
Figure 5.11: West-East Cross-Section through Mine Licence Area



In the northern portion of the TSF there are localised fluvial deposits (up to 4 m deep) associated with Budaa tributaries ephemeral watercourses<sup>15</sup> which have been used by herders historically. These fluvial deposits are a mixture of well graded clean sands and silty sands. To the north of the TSF there are some further sand deposits including the Khaliv Sand Deposit which is located on the eastern side of the Mine Licence Area (see *Section A4 Figure 4.4*) to the north of Cell 2 of the TSF. The Khaliv Sand Deposit is been used of the construction materials with an approved resource of 1,089,500 m<sup>3</sup>. This local sand lens overlies the Cretaceous Clay and is outside the footprint of any of the Project infrastructure. Loose fluvial deposits will also be stripped below the tailings embankments, where applicable.

Overlying much of the Mine Licence Area (and not shown on *Figure 5.10*) is typically between 0.1 and 0.5 m of aeolian soil occasionally reaching over 2 m such as in areas of the TSF. All loose aeolian deposits will be stripped below all TSF structures and key trenches will be installed to cut-off seepage through the deeper fluvial deposits.

**Figure 5.12: Distribution of Alluvial Sediments in Ephemeral Watercourses around Mine Licence Area**



*Note: The model boundary illustrates the area being modelled by Oyu Tolgoi in order to assess the area of influence of the mining operations on the surrounding groundwater*

The Cretaceous sediments are up to 20 m thick across the Mine Licence Area thickening to the northeast. These sediments comprise a thick clay rich sequence overlying weathered bedrock, the clays contain

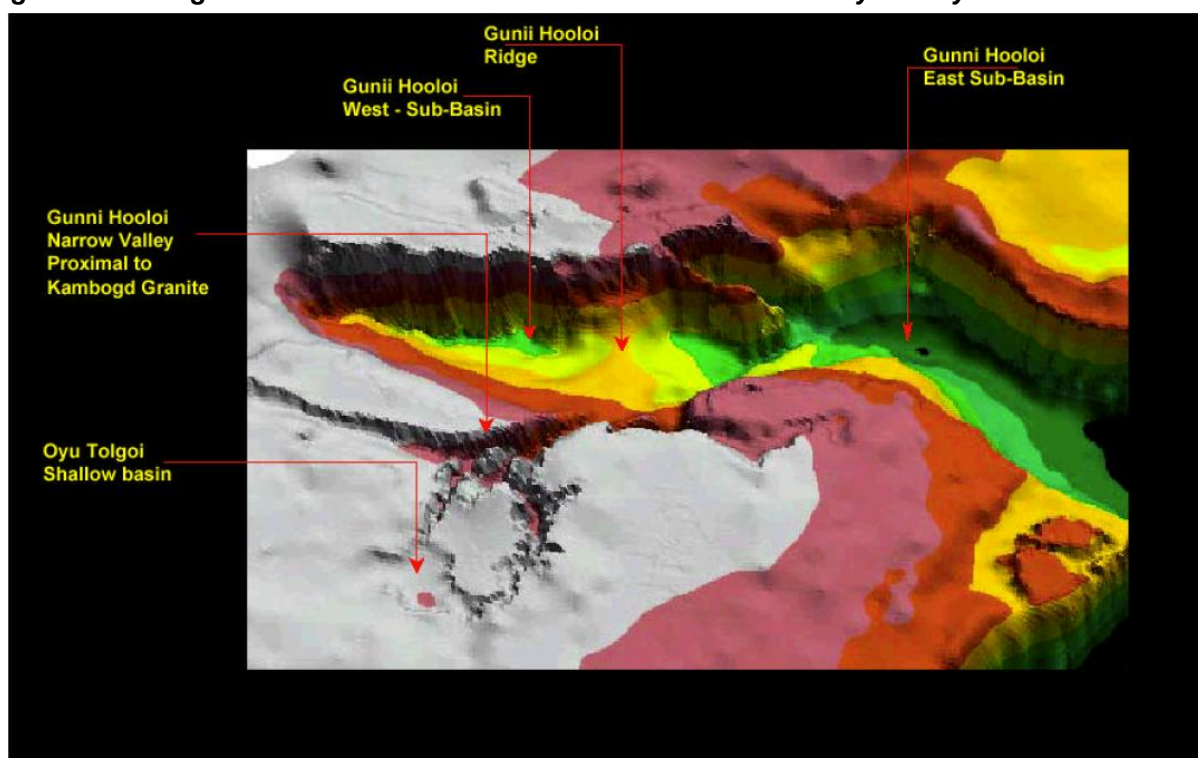
<sup>15</sup> Klohn Crippen Berger 2011, Tailings Storage Facility 2010 Feasibility Study Update, 5<sup>th</sup> August 2011

discontinuous zones of clayey sand grading to gravels up to 2 m thick. Exploration drilling has identified lenses of coarser graded sand and gravel at a depth of approximately 5-30 m below ground level which are thought to be controlled by a series of sand/gravel infilled paleochannels. These horizons have higher hydraulic conductivities than the surrounding clay-rich sediments but have limited yield potential due to their discontinuous nature.

## 5.6 GEOLOGY OF CRETACEOUS BASINS

During the Palaeozoic era, southern “Mongolia” represented the edge of a land mass that grew through the accretion of island arcs along a series of Andean-type subduction zones. This was followed, in the Late Palaeozoic, by basin and range-style rifting which initiated the formation of basins such as Gunii Hooloi as illustrated in *Figure 5.13*, and was accompanied by volcanism. By the early Mesozoic continental uplift was in progress, with erosion ‘unroofing’ the tectonic belts and the rivers present at this time depositing clastic sediments into fault-controlled, foreland basins such as Gunii Hooloi. By the end of the late Cretaceous, the region was becoming increasingly arid, with a similar climate to the present day, and with the reduction in water, the corresponding rate of erosion decreased.

**Figure 5.13: Image of Gunii Hooloi Cretaceous Rift Basin from Gravity Survey**



Source: Aquaterra (2008)

The period of Mesozoic uplift and basin development created the three major sedimentary basins which have been investigated as potential groundwater sources for the Project, i.e. the Gunii Hooloi, Galbyn Gobi and Nariin Zag basins (see *Chapter B6*). The initial exploration of these basins demonstrated that the aquifers were insufficiently developed in Nariin Zag (see *Section B6.4.2*). Although the sedimentation characteristics vary slightly between the Gunii Hooloi and Galbyn Gobi basins, the geology of the two basins can be characterised as three distinct geological units as follows:

- Undifferentiated Quaternary sediments;
- Upper Cretaceous Bayanzag Formation;
- Upper Cretaceous Bayanshiree Formation;
- Upper Cretaceous Sainshand Formation; and
- Middle-Upper Cretaceous Hohteeg Formation.

The undifferentiated Recent-Quaternary sediments, which overlie the Cretaceous sequence contain the linear alluvial aquifers which run along the larger ephemeral water courses that are relied on by the local herders for domestic and stock water supplies (see *Figure 5.14*). These sediments also contain broader aquifers which are relied on by the local communities such as Khanbogd *Soum* Centre located approximately 8 km to the south of the Gunii Hooloi basin. These broader Quaternary aquifers are developed around the edges of the surrounding mountains and not through the central part of the Gunii Hooloi basin. The deeper Bayanshiree Formation forms the main aquifer unit in the Galbyn Gobi and the Gunii Hooloi, and in the case of the Gunii Hooloi forms the aquifer which the Project will access for its water supply (see *Section B6* for a description of the aquifer units). This aquifer is not currently exploited for any purpose in the Project area.

### **Gunii Hooloi Basin**

Within the Gunii Hooloi Basin, the characteristics of the main geological units can be summarised as follows, from shallowest and youngest to deepest and oldest:

- The Recent-Quaternary sediments which are generally unconsolidated form a discontinuous relatively thin veneer of up to 10 m in thickness across much of the central Gunii Hooloi basin, particularly adjacent to the Khanbogd granites. The sediments comprise clays, sands, loams, and some gravel. It is within the upper part of these sediments that the water supply pipeline will be buried. These sediments support local aquifers along the ephemeral watercourses which flow generally west to east across the area.
- The Cretaceous Bayanzag Formation is interpreted to exist across the entire study area and consists predominantly of red brown clays interbedded with lesser sands, sandstones and minor conglomerates in the lower sections. The drilling of monitoring wells adjacent to herder wells around the southern and northern margins of the basin has demonstrated that on average these red brown clays around the basin periphery are over 50 m thick. The clays of this Formation form a low permeability unit that acts as a confining layer for the underlying Bayanshiree formation across large parts of the basin. The formation generally thickens to the north and east, where the lower parts of the Formation become coarser grained and form the upper part of the main aquifer system.
- The Cretaceous Bayanshiree Formation underlies the Bayanzag Formation and has been mapped across the entire Gunii Hooloi region. It is best developed in the eastern part of the Gunii Hooloi basin where it attains thicknesses of up to 200 m. The Bayanshiree Formation consists of significant thicknesses (up to 150 m) of unconsolidated brown sands and gravels with minor interbedded units of clay and conglomerate. This Bayanshiree Formation and underlying Sainshand Formation form the main aquifer units, which will supply the Project. This Formation is also developed in the Khanbogd area where it is present in a sub-basin to the south of the main Gunii Hooloi basin, and in which over 100 m of sands and gravels have been identified by the 2011 Oyu Tolgoi drilling programme which is exploring a potential aquifer to supply Khanbogd. This sub-basin is separated from the Gunii Hooloi basin by a basement high based on data from the TEM line through the area<sup>16</sup>.
- The Cretaceous Sainshand Formation underlies the Bayanshiree Formation across the Gunii Hooloi basin area and comprises conglomerates with minor sandstones and clays. The coarser-grained lithologies of the Sainshand Formation are variably unconsolidated or have well developed secondary permeability that increases the thickness of the main aquifer in localised areas.
- The Cretaceous Hohteeg Formation comprises greyish green clay and sandstone and has a limited distribution in the deepest parts of the Gunii Hooloi basin.

This sequence is illustrated in *Figure 5.15* which shows a SW-NE Section through the Gunii Hooloi Basin (i.e. along the axis of the basin (see *Section B6* for further details on the structures and aquifer units). Overall the Cretaceous sequence in the Gunii Hooloi basin can be considered as a fining upwards sequence with conglomerates at the base and dominantly clays in the upper part

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<sup>16</sup> Aquaterra 2011: Gunii Hooloi Aquifer Boundary Review, Ref: U2513/014a, 10 July 2011.

Figure 5.14: Alluvial Aquifer Distribution in Gunii Hooloi Valley

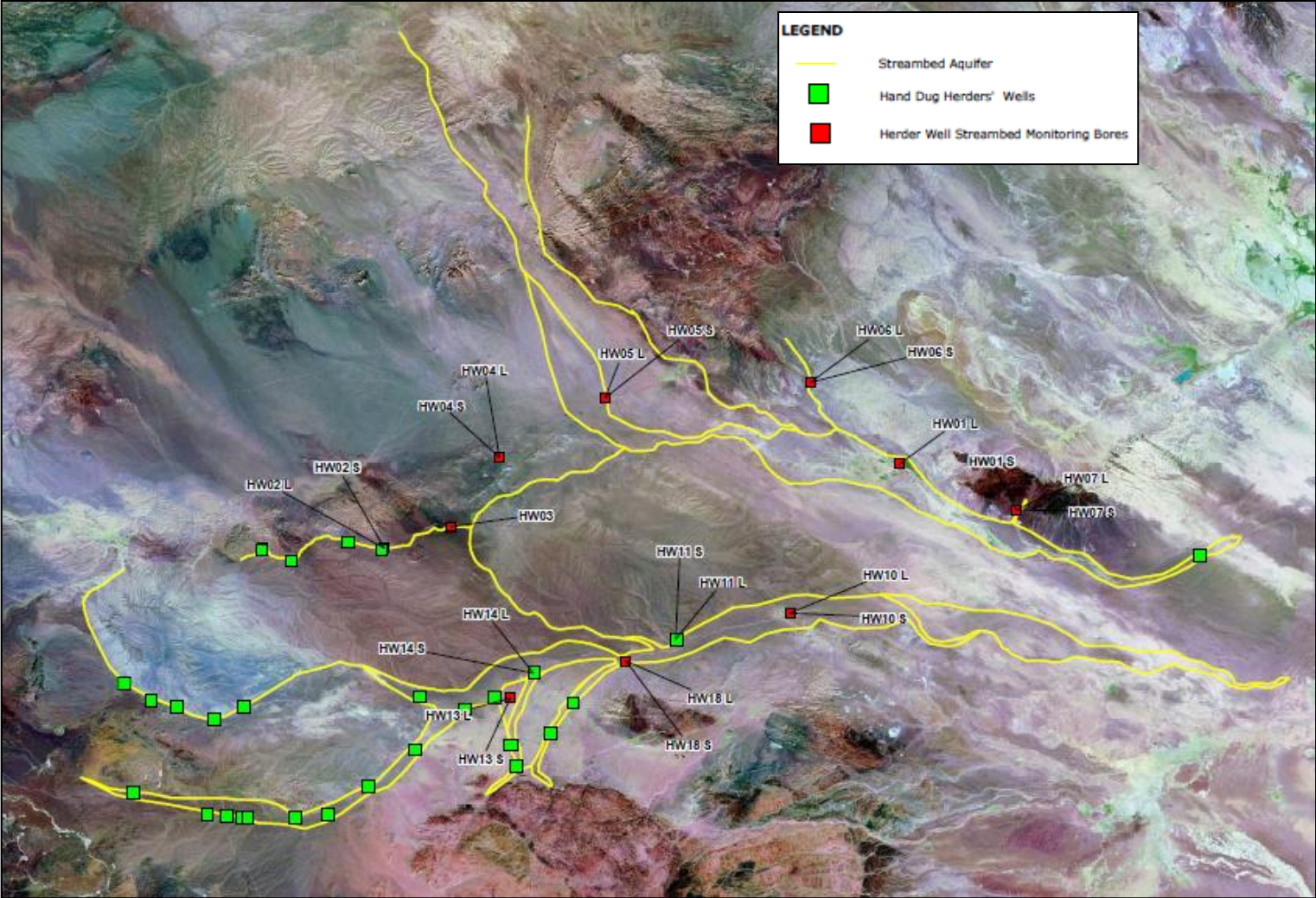
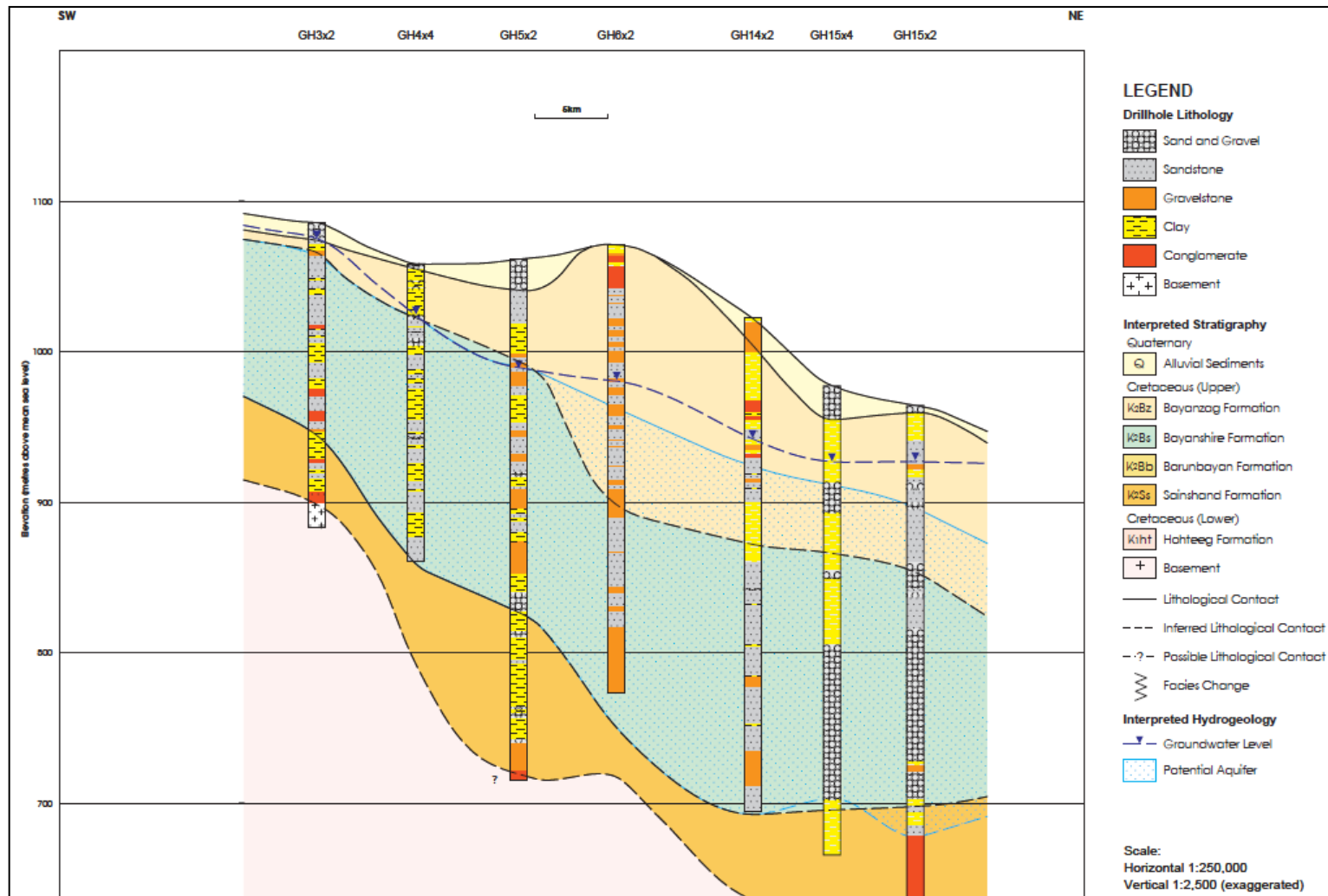


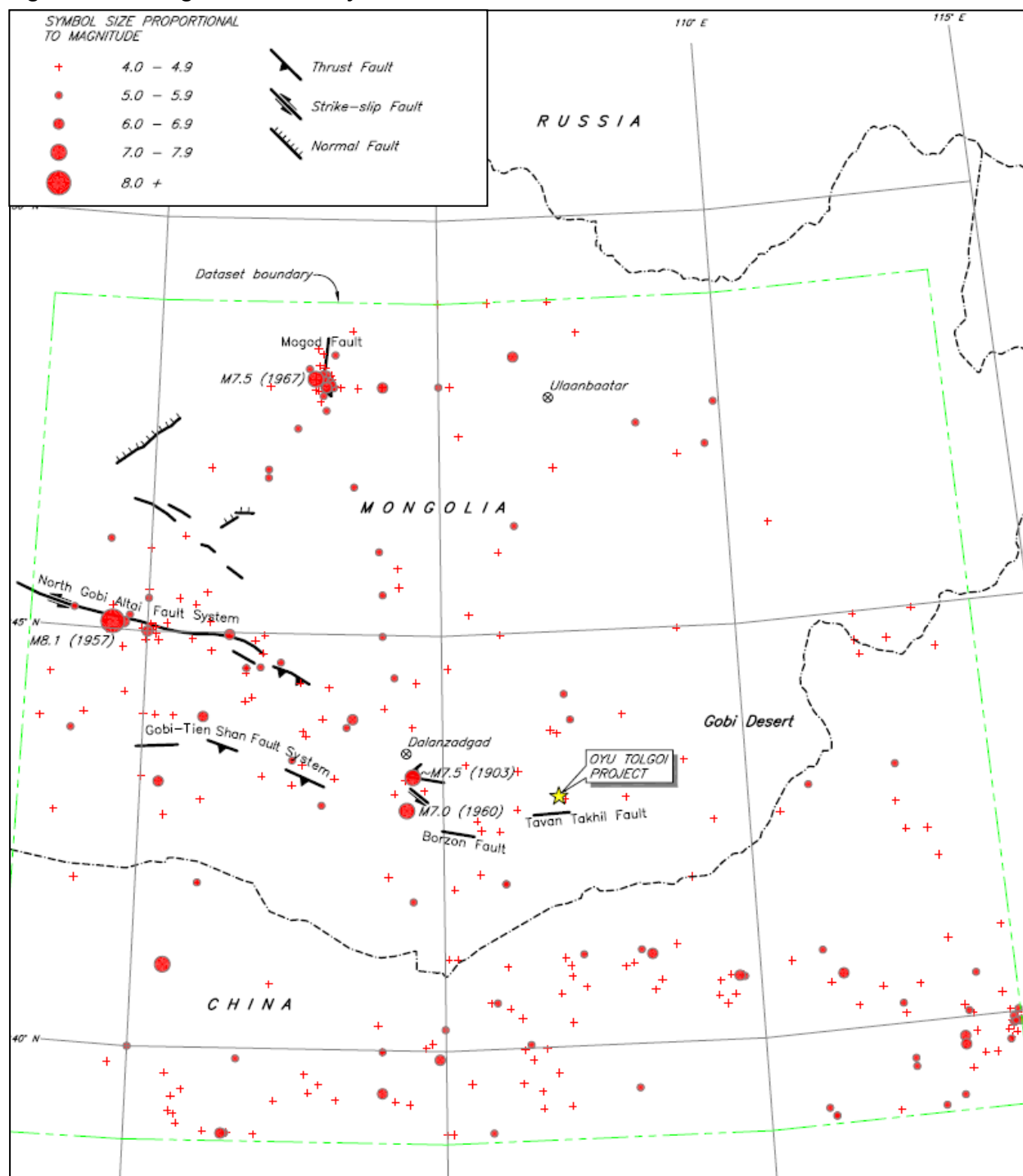
Figure 5.15: Cross-Section through Gunii Hooloi illustrating the Cretaceous Sequence



Source: Aquaterra (2004), Groundwater Exploration Investigation Oyu Tolgoi Process Water Supply; Volume 1: Resource Assessment & Borehole Design

## 5.7 SEISMICITY

**Figure 5.16: Mongolian Seismicity 1900-2000**



Source: Knight Piésold Ltd, Report on Seismic Hazard Assessment 18<sup>th</sup> April 2005

A seismic hazard assessment of the Oyu Tolgoi site has been completed by Knight Piésold (2004)<sup>17</sup> and The Research Centre for Astronomy and Geophysics of Mongolian Academy of Science<sup>18</sup>. The assessment found that Oyu Tolgoi site is situated in an area of low seismic risk, as is much of eastern Mongolia.

Seismic activity of Mongolia is associated with the deformation induced by the collision front 2,000 km to the south between India and Eurasia, and extension tectonics associated with the Baikal extension structures on the eastern side of the Siberian craton to the north of Mongolia. The nearest tectonically active area in Mongolia to Oyu Tolgoi is the Mongolian Altai. These are tectonically active mountain ranges stretching some 1,700 km from southwest Siberia to the Gobi Desert. The easternmost extension of the Mongolian Altai is known as the Gobi Altai with fault systems, which dies out approximately 50 to 100 km west of Oyu Tolgoi. A map of the seismic activity and faults in Mongolia is provided in *Figure 5.16*.

The strongest recorded earthquake within 100 km of Oyu Tolgoi comprised two moderate events both with magnitudes of 4.4 (12<sup>th</sup> March 1978 at a distance of 35 km, and a second on 28<sup>th</sup> July 1989 at a distance of 69 km). The largest seismic event within 150 km occurred on 31<sup>st</sup> August 1992 with a magnitude of 5.1, 124 km from Oyu Tolgoi. The largest known earthquakes near the Oyu Tolgoi area occurred on 1<sup>st</sup> February 1903 and 3<sup>rd</sup> December 1960 (7.5 Unegtei and 6.8 Buuriin Hyar earthquakes) estimated to be 20 and 75 km south of Dalanzadgad (both circa 200 km west of Oyu Tolgoi).

Field investigations conducted in September 2004 for the RCAG seismicity study identified two significant faults with evidence of Quaternary activity (considered to be active). These two faults, known as the Borzon and Tavan Takhil faults, are considered capable of generating earthquakes of up to approximately magnitude 7.0. The Borzon fault is located about 120 km southwest of the Oyu Tolgoi Project site. The Tavan Takhil fault exhibits strike-slip movement and trends in an east-west direction along the southern edge of the Oyu Tolgoi Project area, approximately 20 km south of the proposed tailings storage facility. The RCAG study indicates that the recurrence rate for a magnitude 7.0 earthquake on the Tavan Takhil fault is about 2,000 years.

Based on the results of the seismic assessment, the following seismic design parameters have been selected for the Project which has drawn on Mongolian standards (which refer to Russian Building code) and international standards:

- Foundation Factor is defined by the soil profile. For the Project the majority of the site foundations will be on rock, or on stiff or very stiff clay of less than 15 m thickness. Therefore, site amplification is not expected to be significant, and there are no areas of deeper loose or soft soils or soils that may liquefy.
- For the Oyu Tolgoi Project structures the recommended seismic zone values to be used for seismic design are presented below and assume a peak ground acceleration of 0.06g. This is consistent with an evaluation of risks against the Uniform Building Code, National Building Code of Canada, Russian Code (SNIP II-7-81) and the International Building Code.
  - Uniform Building Code (UBC): For plant site structures, the maximum acceleration associated with an earthquake with a return period of 475 years (equivalent to a 10% chance of the maximum bedrock acceleration being exceeded in 50 years) is 0.06g. Therefore the UBC Zone 1 has been adopted for the design basis;
  - National Building Code of Canada (NBCC): the applicable zonal values for this code applicable to the Oyu Tolgoi location are; Acceleration-Related Seismic Zone,  $Z_a = 1$ ; Velocity-Related Seismic Zone,  $Z_v = 1$ ; Zonal Acceleration Ratio,  $a = 0.05$ ; Zonal Velocity Ratio,  $v = 0.05$ ;

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<sup>17</sup> Knight Piésold Pty Limited (2004), Oyu Tolgoi Project, Feasibility Study Tailings Storage Facility, Ref PE601-00001, December 2004.

<sup>18</sup> RCAG-MAS (2005), Seismic Hazard Assessment of Oyu Tolgoi Site, March 2005

- For the Russian building code SNIP II-7-821, a seismic intensity rating of VI (6) would be suitable for the design of “common” facilities and of VII (7) for “critical” facilities at Oyu Tolgoi; and
- International Building Code (2000): In accordance with the International Building Code, the maximum considered earthquake ground motion has been defined as the ground motion with a 2% probability of exceedance in 50 years (return period of 2500 years). Specifically, the following values have been calculated from the probabilistic seismic hazard analysis: Seismic coefficient,  $SS = 0.27g$ ; Seismic coefficient,  $S1 = 0.09g$ .
- For design of the TSF:
  - The operating basis earthquake (OBE) was selected as the earthquake with a 475 year return period (equivalent to a 10% chance of the maximum bedrock acceleration being exceeded in 50 years), with a maximum acceleration of  $0.06g$ ; and
  - The maximum design earthquake (MDE) with a maximum bedrock acceleration of  $0.08g$  (1,000-year-return-period event) and design magnitude of  $M7.8$  has been adopted. This value was used for the design of closure in those areas that are susceptible to seismic activities upon completion and closure of operations.

This takes into account consideration of the consequences of a failure of the TSF (safety of life, economics, social and environmental impacts), which give the TSF a hazard classification of high.

## 5.8 SOILS OF THE PROJECT AREA

The soils of the Project area (including the Gunii Hooloi borefield and the road and infrastructure corridor) are generally poorly developed and are formed below the very sparse vegetation cover of the Gobi (typical coverage is 8-25%). The organic content of soils is generally less than 1% and they are weakly alkaline, with alkalinity varying according to the concentrations of calcium or magnesium cations in the different layers in the soil profile.

The conditions leading to the formation of desert brown-grey soil are different from the formation of other types of soil. Because of the Gobi's dry climate and infrequent rain, 80% of the soil is mineralised. The soils are characterised by the presence of sodium carbonate and other forms of carbonates and the absence of soluble salts and gypsum. Researchers have suggested that the Gobi soils are formed through the freezing of shallow groundwater which causes carbonate and bicarbonate salt deposition at the surface thereby mineralising it and forming a saline alkaline surface silt layer.

The Gobian soils are characterised by freezing of the upper soils in winter time to a depth of 1 to 1.5 m. This seasonal soil freezing occurs for 6 to 7 months of the year. Biological activity increases in the soil surface layers with summer warming and following summer rainfall events. Given the high silt content and low content of organic matter, the soils are easily eroded and dispersed by water and wind as well as being vulnerable to disruption (e.g. vehicle tracks) which breaks up the surface crust. These are the main contributory factors to soil degradation in the area which is an issue recognised locally as well as within the broader stakeholder community<sup>19</sup>; such degradation of soils is typically focused around areas where there is heavy traffic or footfall such as along vehicle tracks, and around animal watering holes and herder camps.

During the sporadic rainfall events, rainwater can penetrate up to a depth of 20-25 cm utilising cracks and more permeable routes to reach the low permeability carbonate horizons typically present at depths of >25 cm. The moisture remaining at depth after these rainfall events is less susceptible to evaporation and is an important resource for local plant species.

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<sup>19</sup> The World Bank (2010), Mongolian Southern Gobi Regional Environmental Assessment, January 2010

### 5.8.1 Soil Types

Through the baseline field mapping undertaken during the DEIA for the mine<sup>20</sup> the soils of the Project Area have been classified into types of semi-desert plain light-brown soil, hill light brown soil and meadow light-brown soil. The field mapping was sufficiently detailed such that soil types have been mapped at a 1:5,000 scale across the Mine Licence Area as illustrated in *Figure 5.17*. The primary soil types are:

- carbonate light brown soil with clay loam on hills;
- carbonate light brown sandy loam soil with gravels on hills and hillocks;
- carbonate light brown clay soil with gravel;
- semi-desert, carbonate, saline, light brown sandy loam soil with gravel;
- semi-desert, carbonate, saline, light brown sandy loam soil with small stones;
- semi-desert, carbonate, saline, light brown clay loam soil;
- semi-desert, carbonate, saline, light brown clay loam soil with gravel;
- semi-desert, saline, light brown soil with aeolian sand;
- meadow steppe carbonate saline light brown soil with stone gravel;
- meadow steppe carbonate saline light brown soil with stone crumbs under sand;
- dunes; and
- playa ('takyre').

The shallow soils (0.1. to 0.5 m) bear a loose relationship to the underlying shallow geology (see *Figure 5.10*) with for example the weathering of the shallow clays contributing to the clay content of the overlying soils. Overall the linkage between the soils and the underlying geology is weak, with the soils being formed from varying proportions of weathered sediments, windblown materials and fluvial sediments. Where the protective surface cover is damaged, wind and fluvial action can erode the soils and reveal more of the underlying geology.

The baseline characteristics of the soils which cover the area are summarised in *Table 5.1*.

**Table 5.1: Soil Characteristics**

Main parameters	Unit	Amount in Oyu Tolgoi Mine Licence Area		
		Average	max	min
Soil types existing in the Project area	number	8	15	1
Thickness of soil	cm	6.1	30	<1.0
Existing condition		eroded	natural state	degraded
Organic Material content (upper layer)	percent	0.65	0.74	0.56
Organic Material content	percent	0.51	0.85	0.17
Thickness of OM layer	cm	6.1	12	1.0
Organic Material of total mass of soil	mg/kg	0.29	0.33	0.26
pH of soil	-	8.5	9.2	7.7
Unit weight of soil	gram/cm <sup>3</sup>	1.4	1.8	1.3
Porosity of soil	percent	18	21	15
Content of phosphorus	mg/kg	0.6	0.96	0.25
Content of calcium	mg/kg	26.9	43.4	10.4

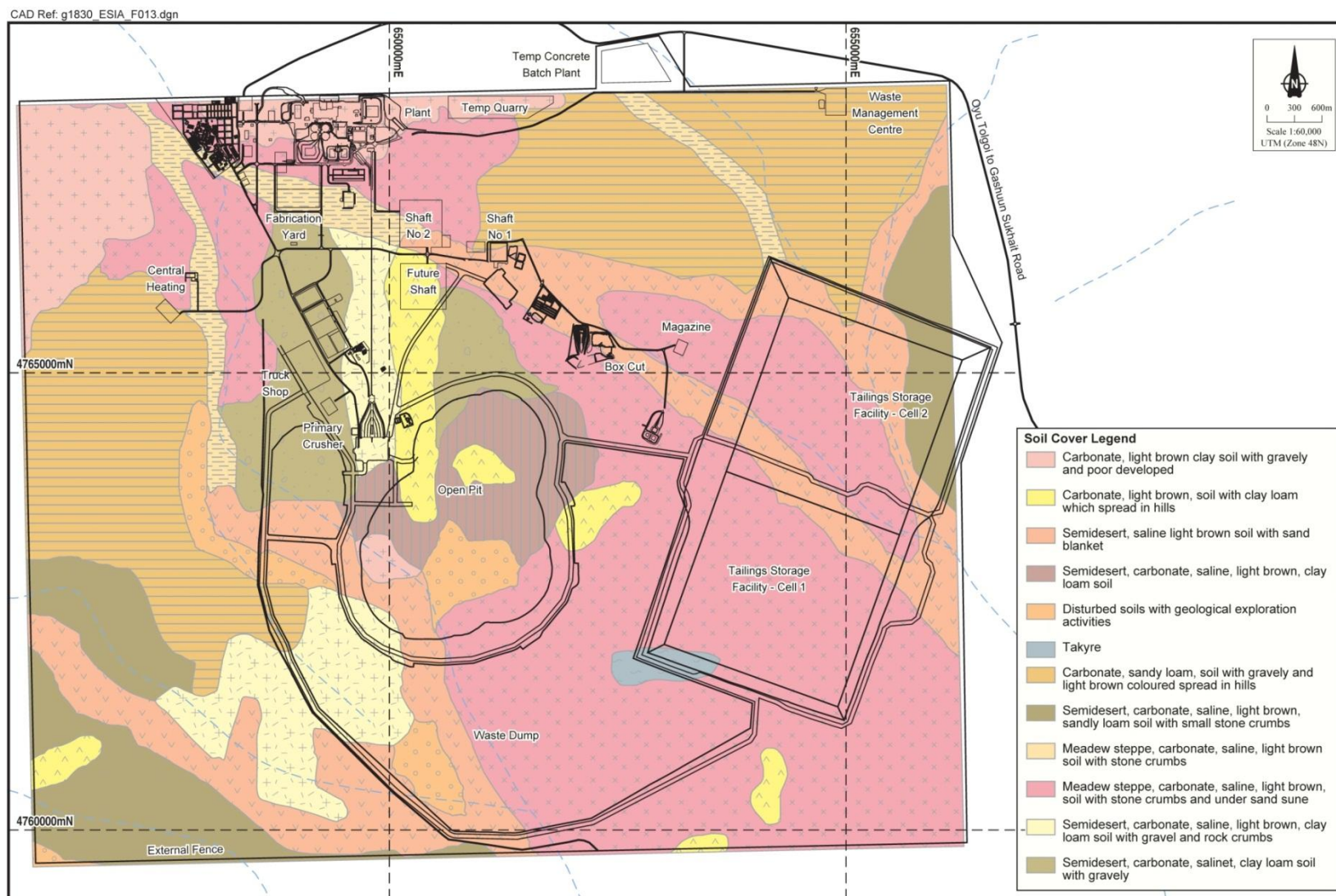
<sup>20</sup> Eco-Trade (2006), Oyu Tolgoi Project Environmental Impact Assessment, Volume 3 Mining and Processing, Eco-Trade LLC May 2006

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Exchangeable (multiple ) nitrogen	mg/kg	0.12	0.20	0.06
Exchangeable (multiple ) phosphorus	mg/kg	0.7	1.3	0.03
Exchangeable (multiple ) potassium	mg/kg	12.5	21.6	3.4

Source: Eco-Trade (2006); Oyu Tolgoi Mining and Processing EIA

**Figure 5.17: Generalised Soil Map of Oyu Tolgoi Mine Licence Area with Proposed Infrastructure Overlain**



Similar to the rest of the Mine Licence Area, the soils in the proposed TSF area are mainly ancient remnant soils, with some recent surficial alluvium and aeolian soils<sup>21</sup>. The dominant soil in the TSF area is a clay, which is derived from the underlying Cretaceous clay which was deposited in a lake environment. The fluvial/aeolian soils in the area contain several shallow fluvial deposits (up to 4 m deep) associated with ephemeral watercourse overlies the northern portion of the TSF. The fluvial deposits are a mixture of well-graded clean sands and silty sands. A thin layer (<2 m) layer of aeolian silt-sand deposits are found over most of the TSF area.

## 5.8.2 Trace Metals

Trace metals in soils are critical for supporting healthy plant (and animal) development, although, at too high a level, some trace metals can have a detrimental impact on plant and animal health (e.g. through dust inhalation, or direct or indirect ingestion with accumulation in the body affecting health). Baseline surveys across the Project area have been undertaken to establish the baseline concentrations of trace metals in the soils.

The results of sampling undertaken across the Project area in 2005 are illustrated in *Table 5.2*. These results indicate that trace metals are present at similar concentrations across the area. *Figure 5.18* illustrates the soil monitoring locations.

**Table 5.2: Soil Trace Metals, Oyu Tolgoi Project area, November, 2005**

Element (symbol)	Unit	Monitoring Loc # 1	Monitoring Loc # 2	Monitoring Loc # 3	Monitoring Loc # 4	Monitoring Loc # 5
Arsenic (As)	mg/kg	8.5	4.7	5.0	8.2	6.4
Cadmium (Cd)	mg/kg	<0.4	<0.4	<0.4	<0.4	<0.4
Chromium (Cr)	mg/kg	21	16	17	24	24
Copper (Cu)	mg/kg	29	20	23	42	28
Mercury (Hg)	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05
Lead (Pb)	mg/kg	5	8	5	6	5
Nickel (Ni)	mg/kg	13	12	12	15	15
Iron (Fe)	mg/kg	23	18	17	27	21

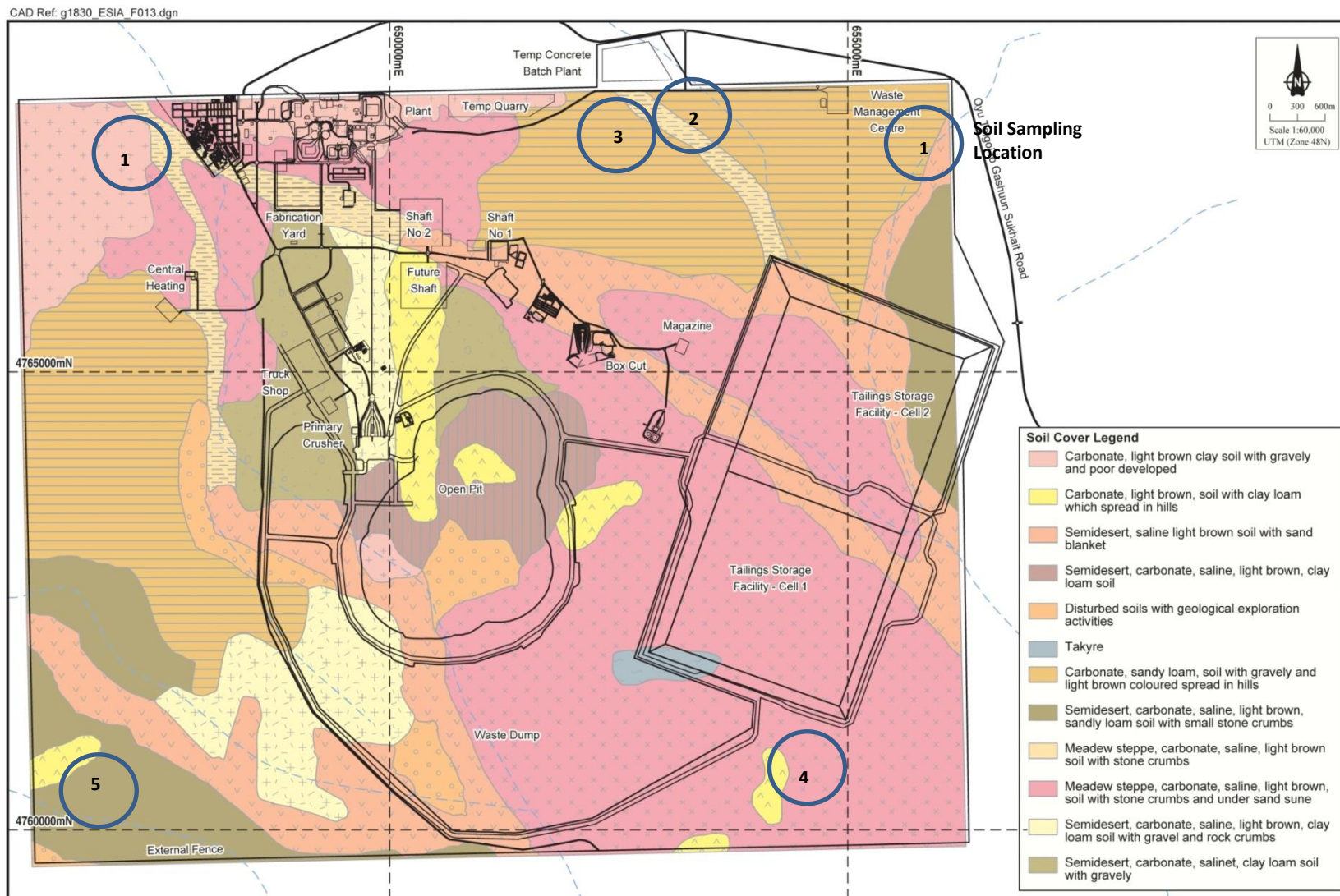
Source: *Eco-Trade (2006); Oyu Tolgoi Mining and Processing EIA*

The locations of the soil monitoring points were chosen to assess a number of different soil types as follows:

- Sample Point 1: Semi-desert, carbonate, saline, light brown clay loam soil with gravel;
- Sample Point 2: Semi-desert, carbonate, saline, light brown clay loam soil;
- Sample Point 3: Meadow Steppe Carbonate Saline Light Brown Soil with Stone gravel;
- Sample Point 4: Meadow Steppe Carbonate Saline Light Brown Soil with Stone Crumbs Under Sand; and
- Sample Point 5: Semi-desert, carbonate, saline, light brown sandy loam soil with small stones.

<sup>21</sup> Klohn Crippen Berger 2011, Tailings Storage Facility 2010 Feasibility Study Update, 5<sup>th</sup> August 2011

**Figure 5.18: Soil Monitoring Locations**



It is recognised that the area is underlain by heavy mineralisation which outcrops at the surface in the Central Oyu area, and these mineralised areas have been subject to exploitation by early civilisations as well as investigated for a significant period of time (over 5 years of exploration drilling). To assess the potential impact of this mineralisation on the trace elements in the soils a further survey was undertaken which focused on the known areas of mineralisation. The survey comprised a comparative survey which assessed the soils of the Central Oyu area where mineralisation is at the surface and a more benign location in the camp area where the soils are influenced by the surficial recent sediment deposits derived from the Undai and underlain by Cretaceous Clay, and the mineralised rock is at depth.

The results of the analysis of trace metal concentrations undertaken by the Central Environmental Monitoring Laboratory (CELM), Mongolia, which also included an assessment of concentration by depth, are presented in *Table 5.3*. These results were also compared to the average trace element concentrations in soils from Dalanzadgad and Ulaanbaatar (a more moist soil area).

**Table 5.3: Trace Metals Analysis in Soils, by Depth**

No	Location (coordination)	Sampling depth	Contents of elements (mg/kg)					
			Pb	Cu	Zn	Cd	Ni	Fe
1	N 648042 E 4766974	0-18 cm	13.0	31.0	67.0	<1	32.0	33.4
		20-30 cm	14.0	34.0	76.0	<1	15.0	42.7
	Camp site	45-65 cm	14.0	47.0	74.0	<1	19.0	39.7
		150-160 cm	13.0	136.0	79.0	<1	11.0	51.8
2	N 650497 E 4763574	0-10 cm	101.0	379.0	57.0	<1	19.0	43.8
		20-30 cm	158.0	574.0	44.0	<1	12.0	55.5
	Central Oyu area	30-40 cm	180.0	628.0	37.0	<1	9.0	53.1
		50-60 cm	276.0	676.0	26.0	<1	4.0	65.9
		70-80 cm	132.0	376.0	16.0	<1	5.0	47.3
Average in soil, Dalanzadgad			3.3	6.3	-	-	5.4	-
Average in soil, Ulaanbaatar			4.3	4.6	46.9	-	2.6	23,940

Source: *Eco-Trade (2006); Oyu Tolgoi Mining and Processing EIA*

The results demonstrate that the trace metal concentrations at the camp, which are taken to represent background conditions at Oyu Tolgoi are elevated in comparison to Dalanzadgad and Ulaanbaatar, but those of Central Oyu are an order of magnitude higher with respect to lead and copper. Both copper and lead concentrations in the soils from Central Oyu increase with depth indicating that the soils are influenced by the weathering of the underlying mineralised rocks. No notable trends are apparent in the zinc and iron concentrations, whereas nickel appears to have the highest concentration in the surface layer in both locations, indicating that this may be concentrated at the surface by some physical or biological process.

### 5.8.3 Soil Erosion

The arid soils of the Gobi are vulnerable to wind erosion following disturbance from grazing and vehicle traffic. The loss of soil from erosion processes results in lost diversity in vegetation, vegetation damage, altered ecological structures and reduced pastoral productivity. This problem is particularly severe along truck routes (see *Figure 5.21*) and where there is overgrazing.

The fine silt layer that forms on the surface of the light brown semi desert soils of the Project area provides a crust which, in conjunction with the pebbles on the surface, protects the soil against wind erosion and maintains the limited organic material in the surface layers. Disturbance of the surface soil crust results in exposure of sub-soils to wind erosion, which can result in reduced organic and nutrient content as well as the loss of soil structure. The reproductive capacity of aridity-tolerant vegetation is also lost during wind erosion as seeds and root material are exposed, and can be blown away or eaten.

The soils of the Oyu Tolgoi Project area have been impacted by the regional desertification processes accentuated by over grazing in the Area of Influence. Livestock concentrations in Khanbogd *soum* are reported to be three times the assessed carrying capacity of the land<sup>22</sup> based on the data of the grass yield of pasture by the Institute of Meteorology and Hydrology compared to the actual number of livestock. Ground disturbance is also accentuated by vehicle traffic. Historical traffic movement and the indiscriminate creation of new tracks in the mining exploration area has led to the creation of many adjacent parallel tracks such that there may be up to 13 separate vehicle tracks connecting a drill site with the Oyu Tolgoi camp.

The ephemeral watercourses that flow in and around the Project area (e.g. the Undai, Buda, and Maanit) when in flood are erosive, moving river bed sediments and river banks, with some over bank deposition. As well as the erosion in the main ephemeral watercourse system, adjacent sheet flow and flow in the channels feeding these ephemeral watercourses can erode the light brown desert soils during the localised storm events. These soils are particularly prone to erosion by storm events where there is existing soil disturbance or reduced vegetation cover.

#### 5.8.4 Soil Contamination

Other than the natural variation in metal concentrations in the soils with increases in concentrations where bedrock is near or at the surface, the baseline soil surveys undertaken within the Oyu Tolgoi Project area have found no evidence of soil contamination resulting from current or historical exploration activities. The drill pads and sumps which were surveyed have been restored, and wastes including waste oils removed from the drill sites and taken to the Project’s temporary waste handling area. These wastes were then recycled, landfilled in clay pits, or in the case of oils are burnt in the site boilers,

### 5.9 ROAD & INFRASTRUCTURE CORRIDOR SOILS

The soil types found along the route of the road and infrastructure corridor comprise the same soil types as found within the Oyu Tolgoi Mine Licence Area. The elevation along the corridor falls steady towards the playa basins of the Galbyn Gobi (see *Figure 5.19*) and there is a corresponding transition in soil types south-eastwards as illustrated in *Figure 5.20*.

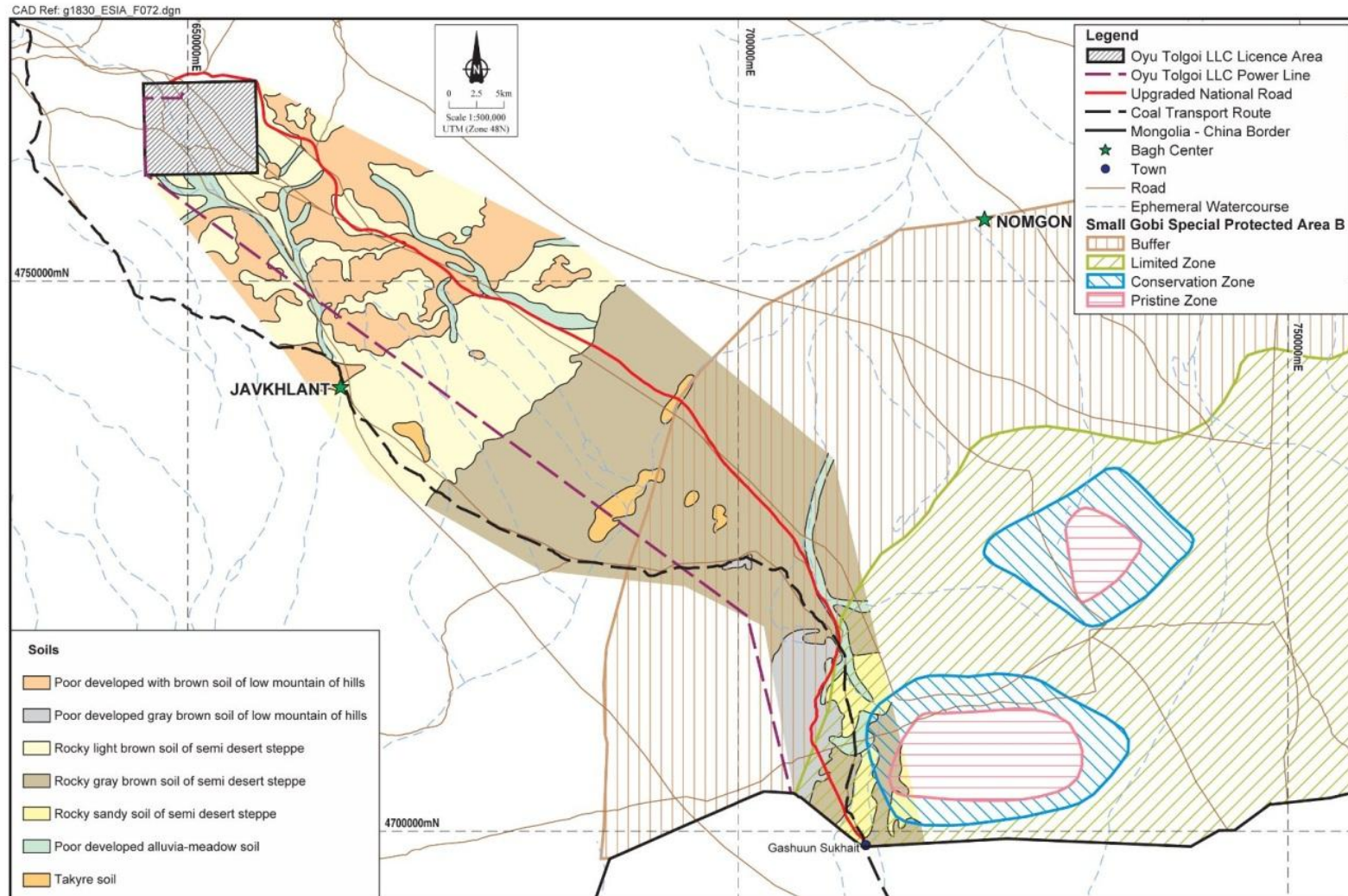
**Figure 5.19: Playa (Takyre) Feature with Vegetation creating Soil Mounds**



Source: Citrus field trip March 2010

<sup>22</sup> Section 8, Oyu Tolgoi (2009), Social, Economic and Environmental Subset Report, by Policy Research and Population Training & Research Centre.

Figure 5.20: Soil Types along Road & Infrastructure Corridor



Source: Eco-Trade (2006) Oyu Tolgoi Supplementary EIA - Oyu Tolgoi to Gashuun Sukhait Road and Infrastructure Corridor

The soils along this corridor have suffered the same impacts as those on the Mine Licence Area, namely overgrazing which is ubiquitous across the area; the use of wide multi-tracked routes along the main corridors has also led to significant erosion. The impact of the road on the local soils and vegetation is illustrated by the current unsealed road being used by Oyu Tolgoi to Gashuun Sukhait in *Figure 5.21*.

**Figure 5.21: Brown Soils with Sparse Vegetation bisected by road to Gashuun Sukhait**




The southern section of road which extends from the border crossing of Gashuun Sukhait northwards to the point where Oyu Tolgoi's road diverges from the existing road alignment and heads north, has been significantly impacted by the use of the route by coal trucks from the Tavan Tolgoi area. The road used by the coal trucks, is significantly degraded, deeply rutted and dusty. Whilst recent grading has improved the road condition, multiple parallel unsurfaced tracks are still used by 4WD vehicles seeking to avoid the worst ruts and the dust generated by the coal trucks, therefore these increase the area of dust generation and degradation of this transport corridor. This route is currently being replaced by a sealed road by the coal companies that use it.

From 2004 to 2007, there was illegal (ninja) mining activity in the Khanbogd *soum* included gold ore treatment using mercury and cyanide near groundwater bores within the Galbyn Gobi. The local and provincial environmental authorities have identified contamination of soils and between 15-20 wells in the Galbyn Gobi area associated with this activity. In 2007, the State regulatory agencies managed to stop the activity, and a total of 35 mills were destroyed and sent for metal recycling. In 2008 & 2009 the majority of these contaminated soils (tailings) from the south Gobi area were collected and brought to Dorvoljin Teeg (about 60 km southeast of Oyu Tolgoi), where a single "licensed" gold refining facility is owned and operated by private businessmen. None of the soil or groundwater contaminated sites have been identified within the proposed infrastructure corridor between Oyu Tolgoi and Gashuun Sukhait.

## 5.10 AIRPORT & GUNII HOOLUI AREA SOILS

The location of the Temporary Domestic Airport, at the western end of the Gunii Hooloi valley, and the rest of the Gunii Hooloi area through which the borefield and its associated infrastructure is being located is characterised by the semi-desert light brown soil with stones. Grazing has stunted the plant cover over the area and some degradation from vehicle tracks is present. The typical soil profile for the area is summarised in *Table 5.4* and typical 'pasture land' over the area is illustrated in *Figure 5.22* and *Figure 5.23*.

**Table 5.4: Soil Profile at Airport Location**

Photographic Record	Depth (cm)	Soil Description
	0-2	Different sized sand gravel cover, windblown origin.
	2-5	Light brown, dry, hardened, low organic matter accumulation, hard crust, vegetation root medium.
	5-13	Light brown, dry-moist, slightly hard, sandy loam textured.
	13-20	Brown, slightly hard, clay, not clear crumb structured, organic accumulation higher than above layer, carbonate accumulated, clear transition.
	20-33	Carbonate accumulation, diffused, hard cemented, stony.

Source: Eco-Trade (2006) Environmental Impact Assessment Report for Oyu Tolgoi Project Domestic Airstrip Relocation

**Figure 5.22: Typical Grassland late in year after rains in the vicinity of the Airport Site in western part of Gunii Hooloi Valley**



**Figure 5.23: Typical Grassland in the vicinity of the Airport Site in the Gunii Hooloi Valley after significant grazing**



In limited areas of the Gunii Hooloi borefield and pipeline area, areas of sandy hummocks (*Nitraria sibirica* vegetation) are present. This soil type is regionally common and the hummocks provide microclimatic opportunities for a wider range of flora and fauna to exploit, however due to the presence of greater vegetation cover in these areas they are often subject to over-grazing.

**Figure 5.24: Area of Sandy Hummocks in the Gunii Hooloi Valley**



*Note: Area being impacted by domestic animal hooves breaking up the surface and breaking vegetation.*

## 5.11 CONCLUSIONS

### 5.11.1 Topography & Landscape

The Oyu Tolgoi Project area comprises a low-lying plain with small hills. The main topographic features are the surrounding mountains which are relatively high for the Gobi and include some sites of religious

and cultural significance such as the Javkhlant Mountain. The Gunii Hooloi basin also comprises gently rolling topography with hills to the southern and eastern limits of the basin. The transport corridor transverses the Galbyn Gobi lowlands and the lowest part of which is characterised by interspersed depressions termed 'playas'.

The Undai is the main landscape feature within the Mine Licence Area. There are no protected landscape areas within the Mine Licence Area; however, and as mentioned above, the landscape value of the surrounding hills is considered to be high. There are no sensitive landscape features in either the Gunii Hooloi valley or transport corridor.

Overall, topography and landscape sensitivity is considered to be low with the exception of the Javkhlant and other mountains which have cultural significance in Mongolia.

### 5.11.2 Geology

There are no geologically-sensitive areas within the Mine Licence Area or transport corridor. The copper-gold porphyry mineralisation in the deposit is related to the oldest recognised intrusive suite (large Devonian quartz monzodiorite intrusions) in the Palaeozoic bedrock.

The overlying undifferentiated Recent-Quaternary sediments contain the alluvial aquifers along the ephemeral watercourses which are relied on by the local herders for domestic and stock water supplies, and also contain more regional aquifers which are relied on by the local communities such as at Khanbogd *soum* centre. These aquifers can vary from ribbon aquifers along ephemeral watercourses to broader sheet type aquifers.

The deeper Cretaceous Bayanshiree Formation forms the aquifer which the Project will access for its water supply and which is not currently exploited in the Project area.

The Oyu Tolgoi site is of low seismic risk, as is much of eastern Mongolia. The nearest tectonically active area in Mongolia is the Mongolian Altai. These are tectonically active mountain ranges stretching some 1,700 km from southwest Siberia to the Gobi Desert. The easternmost extension of the Mongolian Altai is known as the Gobi Altai, which dies out approximately 50 to 100 km west of Oyu Tolgoi. A minor fault (Tavan Takhil fault) is located approximately 20 km south of the proposed TSF. The potential for this, and more distant faults, to generate a seismic event has been taken account of in the TSF design.

### 5.11.3 Soils

Soils in the Project area are generally poorly developed and formed beneath the sparse vegetation cover. The soils have a high silt content and are susceptibility to erosion. This sensitivity to erosion is increased in all areas where there is overgrazing or where unsurfaced tracks are use. The arid conditions, combined with regular strong winds and occasional flood events also contribute to the sensitivity of the area to erosion.