Kenya Electricity Generating Company Limited (KenGen)

REPUBLIC OF KENYA

REPUBLIC OF KENYA
PREPARATORY SURVEY ON
SECOND OLKARIA GEOTHERMAL
POWER PROJECT

FINAL REPORT
(PRIOR RELEASE VERSION)

June 2015

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

WEST JAPAN ENGINEERING CONSULTANTS, INC.

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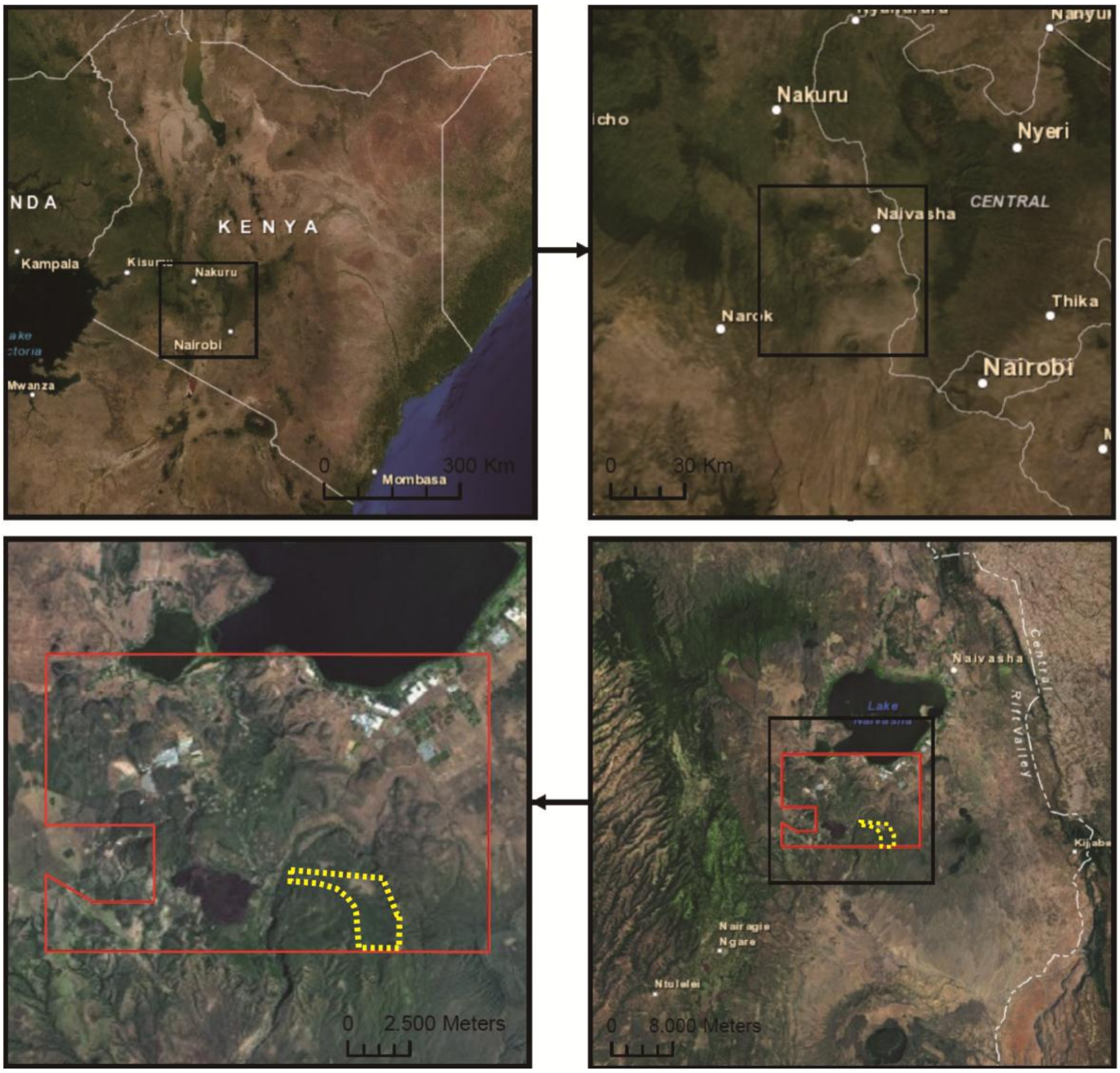
Executive Summary

The objective of the study is to evaluate the appropriateness of the geothermal development plan for Olkaria V, as a project financed by Yen loans, by examining the existing exploration reports and relevant materials.



Olkaria V Geothermal Development Area

The study results can be summarized as follows:

The review of existing exploration reports revealed that the target of the exploration activities was the greater Olkaria region and these reports were not specifically intended for the development of Olkaria V in either the upstream (reservoir) or downstream (power generation facilities) side. Thus the study concentrated on collecting materials and data possessed by KenGen, KPLC and KETRACO which could be utilized for the evaluation of the Olkaria V development plan. Also, additional information collection was attempted by inquiry, site reconnaissance and additional data analysis. The appropriateness of the Olkaria V development plan was examined by integrating all the information collected, together with exploration reports of the greater Olkaria region.

The result of the examination revealed that, from a viewpoint of geothermal resources assessment, the development of 140 MW in the Olkaria V area would be feasible, since

- Olkaria V is located in the up-flow zone of high temperature fluid (> 300 ^{o}C) and a promising geothermal resource is reserved in the area.
- 60% of the necessary amount of steam has been already been confirmed by the discharge tests of existing wells.
- There is a plan to drill an additional eight (8) production wells and eleven (11) reinjection wells. 140 MW of power generation is found to be feasible by using the existing wells and the additional wells.
- An existing forecasting simulation study shows the sustainability of 140 MW of power generation for 30 years.

At present KenGen has not decided the detailed well operation plan, and the plan will be finalized considering the results of drilling that is currently under way. Thus, as a part of the examination in the current study, a tentative well operation plan was assumed, and a suitable piping plan for steam and brine was devised based on the tentative well operation plan. The construction cost was estimated based on the well operation plan and the piping plan. The plan of plant construction and a plan of transmission connecting Olkaria V and the existing Olkaria IV were devised accordingly. The total project cost and project implementation schedule were worked out. The development plan was then examined for its economic and financial efficiency.

The proposed site for the Olkaria V power plant, as shown in the figure below, is the flatland (approximately 250m x 200m) to the west of the proposed wellpad OW-924. Although a long pipeline is needed to bring steam from the production wells, this location has several advantages such as requiring less civil work, no tree felling, and being beside the existing road. The capacity and steam consumption of the power plant are as follows:

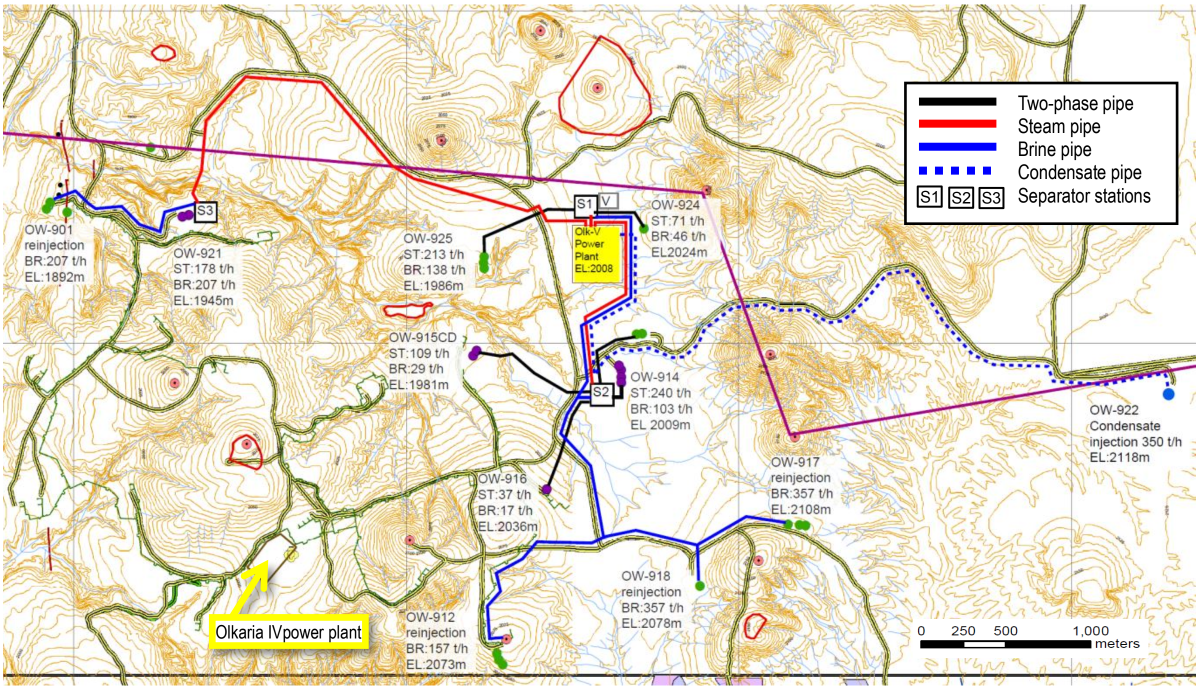
Steam consumption:	518 t/h x 2 units
Gross output:	77 MW x 2 units
Parasitic load:	7 MW x 2 units
Net output:	70 MW x 2 units

The same cooling option of the power plant is assumed (i.e. surface condenser with wet/dry hybrid cooling tower) as that which is assumed in KenGen's report "Feasibility Study for Development of KenGen's Geothermal Concession Area in Olkaria Beyond 430 MWe (Revised September 2012)". This cooling option seeks to increase reinjection by reducing the loss of water through evaporation at the cooling tower. The drawbacks of this cooling option when compared with a conventional direct contact condenser with wet cooling tower are higher capital costs, more maintenance efforts, higher steam consumption, and a larger footprint of the cooling tower. Therefore, the final decision on the cooling option should be made during preparation of the bid documents of the power plant EPC, on the basis of the results of the reservoir simulation and detailed study on power plant's heat-mass balance and cooling tower design.

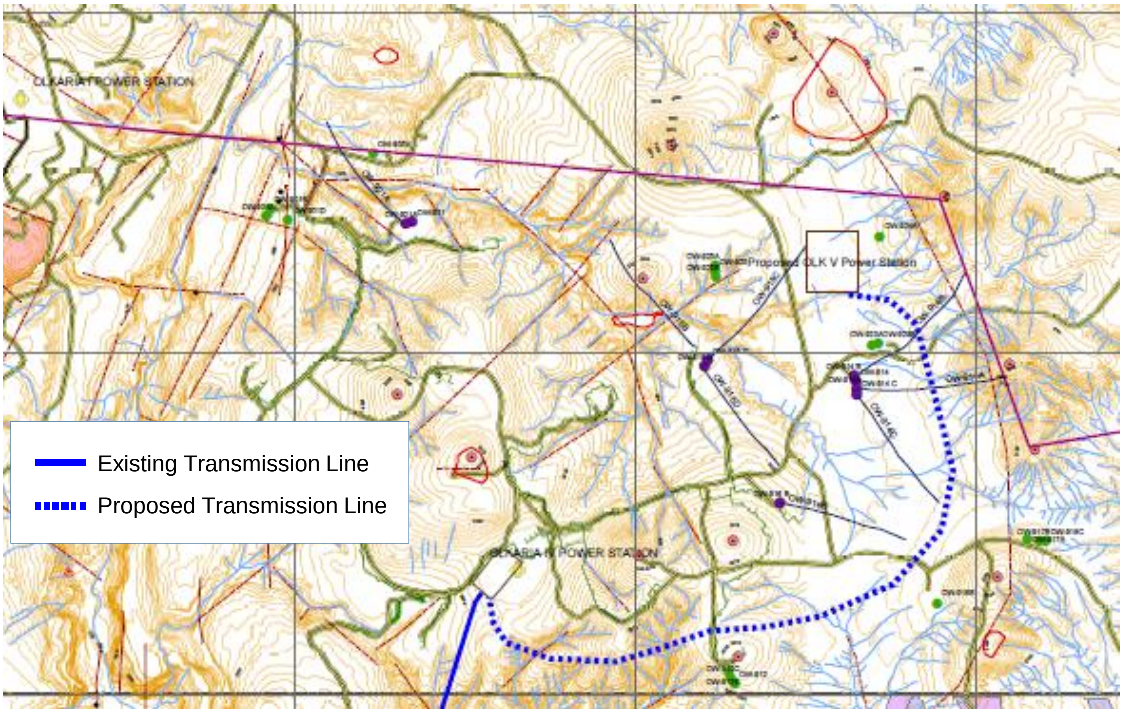
The location of production wells and reinjection wells may be altered and the design of the steamfield will need to be revised during its construction stage depending on the results of production tests of the new wells. In this report, a conceptual design was made based on the development scenario tentatively assumed in the review of the geothermal resource. The overall layout of the pipelines and the separator stations is shown in the figure below.

A 220 kV double circuit transmission line of 5km length will connect the switch yards of Olkaria V and Olkaria IV.

According to the tentative project implementation schedule that was devised assuming the period of the Loan Agreement (L/A) to be late July 2015, it was revealed that the completion date of Olkaria V Unit-1 (70 MW) would be at the end of January 2019, and the completion of Unit-2 would be at the end of April 2019.



Location of power plant and pipeline layout in Olkaria V area



Planned transmission line route

Regarding the environmental and social considerations, KenGen prepared and submitted the ESIA report to NEMA for review, and a conditional license was granted by NEMA in August, 2014, after that review, and a license was granted in September 12, 2014.

According to the Kenya Wildlife Service (KWS) supervisor, there were no animals using the project area as their habitat, as Maasai people were running cattle grazing operations throughout the area. There will be little impact on the habitats of rare species, as their habitats are mainly within the national park. Additionally, there will be little impact from the project on flora.

During the construction period, noise from the drilling of geothermal wells may have some impact. In addition to the mitigation measures proposed by KenGen, the use of silencers, soundproofing walls, or other measures should be considered, as the need arises, when geothermal well drilling and production testing is carried out near the resettlement locations.

KenGen conducted land acquisition and resettlement, which included the area of Olkaria V, during the course of the Olkaria IV construction project. Payment of compensation and physical resettlement of Project Affected Persons (PAPs) was completed respectively in August 2014 and in September 2014. The resettlement site was planned to be transferred to the Community by the end of 2014 or beginning of 2015. The resettlement site is located only 3 km away from the original site. Productivity of the relocation site is equivalent to original site and it is a place where PAPs have already been grazing. In addition, the relocation site is closer to the markets where the PAPs usually trade their livestock. Therefore it is assumed that they can continue grazing as their livelihood. Sufficient compensation has been provided to PAPs such as land, housing and schools, based on the Memorandum of Understanding (MOU). The project site has been purchased at full replacement cost from the land owner. Considering the above, the resettlement and land acquisition was based on JICA Guidelines and no significant gap with the guidelines was found.

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TABLES (ENVIRONMENTAL AND SOCIAL CONSIDERATIONS)

Abbreviations and acronym

Abbreviations and Acronyms	Definition
AFD	French Development Agency
AfDB	African Development Bank
AIDS	Acquired Immune Deficiency Syndrome
B/D	Bid Documents
CAC	Community Advisory Council
CB	Circuit Breaker
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
COD	Commercial Operation Date
DFID	UK-Department for International Development
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
EIB	European Investment Bank
EMCA	Environmental Management and Coordination Act
EMP	Environmental Management Plan
ESIA	Environmental and Social Impact Assessment
EU	European Union
FCRS	Fluid Collection and Reinjection System
FIRR	Financial Internal Rate of Return
FRP	Fiberglass-Reinforced Plastic
F/S	Feasibility Study
GCHM	Grievance and Conflict Handling Mechanism:
GDC	Geothermal Development Company
GDP	Gross Domestic Product
GEF	Global Environment Facility

Abbreviations and Acronyms	Definition
GHG	Green House Gas
GPP	Geothermal Power Plant
HIV	Human Immunodeficiency Virus
H_2S	Hydrogen Sulfide
ICEIDA	Icelandic International Development Agency
IDB	Inter-American Development Bank
IDC	Interest During Construction
IEA	International Energy Agency
IEC	Independent Expert Commission
IEC	International Electrotechnical Commission
IEE	Initial Environmental Examination
IEP	Independent Evaluation Panel
IFC	International Finance Corporation
IPCC	Intergovernmental Panel on Climate Change
IPP	Independent Power Producer
IUCN	International Union for Conservation of Nature
JBIC	Japan Bank for International Cooperation
JICA	Japan International Cooperation Agency
JICA GL	JICA Guideline
KenGen	Kenya Electricity Generating Company Limited
KeRRA	Kenya Rural Roads Authority:
KETRACO	Kenya Electricity Transmission Co. Ltd
KfW	Kreditanstatt fur Wiederaufbau
Ksh	Kenya Shilling
KPLC	Kenya Power and Lighting Company
KWS	Kenya Wildlife Service

Abbreviations and Acronyms	Definition
L/A	Loan Agreement
L/C	Letter of Credit
LCPDP	Least Cost Power Development Plan
masl	meters above sea level
MAED	Model for Analysis of Energy Demand
MOU	Memorandam of Understanding
MVA	Mega Volt Ampere
MT	Electromagnetic Methods
NCG	Non-condensable Gas
NEC	National Environment Council
NEMA	National Environment Management Authority
NGO	Non Govermental Organization
ODA	Official Development Assistance
O.P.	Operational Policies
ORC	Organic Rankine Cycle
OSHA	Occupational Safety and Health Act
OWS	Operator Workstation
O&M	Operation and Maintenance
PAPs	Project Affected People
pH	Hydrogen Power (Potentia Hydrogenii, in Latin)
PPE	Personal Protective Equipment
PPP	Public-Private Partnership
P/Q	Pre-Qualification
PySA	Proyectos y Servicios Asociados (Project and Services Unit)
RAP	Resettlement Action Plan
RAPIC	RAP Implementation Committee

Abbreviations and Acronyms	Definition
rpm	Revolutions Per Minute
SCADA	Supervisory Control And Data Acquisition system
SCC	Stakeholders Coordination Committee
SEA	Strategic Environmental Assessment
SERC	Standards Enforcement Review Committee
STI	Sexually Transmitted Infections
TAC	Technical Advisory Committee
TOR	Terms of Reference
TLV	Threshold Limit Values
UNEP	United Nations Environment programme
UNESCO	United Nations Educationa, Scientific and Cultural Organization
UPS	Uninterruptible Power Supply
USAID/Power Africa	U.S. Agency for International Development Power Africa
VAT	Value Added Tax
VCT	Voluntary Counseling and Testing
WACC	Weighted Average Cost of Capital
WB	World Bank:
WHO	World Health Organization
WRMA	Water Resources Management Authority

I. Geothermal POWER DEVELOPMENT PLAN

1. INTRODUCTION

1.1 BACKGROUND

According to governmental reports of Kenya in 2013, total electric power generation in Kenya in 2013 was 1,644 MW, which consisted of hydraulic power 46% (770 MW), thermal power 37% (622 MW), and geothermal power 14% (241 MW). While the peak demand in 2013 reached 1,357 MW, Kenya has faced serious conditions in terms of power supply, because the capacity factor of hydraulic power plants has been limited due to drought. Moreover, the power demand in Kenya since 2010 to 2020 is expected to annually increase by 14.5%, reflecting the present economic growth. The urgent development of additional new power plants is therefore required for advancing the stability of the power supply in Kenya. A huge potential of geothermal energy, which is not affected by the weather conditions and therefore provides stable power generation, exists in the Great Rift Valley in East Africa. Thus, development of geothermal energy has been counted on in Kenya.

The Vision 2030 that was published in 2008 as a national development plan for Kenya, advances the aims of having a competitive position in the international market and achieving successful economic growth, as an overall goal. The power sector, regarded as an economic foundation, is responsible for securing the electric power necessary to maintain the economic growth, improvements in local electrification, and services for power supply in urban settings. The details of the power development plan have been progressed by implementing the Least Cost Power Development Plan (LCPDP), in which various type of power development and construction of transmission lines are clearly defined, and geothermal power development at the Olkaria area is defined as a project that should be given higher priority among the others in the power development plan.

The Olkaria geothermal power development plan has been implemented or progressed in the areas of Olkaria I, Olkaria II, Olkaria III and Olkaria IV. The additional units 4 to 6 for Olkaria I was already financed by JICA as Yen loans in 2010. KenGen conducted an optimization study on further development of 560 MW in Olkaria, including a feasibility study and an Environmental Impact Assessment (EIA), in September 2012. The EIA report for the new development of Olkaria V has already been completed and submitted (National Environment Management Authority; NEMA, 2014). Although land and houses of the Maasai people exist in the area of development for Olkaria V, the relocation plan was already established at the implementation stage of the Olkaria IV development, and is expected to be completed soon. However, completion of the relocation plan has yet to be confirmed, therefore, it will be necessary to confirm the progress of the relocation. This preparatory survey should be conducted by reviewing the contents, implementation structure, and social environmental considerations of the project, after collecting the information required for the review. It also must define the appropriate ranges for the Yen loans, so that KenGen can use the Yen loans to achieve the further power development plan of 140 MW (70 MW x 2 units) at the Olkaria V area. Production wells to extract geothermal steam needed for power generation, and reinjection wells to inject hot water underground will be drilled by KenGen as their own project. However, as they will be an integral part of this project, environmental and social considerations regarding KenGen's drilling of production and reinjection wells have been included in the scope of this survey, based on JICA Guidelines for Environmental and Social Considerations, published in April 2010 (JICA Guidelines).

1.2 SYSTEM OF GEOTHERMAL POWER GENERATION

(1) Power generation methods:

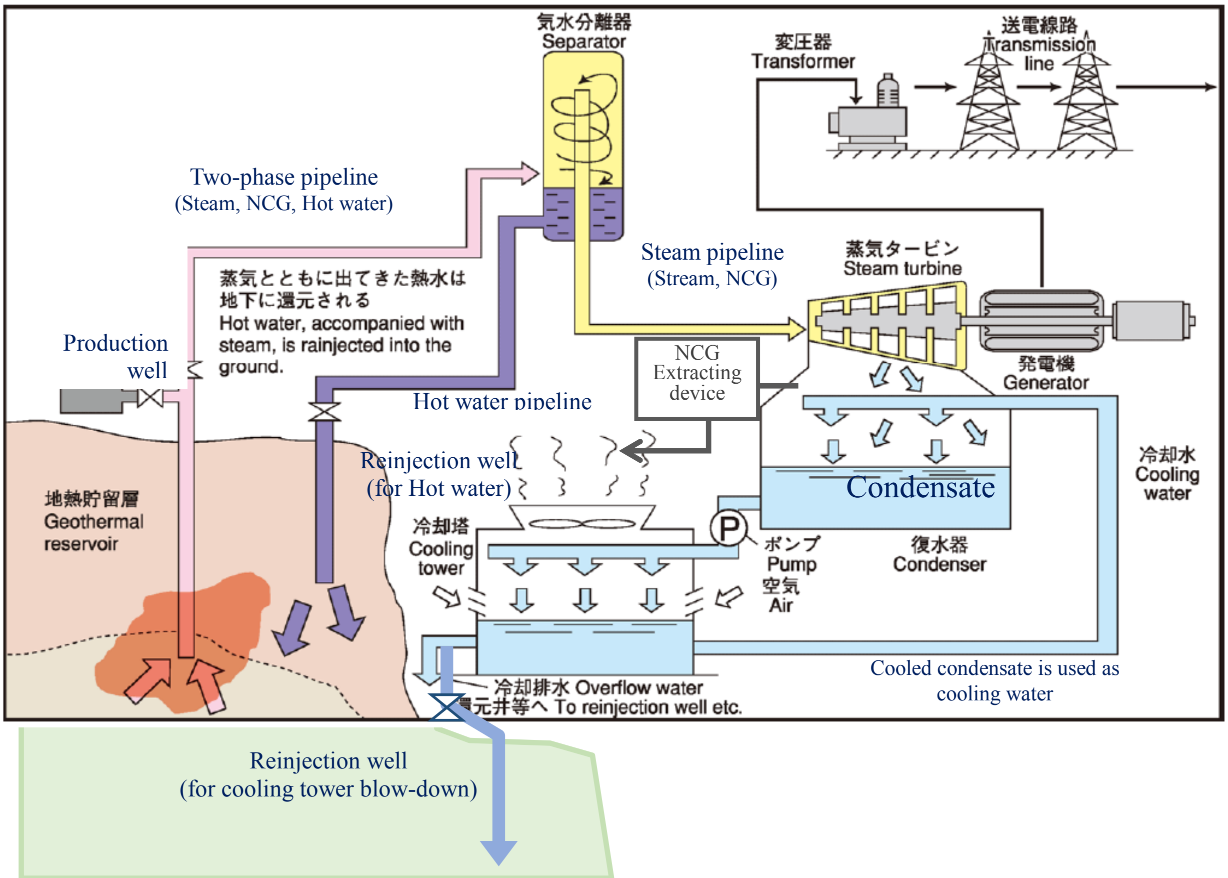
The employment of a single-flash cycle system is being considered for the Olkaria V project.

The mixture of steam and hot water produced at the production wells will be sent via the two-phase pipelines to separator stations, where the steam will be separated from the hot water by use of a steam-water separator (separator). The separated steam will be sent via steam pipelines to the powerhouse, while the hot water will be sent via hot water reinjection pipelines to the reinjection wells, to be injected underground.

Steam sent to the powerhouse will enter the steam turbine, and generate electric power by rotating the steam turbine and the generator (which is directly connected to the turbine). After passing through the steam turbine, the steam will enter the condenser, where it will be cooled by cooling water that is brought in from the cooling tower, to be converted to a liquid form (condensate). The warm mixture of cooling water and condensate will then be pumped to the cooling tower, where it will be air-cooled and thereafter recycled as cooling water. Excess condensate (cooling water) will be sent to the reinjection wells to be injected underground.

Non-condensable gas (NCG) (CO_2, H_2S, etc.) contained in the steam will be extracted by the gas extracting device in the condenser and sent to the fans provided on the upper part of the cooling tower, where it will be mixed with a large amount of hot air exhausted upward by the cooling tower fans and diffused into the atmosphere.

Electric power produced by generator will be adjusted of its voltage to the transmission line by the transformer and will be sent to the grid through the switchgear in the switchyard for providing customers.



(Source: West Japan Engineering Consultant)

Fig. 1.2-1 Conceptual diagram of single-flash cycle system

(2) Fluid collection and reinjection system:

The fluid collection and reinjection system has the following five functions:

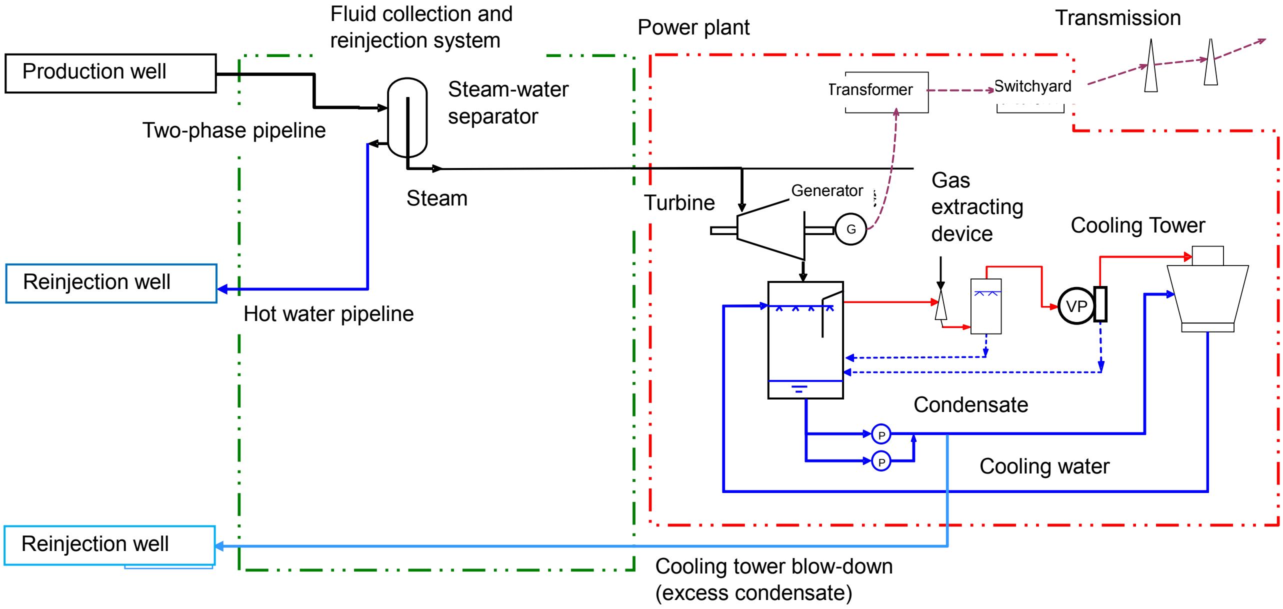
(i) Delivering a mixture of steam and hot water generated at the production wells to the steam-water separator (two-phase pipeline)

(ii) Separating steam from hot water (steam-water separator or separator)

(iii) Delivering separated steam to the powerhouse (steam pipeline)
(iv) Delivering separated hot water to the reinjection wells (hot water pipeline)
(v) Delivering excess condensate to the reinjection wells (cooling tower blow-down, or condensate, reinjection pipeline)

The layout of the fluid collection and reinjection system will be determined after the location of the powerhouse and of the wells to be connected to the powerhouse have been finalized. Basically, a steam pipeline to carry steam will be laid between each production well and the powerhouse, and hot water pipelines will be laid from the powerhouse to reinjection wells, in order to carry hot water that is not needed for power generation.

The finalized plans for the production wells to be connected to the powerhouse will be drawn up after considering the production pressure and other factors at both existing wells and wells that have not yet been drilled. An overview of the fluid collection and reinjection system is shown in Fig.1.2-2.



(Source: West Japan Engineering Consultant)

Fig.1.2-2 Overview of fluid collection and reinjection system

(3) An example of a power plant having the same generation system and installed capacity:

The Olkaria IV geothermal power plant has the same generation system and installed capacity as the Olkaria V, and is located roughly 3 km southwest of the planned location of the Olkaria V power plant.

The cream-colored building at the center is the turbine building, with the cooling tower for Unit 1 on its left and that for Unit 2 on its right. The switchyard (house substation) is behind the turbine building. The site covering the powerhouse and switchyard is roughly 250 m × 350 m.

The transmission lines extend from the switchyard toward the far left in the back. The offices for the contractors and the material yards are to the left of the powerhouse.

To the right of the powerhouse, there are three production wells (OW-908, OW-908A, OW-908B). The separator station is seen at the lower right on the photo, and the vent station to release excess steam into the atmosphere during shutdown of the power plant operation at the lower center on the photo.

(Photographed by West Japan Engineering Consultants Inc. April 27, 2014)
Fig.1.2-3 Olkaria IV Geothermal Power Plant (under construction)

1.3 PURPOSE OF THE PREPARATORY STUDY

The purpose of the Preparatory Study is to investigate the conditions required for reviewing the appropriateness of an ODA loan in terms of the objectives, outline, cost, implementation structure, operation and maintenance structure, environmental and social considerations of the projects.

1.4 STUDY AREA AND INVESTIGATION SCOPE

The project area is in close proximity to Lake Naivasha, the only Rift Valley lake in Kenya with fresh water resources. Though primarily intended for the construction of the Olkaria V power plant, this survey project encompasses the entire Olkaria geothermal field in its scope, in consideration of the extent of impact that neighboring geothermal power plants may have. The study area is the Olkaria geothermal area located at Naivasha, Central portion in Kenya, as shown in Fig.1.3-1. The Olkaria geothermal area and the Olkaria V development area are shown in Fig.1.3-2 and Fig.1.3-3, respectively.

The area is approximately 120 km northwest of Nairobi, and located in the Great Rift Valley. There are already developed well pads and geothermal exploratory wells drilled in the area, and further drilling of production wells and reinjection wells is planned. On the north side, within the project area, lies Hell's Gate National Park. The site slated for the Olkaria V power plant is outside the national park boundary, and the Kenyan government has been conducting its own drilling of wells in the project area. Of the existing well pads constructed by the Kenyan government, those that are likely (at least at this stage) to be connected to the Olkaria V power plant are OW-906, OW-914, OW-915, OW-916 and OW-921. These five well pads comprise 17 wells in all. New additional wells to be connected to Olkaria V Power Plant will, in principle, be drilled outside the national park boundary.

Based on the Geothermal Resources Act, proponents of geothermal development need to obtain a geothermal resource license from the Ministry of Energy to carry out geothermal development projects. KenGen acquired a geothermal resource license for the entire project area in September 2008. New geothermal wells to be connected to the Olkaria V power plant will, in principle, be drilled outside the national park boundary. Slant drilling to access resources under the territory of the national park has been permitted under the Geothermal Resources Act, with an agreement reached between KenGen and KWS.

For this project, a roughly 5-km long 220-kV transmission line is slated to be constructed outside the national park boundary, to connect the Olkaria V power plant and the Olkaria IV power plant in the east around. In principle, the pipelines are scheduled to be installed outside the national park boundaries. However, a part of the steam pipeline connecting the OW-921 and Olkaria V powerhouse will be installed along the existing road that passes inside the national park to minimize environmental impact.

Access roads have already been constructed, and no new roads will be constructed in the Olkaria V project, except for small roads such as those needed to access the transmission towers. These small roads will be constructed on an as-needed basis, will not be paved, and will be rehabilitated with greening after use.

1.5 COUNTERPART AND EXECUTING AGENCY OF THE PROJECT

Kenya Electricity Generating Company Limited.

1.6 ALLOCATION OF EXPERTS

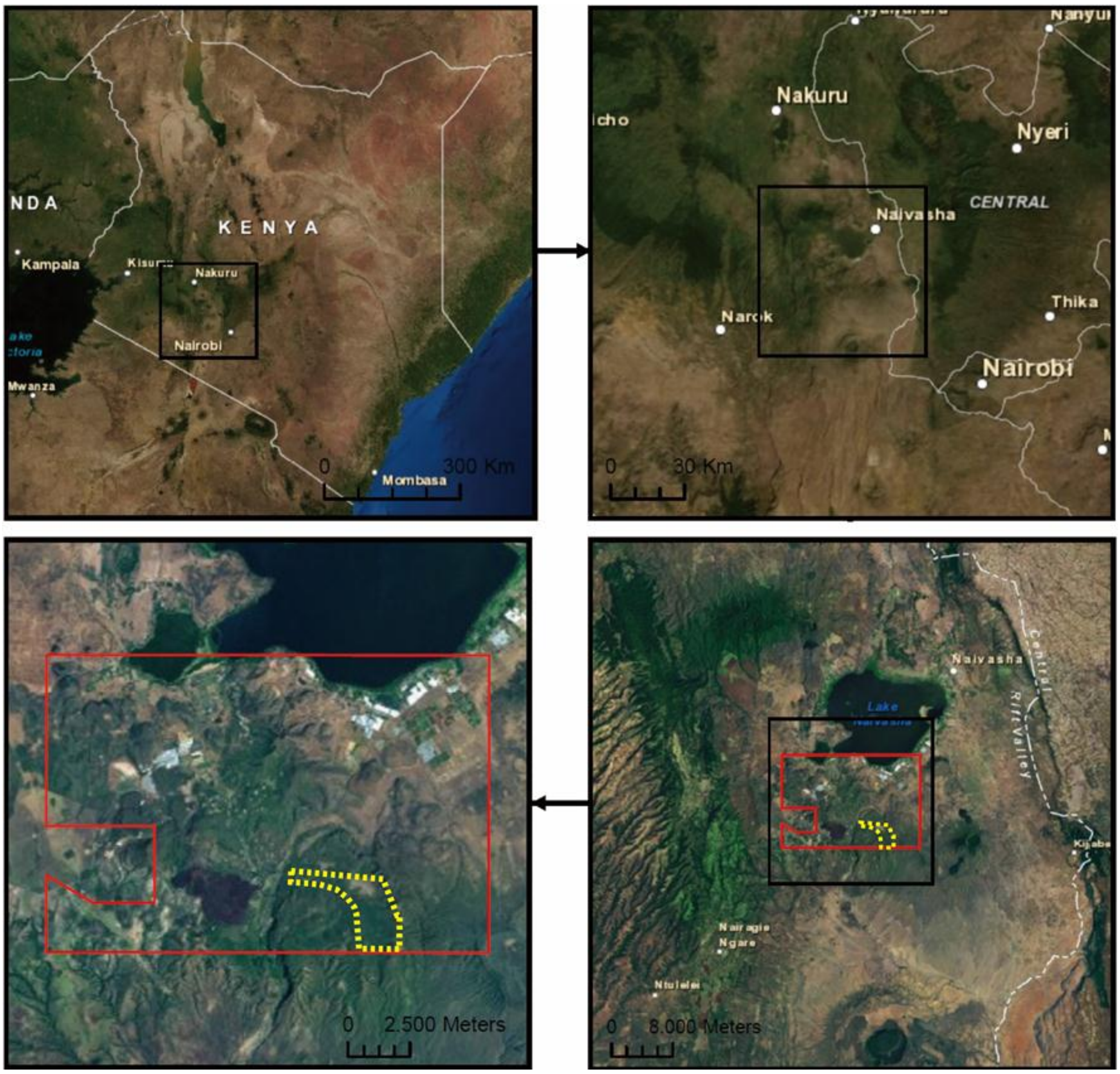
The assignment table of experts in the current project is shown in Table 1.5-1.

1.7 SCHEDULE OF FIRST SURVEY IN KENYA

Schedules of first, second and third surveys in Kenya are shown in Fig.1.6-1, Fig.1.6-2 and Fig.1.6-3, respectively.

1.8 LIST OF COLLECTED INFORMATION

List of information required for the Olkaria V preparatory survey is shown in Table 1.7-1.



Legend :Geothermal License Area :OlkariaV Project Area

Source (The revision to Strategic Environmental Assessment for the Olkaria Geothermal Field Development Programme Draft SEA Report (KenGen, 2014))

Fig. 1.3-1 Location of the project area

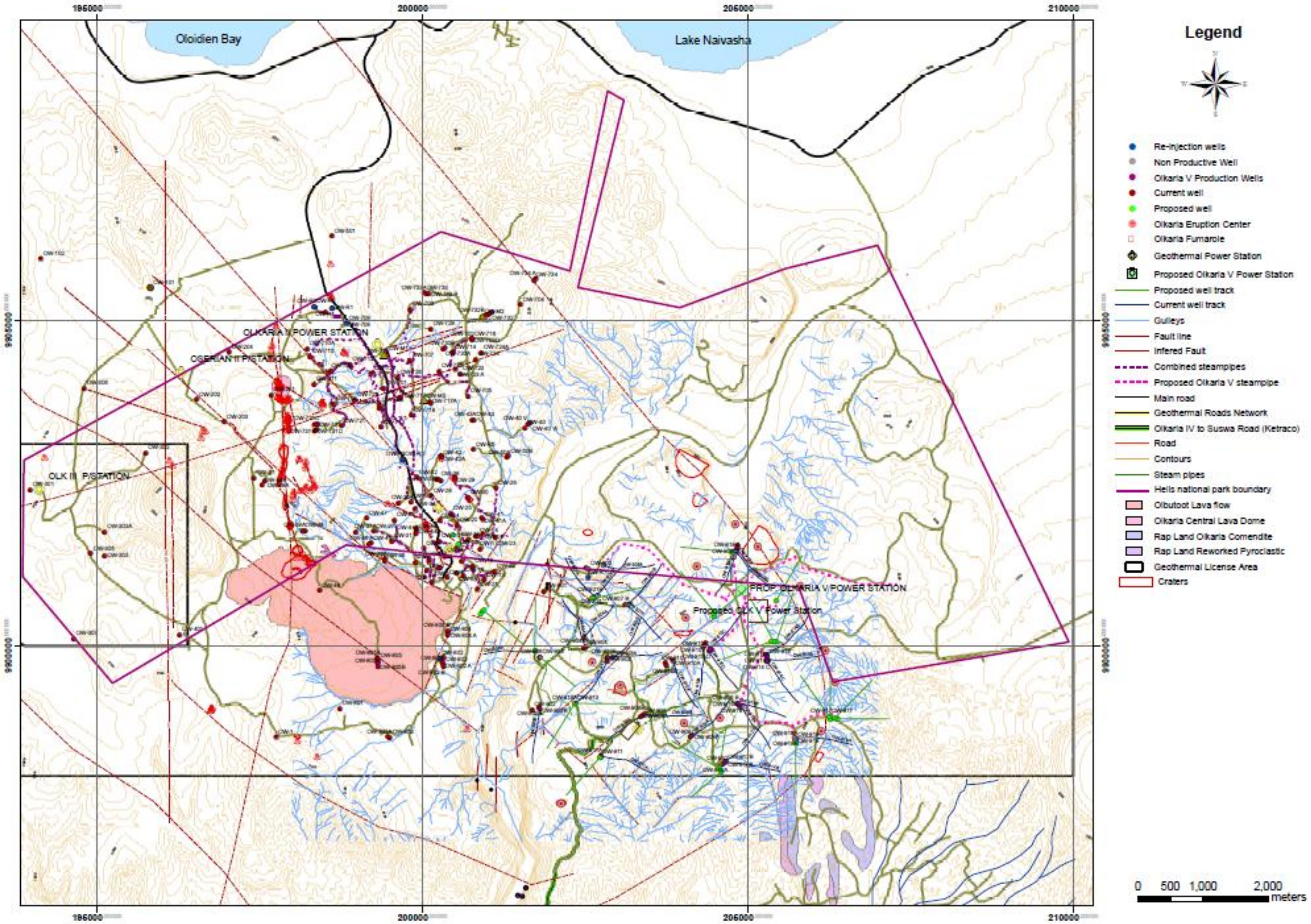


Fig. 1.3-2 Olkaria geothermal area

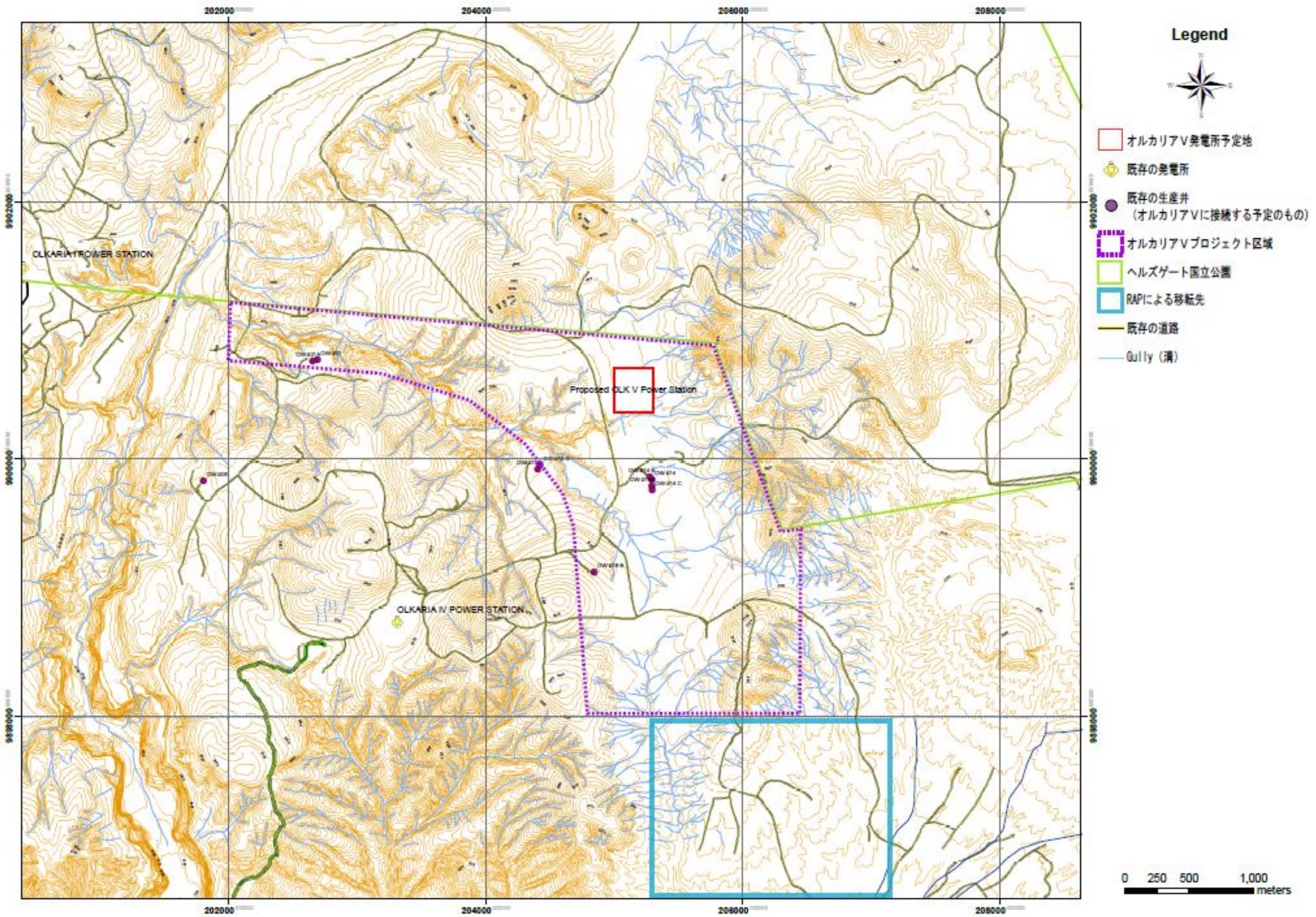


Fig. 1.3-3 Olkaria V development area

Name	Specialization	Aug. 10 Sun	Aug. 11 Mon	Aug. 12 Tue	Aug. 13 Wed	Aug. 14 Thu	Aug. 15 Fri	Aug. 16 Sat	Aug. 17 Sun	Aug. 18 Mon	Aug. 19 Tue	Aug. 20 Wed	Aug. 21 Thu	Aug. 22 Fri	Aug. 23 Sat
Dr. Tokita Mr. Koseki	PM/reservoir Geology	Arrival in Nairobi	Kick Off Meeting at KenGen HQ / Individual Meetings with KenGen Engineers/Staff (NBI)	NV	NV	NV	NV	Depart Naivasha	Arrival in JPN						
				Resource data collection											
Mr. Lima	Sub-PM			NK							NV	NBI	Wrap up at KenGen HQ 10:00AM	Depart Nairobi	Arrival in Japan
Mr. Fukuoka	geophysics			Other project							Data Collection	Ditto, then Nairobi		Other project	
Mr. Ohashi	TL & SS			NV	NV	NV	NV	NV	NV	NV	NV	NBI		Depart Nairobi	Arrival in Japan
				Data Collection	Data Collection	Visit sub-stations (Olkaria & Suswa)		Data Analysis		Data Collection and Discussion with KenGen		Ditto, then Nairobi			
Mr. Yamamoto	Power Plant			NV	NV	NV	NV	NV	NV	NV	NV	NBI			
				Site Visit Olkaria	Site Visit Olkaria	Data Collection and Discussion with KenGen		Data Analysis		Data Collection and Discussion with KenGen		Ditto, then Nairobi			
Ms. Maruyama Mr. Kubota	Socio-Env (social) Socio-Eng (env)			NV	NV	NV	NV	NV	NV	NV	NV	NBI			
				Data Collection at Olkaria				Data Analysis		Data Collection and Discussion with KenGen		Ditto, then Nairobi			
GSL Muthuri GSL Frida	Local consultant Local consultant			NV	NV	NV	NV	NV	NV	NV	NV	NBI			
				NV	NV	NV	NV								

NBI	Nairobi
NV	Naivasha

Fig. 1.6-1 Schedule of the first survey in Kenya

Name Phone number	Specialization	Sep.29	Sep.30	Oct.1	Oct.2	Oct.3	Oct.4	Oct.5	Oct.6	Oct.7	Oct.8	Oct.9	Oct. 10	Oct.11	Oct.12
		Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat	Sun.
Dr. Tokita Hiroyuki Tokita	PM/reservoir						leave for kenya	arrive in Kenya	KenGen meeting at Naivasha, then move to Nairobi	Meeting with KenGen CEO from 9:00 to 10:00 am, then move to Naivasha	Data collection with KenGen and site reconnaissance	move to Nairobi to have a meeting with JICA, then go to airport	back to Japan		
								check in NV	check in NB1	check in NV	NV	check out			
Dr.Nagano Hiroshi Nagano T.B.D.	Economic evaluation							arrive in Kenya	KenGen meeting at 9:00am at Naivasha, then move to Nairobi	Meeting with KenGen CEO from 9:00 to 10:00 am	Data collection with KenGen	move to Nairobi to have a meeting with JICA, then go to airport			
								check in NV	check in NB1	NB1	NB1	check out			
Mr. Yamamura Yoshiteru Yamamura T.B.D.	Civil							arrive in Kenya	Data collection with KenGen, and site reconnaissance			move to Nairobi to have a meeting with JICA, then go to airport			
								check in NV	NV	NV	NV	check out			

Mr. Ohashi Keiichiro Ohashi	TL & SS							arrive in Kenya	KenGen meeting at 9:00am Naivashai, then move to Nairobi	Meeting with KenGen CEO from 9:00 to 10:00 am	Data collection with KPLC at 10:00am	move to Nairobi to have a meeting with JICA, then go to airport			
								check in NV	check in NB1	NB1	NB1	check out			
Mr. Yamamoto Takeshi Yamamoto	Power Plant	leave for Kenya	arrive in kenya	Data collection with KenGen and meeting with JICA if necessary.			Data review	Move to Naivasha	Data collection with KenGen, and site reconnaissance			Data collection with KenGen	Data collection with KenGen	move to airport	back to Japan
			check in NB1	NB1	NB1	NB1	NB1	check in NV	NV	NV	NV	NV	NV	check out	
Ms. Maruyama Naoko Maruyama	Socio-Env (social)		arrive in kenya	Data collection with KenGen		Move to Naivasha and then KenGen meeting at Naivasha	Data review		Data collection with KenGen, then move to Nairobi	Meeting with KenGen CEO from 9:00 to 10:00 am, then move to Naivasha	Data collection with KenGen	Site visit with KenGen, then move to Nairobi	Data collection with KWS	move to airport	
			check in NB1	NB1	NB1	check in NV	NV	NV	check in NB1	check in NV	NV	check in NB1	NB1	check out	
Mr.Kubota Jumpei Kubota	Socio-Env (env)						leave for Kenya	arrive in Kenya	KenGen meeting at 9:00am at Naivashai, then move to Nairobi	Meeting with KenGen CEO from 9:00 to 10:00 am, then move to Naivasha	Data collection with KenGen	Site visit with KenGen, then move to Nairobi	Data collection with KWS	move to airport	back to Japan
								check in NV	check in NB1	check in NV	NV	check in NB1	NB1	check out	

GSL Muthuri	Local consultant								KenGen meeting at 9:00am at Naivasha, then move to Nairobi	Meeting with KenGen CEO from 9:00 to 10:00 am, then move to Naivasha	Data collection with KenGen	Site visit with KenGen, then move to Nairobi	Data collection with KWS		
								check in NV	Nairobi	check in NV	NV	Nairobi	Nairobi		
GSL Frida	Local consultant			Data collection with KenGen		Move to Naivasha and then KenGen meeting at Naivasha	Data review		Data collection with KenGen, then move to Nairobi	Meeting with KenGen CEO from 9:00 to 10:00 am, then move to Naivasha	Data collection with KenGen, Site Visit	Site visit with KenGen, then move to Nairobi	Data collection with KWS		
						check in NV	NV	NV	Nairobi	check in NV	NV	Nairobi	Nairobi		
			NBI	stay in Nairobi											
			NV	stay in Naivasha											

Fig. 1.6-2 Schedule of the second survey in Kenya

<table>
<tr><td rowspan="2">Name</td><td rowspan="2">Specialization</td><td>Dec. 13</td><td>Dec. 14</td><td>Dec. 15</td><td>Dec. 16</td><td>Dec. 17</td><td>Dec. 18</td><td>Dec. 19</td></tr>
<tr><td>Sat</td><td>Sun</td><td>Mon</td><td>Tue</td><td>Wed</td><td>Thu</td><td>Fri</td></tr>
<tr><td>Dr. Tokita</td><td>PM/reservoir</td><td rowspan="4">Leave for Kenya</td><td rowspan="4">Arrive at Nairobi</td><td rowspan="4">Discussion with KenGen HQ at Nairobi, then move to Naivasha</td><td rowspan="4">Discussion with KenGen Olkaria at Naivasha, then move to Nairobi</td><td rowspan="4">Discussion with KenGen HQ at Nairobi to make Minutes of Meeting</td><td>Data review, then move to airport</td><td rowspan="4">Arrive in Japan</td></tr>
<tr><td>Mr. Lima</td><td>Sub-PM</td><td rowspan="2">Discussion with ERC (Energy Regulatory Commission) at Nairobi, then move to airport</td></tr>
<tr><td>Mr. Ohashi</td><td>TL & SS</td></tr>
<tr><td>Mr. Yamamoto</td><td>Power Plant</td><td>Data review, then move to airport</td></tr>
<tr><td colspan="2">Accommodation</td><td></td><td>NBI</td><td>NV</td><td>NBI</td><td>NBI</td><td></td><td></td></tr>
<tr><td colspan="2">Hotel</td><td>NBI: Nairobi
NV : Naivasha</td><td colspan="6"></td></tr>
</table>

Fig. 1.6-3 Schedule of the third survey in Kenya

Table 1.5-1 Assignment of experts

Name	Assignment	Contents of Work
Hiroyuki TOKITA	Team Leader/ Reservoir Engineering	Study coordination F/S Review(Reservoir)
Enrique LIMA	Geothermal Develoopment Plan	Review of geothermal develeopment/ Project Implementation Plan
Takeshi YAMAMOTO	Geothermal Power Plant (Mechanical Eng.)	Review of geothermal power plant construction Project implementation plan
Teruaki MATSUO	Geothermal Power Plant (Electrical Eng.)	Review of geothermal powerp platn construction Poject Implementation plan
Takehiro KOSEKI	Geology	F/S Review (geology)
Koji MATSUDA	Geochemistry	F/S Review (geochemistry)
Koichiro FUKUOKA	Geophysical Prospecting	F/S Review (geophysical explorations)
Keiichiro OHASHI	Power Transmission	Review of power transmission plan
Yoshiteru YAMAMURA	Civil Engineering	Review of geothermal develeopment/ Project Implementation Plan
Hiroshi NAGANO	Economic Evaluation	Project econimic evaluation
Jumpei KUBOTA	Socio-Environmental Considerations (Environment)	Review of existing EIA, Supplemental survey, Support in advisory committee for socio-environmental considerations
Naoko MARUYAMA	Socio-Environmental Considerations (Social)	Review of existing EIA, Supplemental survey, Support in advisory committee for socio-environmental considerations
Local consultant Prof. Francis Muthuri	Socio-Environmental Considerations (Environment)	Review of existing EIA, Supplemental survey
Local consultant Ms. Frida Nzisa	Socio-Environmental Considerations (Social)	Review of existing EIA, Supplemental survey

Table 1.7-1 List of information collection

[Geothermal resource]

No.	Information, reports and data required
[Well location map, contour map]	
1	Well location map of the entire Olkaria area
2	Well location map of Olkaria IV and V(in detail)
3	Base Map (Scale; 1:10000) around the Olkaria-V
4	Contour Map (Scale; 1:1000) around the Olkaria-V
5	Information of coordinate system. Whether or not same coordinate system is used in all maps.
[The existing resource study reports]	
6	Report No.2 Preliminary assessment of the electrical generating capacity of greater Olkaria geothermal system
7	Report No.3 Revision of the conceptual model of the greater Olkaria geothermal system –phase I.
8	Report No.6? No information of the report title
[Data of all wells for Olkaria IV and V]	
9	Coordinates and drilling program of each well (easting, northing, and elevation of each well head, and casing program)
10	Trace data of each well (azimuth and incline angle data)
11	Geological column section with lost circulation depths during drilling, and Distribution of alteration mineral
12	Well-logging data: static pressure and temperature profiles (recovery profiles) data of each well
13	Completion test data of each well (injection test, gross permeability tests [pressure fall-off test] with interpretation of the permeability-thickness products (kh)
14	Production test data: Changes over time of production, injection mass flow rates and wellhead pressure during the production test
15	Relationship between different wellhead pressures and steam mass flow rates, brine mass flow rates and enthalpy (=well deliverability curve or characteristics curve)
16	Chemical analysis for steam and brine including non-condensable gas
[Geophysical Exploration]	
17	Reports of exploration in Olkaria, especially MEQ observation and analysis.
18	MT/TEM apparent resistivity data, and Bouguer anomaly data, if possible.
[Other well data]	
19	Drilling costs (production well and reinjection well)
20	Drilling schedule for the Olkaria V project

[Power plant and Gathering system]

No.	Information, reports and data required
[Power plant and Gathering system]	
21	Detailed topographic maps of Olkaria V and Olkaria IV
22	As-Built Drawings of Olkaria IV power plant (HMB, P&ID, SLD, control block diagram, layout, etc.) and cost breakdown.
23	As-Built Drawings of Olkaria IV gathering system (PFD, P&ID, layout, etc.) and cost breakdown.
24	Design conditions of Olkaria IV power plant (steam conditions, predominant wind direction, wind speed, wet-bulb temperature, seismic conditions, etc.)
25	Water supply and capacity for fire protection and general use in the power plant. (Actual situation in Olkaria IV and the plan for Olkaria V)

26	Discharge point of storm water and general waste water. (Actual situation in Olkaria IV and the plan for Olkaria V)
27	Does KenGen intend to connect the gathering system of Olkaria V with Olkaria IV for the sake of sharing steam and brine?
[Construction work]	
28	Geotechnical information of Olkaria IV and V
29	Actual construction schedule of each lot for Olkaria IV project.
[Procurement method]	
30	Procurement lots (packaging) of Olkaria IV, and plan for Olkaria V
31	Information about local contractors who participated in the Olkaria IV project. (company name, quality of work,
32	Information about material and equipment available in Kenya.
[Organization structure of the execution agency]	
33	Organizational charts of KenGen and Olkaria field.
34	Organizational charts and number of staff of each section in Olkaria IV power plant and steam field
35	Planned organization structure and number of staff of each section in Olkaria IV power plant and steam field
36	Statistical operation record of Olkaria II power plant (availability factor, capacity factor, forced outage)

[Transmission line]

No.	Information, reports and data required
[Annual Reports]	
37	Updated Least Cost Power Development Plan 2013-2033
38	5000+ MW by 2016 Power to Transform Kenya 2013-2016
[Drawings]	
39	Transmission Line Route Map of Olkaria area including future plan if available
40	Layout Drawings of Substations of Olkaria Power Plants including future plan if available
41	Detail Single Line Diagrams of Substations of Olkaria Power Plants
[Contract Documents]	
42	Contract Documents of Olkaria II 3 Plant (Tech. & Financial) for (Power Plant,) Substation and Transmission Line
43	Actual Load Flow of Transmission Network at the time maximum load recorded Simulated Load Flow analysis information for future (LCPDP)

[Environmental and social consideration]

No.	Information, reports and data required
[Laws, regulations, guidelines]	
44	Laws, regulations and guidelines related to the environmental assessment. The formalities and concrete procedures to be taken with the governing authorities
45	Laws, regulations and guidelines related to the disclosure of information, land acquisition, and resettlement of residents
46	Laws, regulations and guidelines related to the environmental matters. The formalities and concrete procedures to be taken with the governing authorities
47	Table-form documents of environmental standards in Kenya (water quality, air quality, noise and vibration, soil contamination, etc.)
48	Natural protection and environmental treaties. Treaty names and dates of signature by the Kenya

[Project]	
49	Detailed location maps around the planning area. (Including well location) Maps of the planning modification area by the construction.
50	Studies about the alternative plans. (Zero option, Project sites, Sources of electricity generations, etc.)
51	The situation of the environmental and social considerations about the appurtenant works.
[EIA]	
52	Status of the examination of EIA of Olkaria V. Approval time.
53	Full text of the EIA report of Olkaria and its detailed survey data.
54	Detailed information about the stake holder consultations (time, location, number of times, participants list, photos, handouts, opinions)
55	Status of the reflections about the stakeholder's opinions of stakeholder consultations.
56	Information of opposition movement by local residents.
57	Acquisitions of approvals and licenses
58	Number of affected people and households for land acquisition and resettlement due to Olkaria V with cutoff date.
59	Any affected people who were not eligible for compensation.
60	Current status of land acquisition and resettlement. (Reason of delay, if there is any. Will the resettlement finish before the Olkaria V construction starts. Implementation status of MOU between KenGen and PAPs.)
61	Implementation status of resettlement monitoring and its result
62	Status of resettlement site. Especially the status of infrastructure such as power, water & roads and access to agricultural land/pasture etc. which is essential for forging their livelihood, access to educational facility and public facility.
63	Progress of compensation to PAPs and livelihood restoration.
64	Confirmation that The Land act 2012, The Land Registration Act, 2012; and The National Land Commission Act, 2012.
65	Current status of Grievance Redress Mechanism.
66	Possibility that impact the amount of water used by the project will adversely affect existing water uses and uses of water areas. (Fishing, water for livestock)
67	Environmental and Social Management Plan and it implantation status.
[Data of the neighborhood]	
68	Environmental monitoring data of Olkaria I to IV.
69	Data of the water level changes of Lake Naivasha
70	Information of land subsidence at Olkaria district after Olkaria I was in service.
71	Information of complaints about Olkaria I to IV
72	Water quality data of the thermal discharge of existing plants. Information about the use of thermal discharge.
[Data about natural environment]	
73	Landscape points around the planning point.
[Data about pollution]	
74	Meteorological data in Olkaria region (Temperature, wind direction, wind speed, rainfall, etc.)
75	Current water quality of Lake Naivasha
76	Conservation plan of Lake Naivasha. Consistency with the conservation plan and the water intake plan.
77	Predetermined volume and quality of water of general effluents
78	Total water usage for geothermal project in Olkaria and its water source. (Including cumulative impact of Olkaria I-IV)
79	Current state of noise around the planning area (Including cumulative impact of Olkaria I-IV)

80	Impact on the geology (Including cumulative impact of Olkaria I-IV)
81	Recent result of H2S monitoring and damage, if any.
[National park]	
82	Regulation about diagonal digging from the outside of National park.
83	Location map of Hell's gate national park.
[Social]	
84	Impact to local archeological, historical, cultural, and religious heritage sites and mitigation measures, if necessary.
85	Impact to local landscape and mitigation measures, if necessary.
86	Laws and ordinances associated with working conditions in the country, which the project proponent should observe in the project and its compliance status.
87	Tangible and intangible safety considerations in place for individuals involved in the project.
[Others]	
88	Information about NGO groups working in Olkaria

KWS：Kenya Wildlife Service
MOU: Memorandum of Understanding
PAPs: Project Affected People

2. METHODOLOGY

2.1 STATUS OF ELECTRIC POWER DEMAND AND CLARIFICATION OF NECESSITY OF THE PROJECT BASED ON THE POWER DEVELOPMENT PLAN

Assuming that the Olkaria V project will be financed by Yen loans, the necessity of the project was verified by referring to predictions of the future power demand in Kenya. For the verification, the power development plan should be reviewed based on (i) the Least Cost Power Development Plan (LCPDP), (ii) the current situation and issues of the power sector, (iii) predictions of power demand, and also, (iv) the policy and plan of the power sector. The latest information should be collected from KenGen, Kenya Electricity Transmission Co. Ltd (KETRACO), and Kenya Power and Lighting Company (KPLC).

2.2 COMPREHENSIVE REVIEW OF THE GEOTHERMAL RESOURCE POTENTIAL, TAKING INTO ACCOUNT THE EXISTING PLANT OPERATIONS

Since the project area for Olkaria V is close to that of the Olkaria IV power plant, it is necessary to review the resource potential, while considering the development plan of the existing power plants. This review should be undertaken through discussion with KenGen, and based upon the existing resource evaluation (simulation) reports, together with updated data of the recently drilled wells.

Based on the existing resource feasibility study reports KenGen provided to the JICA team, the staff of the JICA team reviewed the data quality, methodology of the data analysis, and modeling in terms of geology, geochemistry and geophysics. Whenever the JICA team found issues to be clarified while reviewing the reports and data, the team asked KenGen to clarify them. For the review works, important factors such as the possibility of acidic fluids and scale-deposition were considered together with the resource potential review. In addition, the JICA team reviewed the validity of not only the geothermal reservoir conceptual model which was established based on the results of surface survey and well drilling, but also established harmony between the reservoir conceptual model and the numerical model.

Accuracy of the reservoir simulation study can be commonly evaluated by comparison between the measured and calculated pressure/temperature profiles of the wells in a natural (steady) state simulation. The JICA team checked the matching results of the natural state simulation. The final stage of the reservoir simulation study is to forecast future response in the reservoir during production and reinjection, and also to predict the number of make-up wells required for maintaining the rated power output for the entire plant operation term. The JICA team reviewed the results of the forecasting simulation in order to evaluate sustainability and feasibility of the project.

2.3 CONFIRMATION OF THE PLANT DESIGN BASED ON THE RESERVOIR PROPERTIES

A conventional type, single-flash system is expected to be adopted because the same system has been adopted at all of the existing power plants at Olkaria. However, in this study, the appropriate design of the power generation system and the steam conditions (in accordance with the reservoir properties) were confirmed, by considering topograpy, constraints from environmental and social considerations, the method of connecting to the transmission line, the power generation system's capability, economy, ease of operation and maintenance, and KenGen's opinions.

The study team reviewed KenGen's feasibility study report with regard to the type and capacity of the power plant. The layout of the power plant took into account the relationship with existing facilities, topography, land ownership, and environmental restrictions. To this end, during the first site visit, the specifications, drawings, and cost data of the existing facilities in the Olkaria IV field were investigated together with the field survey of the proposed site for the additional unit.

Based on KenGen's Feasibility Study, including the results of the resource evaluation, drilling plan, and the selected type of the power plant, the design of the gathering system was reviewed. This review took into account the relationship with existing facilities, the topography, land ownership, and environmental restrictions. Detailed topographic maps and technical documents of the Olkaria V field, and the drawings and cost data of the Olkaria IV gathering system were collected during the first site visit. The possibility of connecting with the gathering system of Olkaria IV was also considered for optimum operation of the geothermal resource.
The construction methods adopted for Olkaria IV and those described in KenGen's Feasibility Study report were reviewed in order to decide whether or not they are appropriate for Olkaria V. Information regarding difficulties and technical challenges which were experienced during the construction of Olkaria IV was collected during the first site visit. In addition the method of construction was reviewed to determine whether or not the construction method was a special and/or uncommon type, which influences whether procurement is to be through international tender or sole source contract, and suggestions for remedies were provided.
Regarding the method of construction, the construction methods which were envisaged in the past Feasibility Studies, and the as-built drawings which were prepared in the Olkaria IV project (currently under trial operation), were reviewed and technical difficulties were evaluated for application to the construction planning of the Olkaria V power plant. In addition, remedies for the difficulties were proposed.

The number of the production and reinjection wells and specifications of the power plant, gathering system, substations, and transmission line were outlined as a result of the review mentioned above. In addition, scope and budget of the consultancy services for the project was reviewed based on KenGen's Feasibility Study and the Request for Proposal for Consultancy Services for Olkaria (KGN-GRD-34-2014, 27 May 2014).

2.4 REVIEW OF PLAN/DESIGN OF THE TRANSMISSION LINE AND SUBSTATION

It is expected that KenGen will update the project plan based on the Feasibility Study conducted in 2012. In accordance with the update of the project plan, the reviewed documents for the well drilling plan, plant facility design and transmission plan were also updated in this study. Based on the result of the investigations mentioned above, an analysis was conducted of the importance, priority and feasibility of the Olkaria V geothermal power project in Kenya's power development plan. Information on the legal and institutional framework for geothermal development in the country were collected and integrated into the Study. Furthermore, information on socio-environmental restrictions, technical challenges in constructing the surface facilities, transmission system and the stability of the system in relation to the Olkaria V project was obtained to be analyzed to confirm the feasibility of the project.

There are many geothermal units either under operation or under construction in Olkaria, and the transmission lines are complicated in the area. Thus, the current situation of the transmission lines and substations such as voltage, configuration, capacity of equipment, route of lines, etc. was investigated prior to review of the existing Feasibility Study. Based on the results of the investigation above, the appropriateness of the transmission line and substation plan that is described in the existing Feasibility Study was studied. Since the Olkaria V area is close to the national park, the route of transmission lines was carefully reviewed so as not to enter the park. Furthermore, the impact on the grid and the possible range of its influence in the grid was studied in terms of power flow and fault current when the Olkaria V power plant has been constructed.

2.5 REVIEW OF ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

The category of environmental and social consideration is category "A", which is expected to be classified into the thermal power generation sector (including geothermal). In this study, referring to the JICA Environmental Guideline, the existing EIA Report (February 2014) was reviewed, and the situation of the adherence to the JICA EIA Guideline was confirmed in terms of involuntary resettlement. Furthermore, in this study, the investigation and information collection in relation to environmental and social considerations were delegated to a local consultant in Kenya for efficiency.

2.6 ESTIMATION OF THE PROJECT COST

The steam development costs for well drilling, well-loggings, and production tests were estimated by referring to the drilling records of KenGen and recent drilling costs. The construction costs for the power plant, gathering system, substation and transmission line were estimated based on both the scope of work which would be necessary, as determined by the results of the review and actual records of similar geothermal projects in Kenya and other countries. The cost data of Olkaria IV and Olkaria IAU is a good reference. The O&M costs were estimated based on the actual records for KenGen's existing power plants of a similar type located in Olkaria II, while taking into account the estimated O&M costs of Olkaria IV and IAU and KenGen's policies for the operation and maintenance. The costs related to reservoir management and the drilling of make-up wells was also estimated.

Based on the above cost estimations, the total project cost was calculated. In calculating the total project cost, all the components which are necessary to consider in connection with an ODA loan project, such as the distinction between foreign and local currencies, price escalation, contingency, interest during construction, land acquisition costs, administrative expenses, taxes and commitment charge, were taken into account.

2.7 PROJECT IMPLEMENTATION SCHEDULE

Based on the records of the Olkaria IAU and IV projects and similar ODA Yen loan-financed geothermal projects in Indonesia, the necessary periods of time for the various procurement steps (preparation of bid documents, bidding, bid evaluation, contract negotiation, approval process, concurrences of JICA, etc.) and a construction schedule was determined.

The packaging of the project, (the procurement method for each lot in KenGen's Feasibility Study) was reviewed and discussed with KenGen on the basis of experience with Olkaria IAU and IV. The study team also collected information regarding construction firms and materials available in Kenya, and KenGen's experiences in project management and safety management with Olkaria IAU and IV. This information and the results of the discussion with KenGen were reflected in the implementation plan of the Olkaria V project. The important notices were evaluated regarding the method of tender, selection of contractor & consultant, contractual management, and safety control. This review was based on research results regarding general conditions for tender & contract, local consultants, local contractors, and procurement conditions for machinery & materials, on such similar studies as the on-going loan project located next to this concerned construction project (Olkaria-I unit 4-6 and Olkaria-IV geothermal power plants). Finally, in order to reduce risks associated with bribery from local officers, the past lessons of loan projects, such as Olkaria-I (Unit 4-6) & Olkaria-IV geothermal power plant projects were also examined for application to this project.

2.8 ORGANIZATIONAL STRUCTURE FOR THE PROJECT AND FOR OPERATION AND MAINTENANCE (O&M)

Based on the organizational structure for geothermal resource development, drilling, construction, environmental monitoring and O&M at KenGen's existing power plants (Olkaria II, IAU, and IV), and in collaboration with KenGen engineers, the organizational structure for construction of Olkaria V and its operation and maintenance was reviewed.

2.9 ECONIMICAL EVALUATION

Based on the estimated overall project cost, the internal rate of return for the financial viability of the project (FIRR) was evaluated. The economic feasibility of the project was verified by the economic internal rate of return (EIRR). Financing terms and conditions and other parameters related to the operation of a geothermal plant and an alternative plant was discussed with KenGen, and the evaluation was conducted on the basis of the consensus reached with KenGen. In addition, the sensitivity analysis of several parameters that affect the financial and economic feasibility of the project was carried out, such as the utilization rate of the power plant, and fluctuations in operating costs and in the power sales price.
ODA Yen loan projects are subject to ex-post evaluation after the project is completed. Performance indicators showing actual results relative to what was planned, such as power output (MW), generated electricity (MWh), capacity factor, and availability factor, were proposed. The target values of the indicators were determined based on operation records from KenGen's existing geothermal power plants.

The reduction in greenhouse gas emissions was estimated based on the JICA Climate Finance Impact Tool for Mitigation and Adaptation taking into account the amount of non-condensable gases in steam, conceptual design of the facilities and the assumed capacity factor which are supposed to be found in KenGen's Feasibility Study.

2.10 REMARKS

Since the results of this preparatory survey were utilized as references for making decisions regarding the granting of a Yen Loan, sufficient discussions on the project contents and implementation plan with JICA and KenGen are required to make an agreeable report to both parties. Moreover, it should be noted that the implementation of this preparatory survey is not a promise to grant a Yen Loan.

2.11 IMPLEMENTATION FLOW

The implementation flow of this study is shown in Fig.2.11-1.

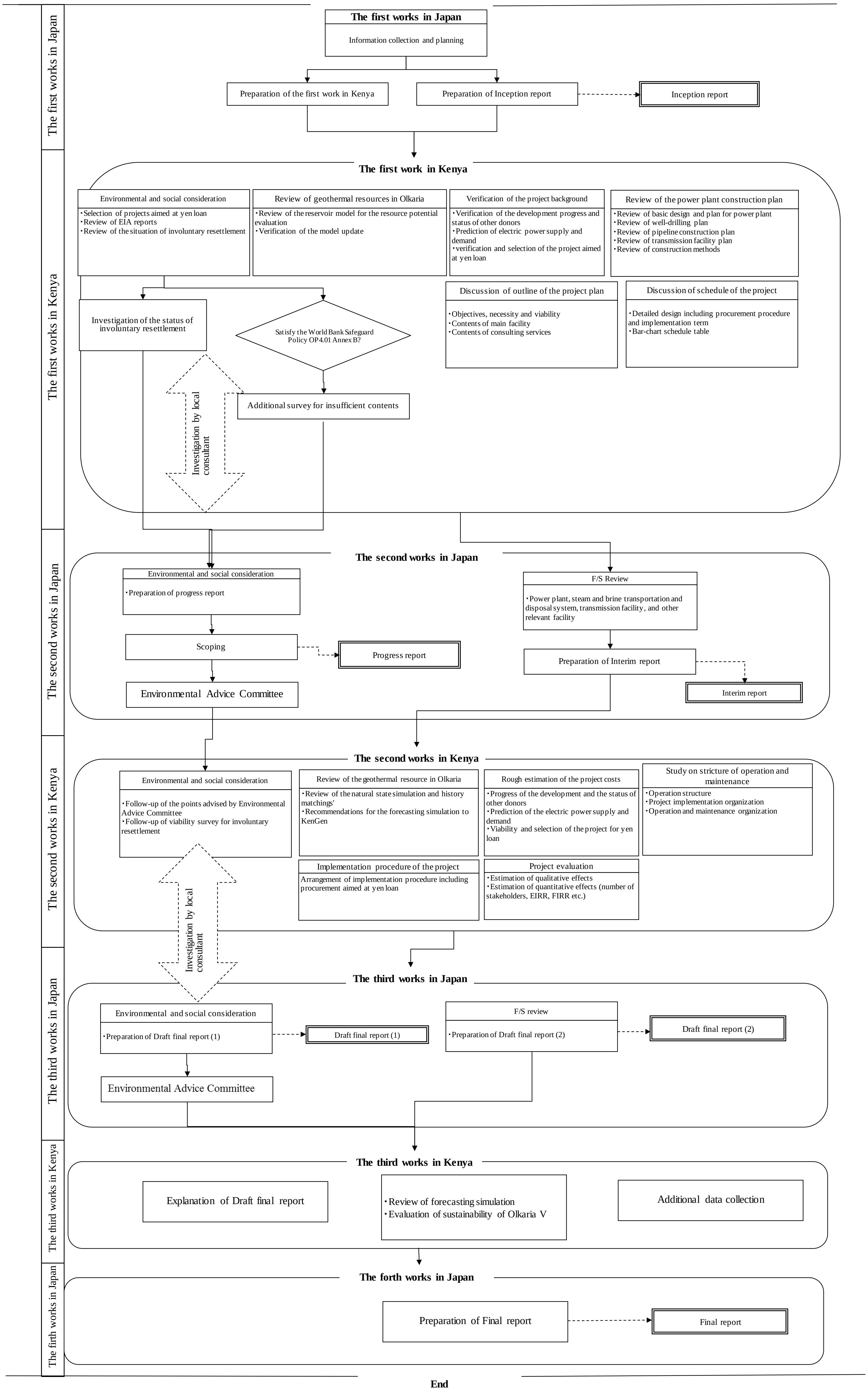


Fig. 2.11-1 Implementation flow

2.12 TIME TABLE

In the current project, the methodology described in “II-2 Methods of the Study” was executed from late July 2014 to January 2015 according to the schedule show below. The time table of the project is shown in the Table. 2.12-1.

Table 2.12-1 Time table of the project

Work Plan

Period / Activities	2014							
	7	8	9	10	11	12	1	2
First Work in Japan								
(1)Collection and analysis of data and information								
(2)Explanation and discussion on the Inception Report		Ic/R						
(3)Preparation for the study in Kenya								
First Work in Kenya								
(1)Confirmation on the background and validaty of the project								
(2)Review on the geothermal resource in Olkaria Geothermal field (1)								
(3)Review of the Olkaria Power Plant construction plan base on existing data								
(4)Considerration of the project summary								
(5)Consideration of the project schedule								
(6)Review on the existing environmental assessment reports								
(6)'（If necessarry） Additional study on environemental study								
(7)Confirmation on the sitation for the involuntary resettlement								
Second Work in Japan								
(1)Preparation of the progress report（Environmental and Social Consideration draft)			PR/R					
(2)Preparation of theInterim report（Technical results）								
Second Work in Kenya								
(1)Follow up on the suggestions by the Environmental Advisory Board (additional study)								
(2)Review on the geothermal resource in Olkaria Geothermal field (2)								
(3)Estimation of the project cost								
(4)Establishment of the project implementaion plan								
(5)Consideration on the projects implementation and maintanace scheme								
(6)Evaluation of the project								
Third Work in Japan								
(1)Preparation of the DFR, discussion and explanation						DF/R(2)		
(2) Assist torespond the Environmental Advisory Board				DF/R(1)				
third Work in Kenya								
(1) Discussion and explanation for the DFR								
(2)Review on the geothermal resource in Olkaria Geothermal field (3)								
(3)Collection of additional data and information								
Fourth Work in Japan								
(1)Preparation of the FR								F/R
The submision of each type of reports		Ic/R	PR/R	DF/R(1)	It/R DF/R(2)		F/R	

Legend：Preparation——— Work in Kenya Work in Japan Explanations of the reports△——△ Other works period ----------

3. RESULTS OF THE SURVEY

3.1 REVIEW OF ELECTRIC DEMAND AND POWER DEVELOPMENT PLAN IN KENYA

In order to understand the electric power demand in the future and the power development plan in Kenya, the following information was collected in the first survey in Kenya. Based on this information, the electric power sector's plan will be interpreted.

No.	Report
1	5000+ MW by 2016 Power to Transform Kenya 2013-2016
2	2013-2033 (Least Cost Power Development Plan 2013-2033 (LCPDP))
3	2014-2024（Ten Year Power Sector Expansion Plan 2014-2024）
4	2014-2018（Power Sector Medium Term Plan 2014-2018）
5	Annual Reports of Kenya Electricity Generation Company (KenGen), Kenya Electricity Transmission Co. Ltd (KETRACO) and Kenya Power and Lighting Company (KPLC)

3.1.1 Power Sector Situation

The government of Kenya is preparing itself for a major economic and social transformation within the framework of "Vision 2030". Vision 2030 identifies energy as a key driver for the requisite economic growth at a steady 10%. The power sector is preparing long term electricity planning through an annual 20 year Least Cost Power Development Plan (LCPDP) in which several kinds of generation and development projects are clearly introduced. According to the "Vision 2030－Updated Least Cost Power Development Plan 2013-2033 (March 2013)－, which indicates the development plan for each power source and transmission line, the composition of power generation in the year 2033 is estimated as follows: hydro (3%), nuclear (11%), diesel (2%), import (8%), natural gas (16%), geothermal (29%), coal (22%) and wind (9%). Further, the government aims to rapidly increase the installed capacity to 6,762 MW by 2017 in a project dubbed "5000+ MW power to transform Kenya". While the LCPDP considers both the committed and candidate projects to inform long term investment options, the power sector is preparing a Medium Term Plan 2014 – 2018 (MTP 2014 – 2018) which is a more accurately predicative plan based on already committed projects and a Ten Year Power Sector Expansion Plan which builds on the MTP 2014-2018 in light of the government policy to accelerate power generation in the country.

In these plans, geothermal power plants, including Olkaria, is one of the highest priority businesses due to its position as an indigenous, renewable energy source and lower generating cost plant for a base load operation. The project of Olkaria V is appeared in the three plans mentioned above as the committed plant to commence operation in 2017.

3.1.2 Power Sector Institutional Structure

The power sector is currently structured as defined in the Energy Act 2006 and the institutional structure for the sector is as follows:

1) Ministry of Energy (MOE): Responsible for policy formulation and overall guidance in the sector
2) Energy Regulatory Commission (ERC): Oversees all regulatory functions including coordinating the development of indicative energy planning, tariff setting and oversight, monitoring and enforcement of sector regulations.
3) Kenya Electricity Generating Company (KenGen): The Company accounts for over 70%

of the installed capacity in the country from various power generation sources and is the main player in electricity generation. It is listed at the Nairobi Stock Exchange with the shareholding being 70% by the Government of Kenya and 30% by private shareholders.

4) Kenya Power and Lighting Company (KPLC): The single off-taker in the power market, buying power from all power generators for onward transmission, distribution and supply to consumers (single seller). KPLC is also the system operator in charge of power dispatch and retailing. It is listed at the Nairobi Stock Exchange with the shareholding being 50.1% by the National Social Security Fund (NSSF) and the GoK whereas the private shareholders own 49.9%.

5) Rural Electrification Authority (REA): A special purpose vehicle (SPV) charged with the mandate of implementing the Rural Electrification Programme which came into operation in July 2007.

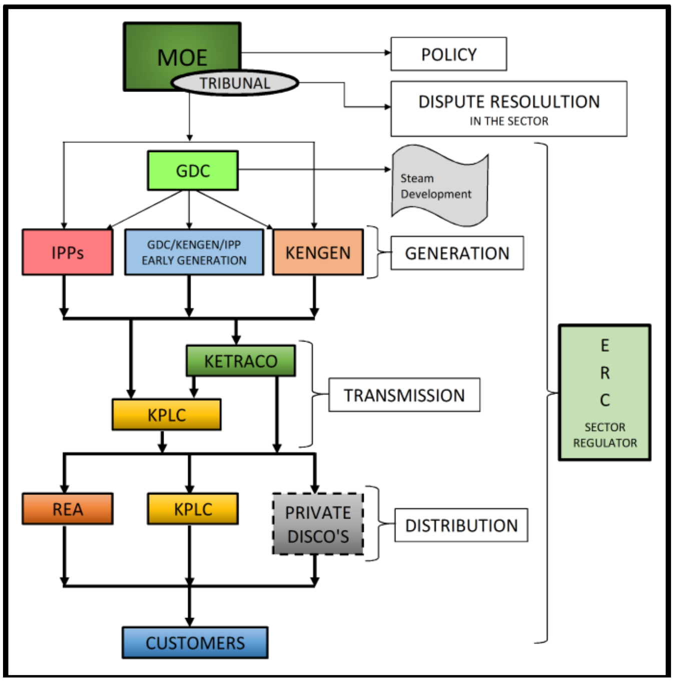
6) Geothermal Development Company (GDC): A specialized institution established to undertake surface exploration of geothermal fields, undertake exploratory, appraisal and production drilling, develop and manage proven steam fields and enter into steam sale agreements with investors in the power sector.

7) Independent Power Producers (IPPs): Private investors in the power sector involved in competitively procured, large scale generation and the development of renewable energy under the Feed-in-Tariff Policy.

8) Kenya Electricity Transmission Company (KETRACO): A government owned company established to plan, design, construct, own, operate and maintain new high voltage (132kV and above) electricity transmission infrastructure that will form the backbone of the National Transmission Grid and regional inter-connections.

9) Energy Tribunal: The sector dispute resolution entity largely involved in settling disputes arising from decisions made by the Energy Regulatory Commission or settling of consumer complaints.

10) Kenya Nuclear Electricity Board (KNEB): It is tasked with driving the nuclear energy generation program for Kenya. This will be achieved through the preparation, endorsement and implementation of a detailed road map for the realization of the requirements and guidelines by the International Atomic Energy Agency (IAEA) for establishment of the first nuclear power plant.



(Source) Updated Least Cost Power Development Plan 2011-2031

Fig. 3.1.2-1 Power Sector Institutional Structure

3.1.3 Current Status of Power Facilities

(1) Generating Facilities

The interconnected system in Kenya had a total installed generating capacity of 1,720 MW as of December 2013; made up of 820 MW of hydro, 620MW of thermal, 250 MW of geothermal, 5 MW of wind, and 26MW from cogeneration. The total effective capacity was 1,663 MW during normal hydrology from the interconnected system. Hydro accounts for around 47.5% of the total energy supply.

The installed generating capacity owned by KenGen is 1,238.7 MW and the effective one is 1,127.8 MW.

It is noted that since Olkaria IV (140 MW) and Olkaria I Additional Units (140 MW) have been operating since October 2014 and January 2015 respectively, therefore, the installed capacity of Geothermal is 529.90 MW and the contribution of Geothermal becomes 26 % at the time of the reporting.

Table 3.1.3-1 Generating Capacity by Technology（as of December 2013）

	Installed	Effective	Contribution
Hydro	820.20	789.90	47.5%
Geothermal	249.90	233.08	14.0%
Thermal (MSD)	564.00	559.35	33.6%
Thermal (GT)	54.00	54.00	3.2%
Wind	5.10	5.10	0.3%
Solar	0.00	0.00	0.0%
Cogeneration	26.00	21.50	1.3%
Interconnected System	**1720**	**1,662.93**	**100%**
Off grid	27.61	21.64	
Total Capacity	**1,748.16**	**1,684.56**	

(Source) Ten Year Power Expansion Plan 2014-2024

(2) Transmission and Distribution System

Currently the transmission network is shared between KPLC and KETRACO. The total transmission network (220kV and 132kV) stood at 3,871kms as of December 2013 of which 424km (all at 132 kV) were under KETRACO while the rest were under KPLC. The Transmission Network in Kenya is shown in Figure 3.1.3-1

The entire distribution network of over 42,176kms in the country is operated by KPLC. The network consists of 66kV feeder lines around Nairobi and 33kV and 11kV medium-voltage lines elsewhere in the country where distribution sub-stations have been.

The transmission sub-station capacity was 2,976 MVA and the capacity of distribution sub-stations was 2,442MVA in 2012, while in 2007 those figures were 2,714 MVA and 1,874 MVA respectively.

Kenya is a member of the Eastern Africa Power Pool (EAPP). The purpose of EAPP is to interconnect all the countries of the Eastern Africa Region, so as to optimize power generation resource development in an economically and environmentally sustainable manner and ensure the efficient provision of adequate, secure and affordable, quality power. Interconnection transmission lines such as a 220 kV double circuit line to Uganda, a 400 kV double circuit line to Tanzania and a 500 kV DC line to Ethiopia, are proposed by the EAPP.

3.1.4 Electricity Supply and Demand

The peak demand showed an upward trend in the last several years, as indicated in Figure 3.1.4-1, and recorded 1,463 MW as a maximum in 2013. (2013/14) increased by 8 % in comparison with the year 2012.

The load curve is illustrated in Figure 3.1.4-2, showing the amount of electricity which customers use over the course of time and indicates a maximum around 20:00 hours when household customers consume the most energy. This consumption pattern is consistent throughout the year.

The supply energy increased to 8,088 GWh in 2013 from 7,670 GWh in 2012, presenting a 5 % increase as shown in Table 3.1.4-1. The growth in demand can be attributed to a combination of normal growth; increased connections in urban and rural areas as well as the country's goal to transform into a newly industrialized country as articulated in Vision 2030.

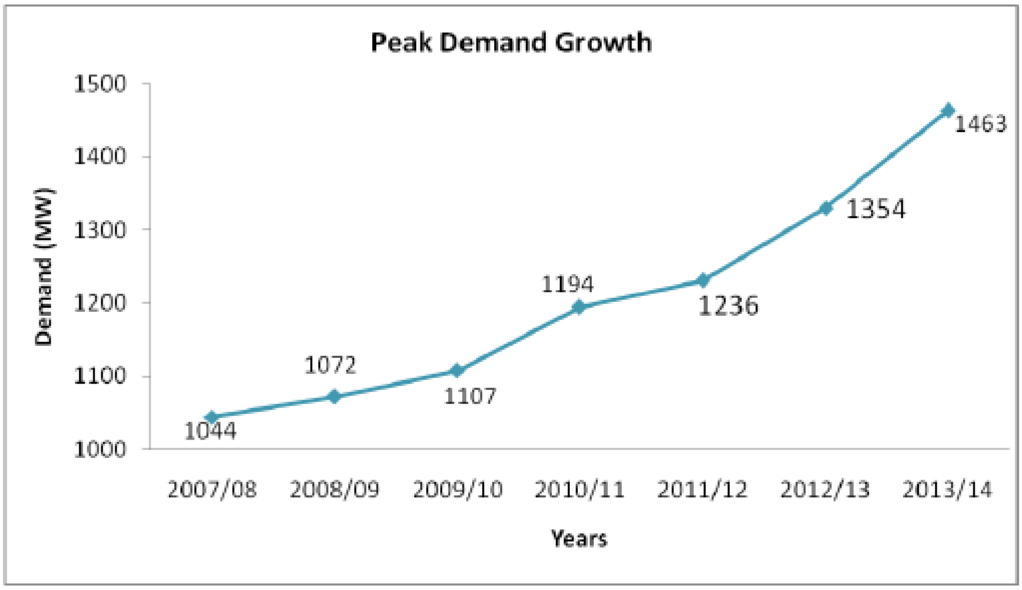
Total overall customers increased from 2,038,625 in 2011 to 2,330,962 in 2012. These increases can be broken down into two categories; an increase of 1,655,994 to 1,877,418 in urban areas and an increase of 382,631 to 453,544 in rural areas.

In Kenya, electricity is supplied to about 30% of the total population. This is predominantly to middle and upper income groups. The utility's strategy to extend lines to rural areas in order to connect more customers and enhance sales growth is currently under implementation.

The rural electrification scheme has seen rapid expansion and recorded consumption of 313GWh in 2012/13, up from 240GWh in the 2007/08 period. Recent accelerated growth can be attributed to the creation of the special purpose vehicle, Rural Electrification Authority, which is dedicated to expanding electricity access in rural areas as provided for in the Energy Act 2006.

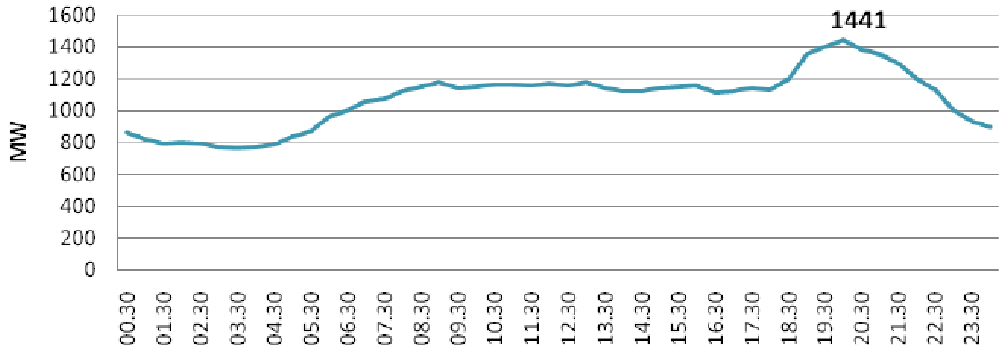
(Source) MTP (2014-2018)

Fig. 3.1.3-1 Transmission Network in Kenya（132kV and above）



(Source) Ten Year Power Expansion Plan 2014-2024

Fig. 3.1.4-1 Annual Peak Demand (2007 – 2013)



(Source) Ten Year Power Expansion Plan 2014-2024

Fig. 3.1.4-2 Day Load Curve (November 21, 2013)

As for regional sales trend, the Nairobi region has consistently recorded the highest sales in electricity in the country, accounting for an average of 53% of total sales. During the review period, Nairobi sales increased from 3,315 GWh in 2011/12 to 3,507 GWh in 2012/13. The coast region was the second highest customer.

Technical loss in transmission and distribution lines was recorded at 18.6 % in total in 2013 and the low voltage distribution line loss of 13.6 % represents the greatest value of the loss. Since loss minimization is reciprocated by financial gains of revenue and trading margin maximization, strategies and programs are being discussed in KPLC to reduce losses.

Table 3.1.4-1 Supply Energy（GWh）

	2009	2010	2011	2012	2013
Generation in Kenya					
1. Renewable Energies					
1.1. Hydro plants KenGen	2849	2170	3427	3450	4298
IPP Tee factory	0.0	0.3	0.4	0.8	0.7
Total Hydro	**2849**	**2170**	**3427**	**3451**	**4299**
1.2 Geothermal plants KenGen	903	939	1081	1106	1096
IPP OrPower	276	400	372	392	503
Total Geothermal	**1179**	**1339**	**1453**	**1498**	**1599**
1.3 Wind Farms	0.3	16	18	15	14
Total Wind	**0**	**16**	**18**	**15**	**14**
1.4 Cogeneration KenGen					
Cogeneration IPP	4	99	87	100	71
Total Cogeneration	**4**	**99**	**87**	**100**	**71**
Total renewable	**4032**	**3625**	**4985**	**5063**	**5983**
2. Fossil Fuels					
2.1 Diesel plants KenGen	393	335	514	806	533
AGGREKO	914	1096	267	381	261
Diesel plants IPP	910	1434	1484	1326	1213
Total diesel	**2217**	**2865**	**2265**	**2513**	**2007**
2.2. Gas Turbines KenGen	193	145	1	33	27
Total Gas turbines	**193**	**145**	**1**	**33**	**27**
Total fossil fuels	**2410**	**3010**	**2266**	**2546**	**2034**
Total Domestic Generation KenGen	**4338**	**3605**	**5041**	**5410**	**5968**
Total IPP	**1190**	**1933**	**1943**	**1819**	**1788**
Total IPP+AGGREKO	**2104**	**3029**	**2210**	**2200**	**2049**
Off Grid (REP)	**16**	**19**	**21**	**23**	**27**
Global Generation	**6458**	**6654**	**7272**	**7632**	**8045**
Plus Imports	30	38	31	37.1	42
Global Supply in Kenya	**6489**	**6692**	**7303**	**7670**	**8088**
Less Exports : (Uganda, Tanesco)	**27**	**27**	**31**	**42**	**32**
Total Resources Available for Consumption in Kenya	**6462**	**6665**	**7272**	**7628**	**8056**

(Source) Ten Year Power Expansion Plan 2014-2024

3.1.5 Electricity Retail Tariff

Kenya's retail tariff incorporates the combined cost of generation, transmission and distribution and ensures sustainability as it is based on the revenue requirements of the transmitting and distributing company, KPLC. Table 3.1.5-1 shows the retail electricity tariff structure of December 2013 and later.

Table 3.1.4-2 Demand Energy（GWh）

	2009	2010	2011	2012	2013
1. HV Customers	**430**	**466**	**547**	**548**	**586**
2. MV Customers	**1147**	**1218**	**1362**	**1359**	**1408**
3. LV Customers					
3.1 Domestic Customers					
Dom 1	1254	1290	1424	1520	1645
Total Domestic	**1254**	**1290**	**1424**	**1520**	**1645**
3.2. Commercial and Industrial LV Consumers					
Small Commercial	823	823	904	993	1059
Comm. & Indust. – CI1	1443	1469	1492	1511	1493
3.3 Street Lighting	15	17	18	16	24
3.4 REP	250	279	307	308	313
3.5 IT Off-peak load	42	37	38	43	22
Total Comm & Industrial =	**2574**	**2625**	**2759**	**2871**	**2911**
Total LV	**3828**	**3915**	**4183**	**4391**	**4555**
Total End-use Consumption	**5405**	**5599**	**6092**	**6299**	**6549**

(Source) Ten Year Power Expansion Plan 2014-2024

Table 3.1.4-3 Losses（GWh）

	2009	2010	2011	2012	2013
Total Energy Consumed in Kenya	6461	6666	7272	7628	8045
Total End-use Consumption	5405	5599	6092	6299	6549
Total Technical Losses	**1057**	**1068**	**1180**	**1329**	**1497**
Technical Loss Rates					
High Voltage	3.70%	3.70%	3.80%	4.20%	4.20%
Medium Voltage	5.80%	5.70%	5.80%	6.20%	6.20%
Low Voltage	11.18%	10.96%	11.24%	11.84%	13.60%
Global	**16.4%**	**16.0%**	**16.2%**	**17.4%**	**18.6%**

(Source) Ten Year Power Expansion Plan 2014-2024

Table 3.1.4-4 Total Sales by Region（GWh）

REGION	**2009**	**%**	**2010**	**%**	**2011**	**%**	**2012**	**%**	**2013**	**%**
Nairobi	2,898	53%	3,014	54%	3,268	53%	3,315	52%	3,507	53%
Coast	979	18%	1,027	18%	1,118	18%	1,147	18%	1,134	17%
West	867	16%	853	15%	932	15%	1,003	16%	1,056	16%
Mt. Kenya	411	8%	424	8%	467	8%	494	8%	539	8%
KPLC Sales	**5,155**	95%	**5,318**	95%	**5,785**	94%	**5,959**	94%	**6,236**	94%
R.E.P.	250	5%	279	5%	307	5%	340	5	313	5%
Export	27	0%	27	0%	31	1%	42	1	32	1%

(Source) Ten Year Power Expansion Plan 2014-2024

Table 3.1.5-1 Retail Electricity Tariff Structure

				1st Dec 2013 to 30th June 2014			1st July 2014 to 30th June 2015			1st July 2014 to Next Review		
Tariff	Type of Customer	Supply Voltage (V)	Consumption (kWh/month)	Fixed Charge (KSh/month)	Energy Charge (KSh/kWh)	Demand Charge (KSh/kVA	Fixed Charge (KSh/month)	Energy Charge (KSh/kWh)	Demand Charge (KSh/kV	Fixed Charge (KSh/month)	Energy Charge (KSh/kWh)	Demand Charge (KSh/kVA /month)
DC	Domestic Consumers	240 or 415	0-50	120.00	2.50	-	150.00	2.50	-	150.00	2.50	-
			51-1,500		11.62			13.68			12.75	
			1,500 over		19.57			21.57			20.57	
SC	Small Commercial	240 or 415	Up to 15,000	150.00	12	-	150.00	14.00	-	150.00	13.50	-
CI1	Commercial /Industrial	415-3 相	Over 15,000 No Limit	2000.00	8.7	800.00	2,000.00	9.45	800.00	2,500.00	9.20	800.00
CI2		11,000		4,500.00	7.5	520.00	4,500.00	8.25	520.00	4,500.00	8.00	520.00
CI3		33,000/40,000		5,500.00	7	270.00	5,500.00	7.75	270.00	5,500.00	7.50	270.00
CI4		66,000		6,500.00	6.8	220.00	6,500.00	7.55	220.00	6,500.00	7.30	220.00
CI5		132,000		17,000.00	6.6	220.00	17,000.00	7.35	220.00	17,000.00	7.10	220.00
IT	Interruptible Off-peak supplies	240 or 415	Up to 15,000	240.00 - when used with DC and 270 When used with SC	13	-	240.00 - when used with DC and 300 When used with SC	13.75	-	240.00 - when used with DC and 300 When used with SC	13.50	-
SL	Street Lighting	240	-	200.00	10.50	-	200.00	11.25	-	200.00	11.00	-

(Source) Ten Year Power Expansion Plan 2014-2024

3.1.6 Load Demand Forecast

The previous load demand forecast made in LCPDP (2013 – 2033) based on the load of 1,370 MW in 2012, forecasted 3,034 MW in 2018 and 14,446 MW in 2030 as the reference case. MTP (2014 – 2018) and the Ten Year Power Sector Expansion Plan 2014 – 2024 have been updated taking into consideration the economic context of Kenya’s current and future development using the available data in 2013. This resulted in two scenarios; the moderate growth case (low scenario) and the high growth case with fast tracked Vision 2030 projects capacity demand requirements. The results of the forecasts are shown in Table 3.1.6-1.

The Model for Analysis of Energy Demand (MAED) developed by the International Atomic Energy Agency (IAEA) was used for the previous load demand forecast in Kenya. For the latest analysis, some complemental factors were additionally taken into account such as the results of a household energy consumption survey and projected energy consumption, to allow the prediction to consider Kenya specific circumstances.

Table 3.1.6-1 Load Demand Forecast (2014-2024)

	Low Scenario				High Scenario			
Year	GWh	MW	Load factor	Growth	GWh	MW	Load factor	Growth
2013	8,045	1,463*	68%		8,045	1,463*	68%	
2014	9,265	1,562	67%	7%	9,521	1,606	68%	12%
2015	10,086	1,714	67%	10%	13,310	2,161	70%	35%
2016	11,603	1,963	68%	15%	17,418	2,832	70%	31%
2017	13,641	2,295	68%	17%	24,595	4,062	69%	43%
2018	15,882	2,665	68%	16%	32,564	5,338	70%	31%
2019	17,895	3,018	68%	13%	36,039	5,949	69%	11%
2020	21,338	3,580	68%	19%	41,584	6,894	69%	16%
2021	23,452	3,965	67%	11%	45,360	7,554	69%	10%
2022	26,980	4,577	67%	15%	48,546	8,141	68%	8%
2023	31,483	5,346	67%	17%	52,143	8,808	68%	8%
2024	36,836	6,261	68%	17%	56,655	9,642	67%	9%

(Source) Ten Year Power Expansion Plan 2014-2024 * Actual

3.1.7 Generation Expansion Plan

Development projects being implemented under Vision 2030 and overall economic growth will increase the country‘s power demand. Sources of energy to be developed will include the exploitation of geothermal power, coal, renewable energy sources and connecting Kenya to other countries in the region for energy trade. The current exploration of oil and gas in the country creates an opportunity for cheaper power as the country taps into its natural resources. The government announced the project dubbed "5000 MW+ power to transform Kenya" in September 2013 in order for Kenya to achieve its goal of transforming into a middle income country and has created an initiative to increase the existing national installed capacity to >6,700MW in 40 months.

The Fast-tracked/Reference capacity expansion scenario in MTP (2014 – 2018) is based on the committed 5000 MW+ generation capacity project, and it meets the high scenario of the load forecast, which would result in 7,568MW total capacity in 2018. A corresponding growth in demand was projected at 5,338 MW in 2018.

Table 3.1.7-1 Development of Generation Capacity in MW – enhanced reference scenario

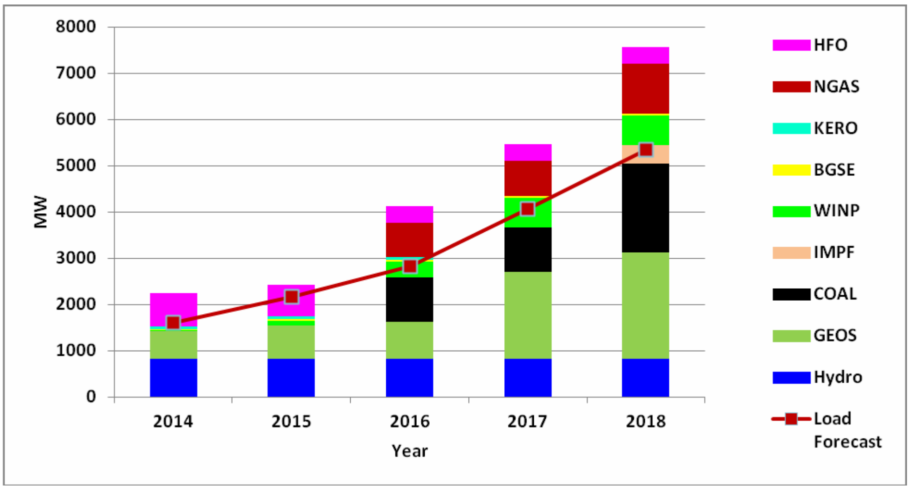
Year	Hydro	N. Gas	AGO-Nairobi	HFO-Mombasa	Import	Bagasse	Kerosene	Geo-thermal	Coal	Wind	**Total**
2014	820	0	30	698	0	26	54	593	0	26	**2,247**
2015	820	750		698	0	44	54	730	0	86	**3,182**
2016	820	750		359	0	44	54	800	96	336	**4,123**
2017	820	1089		359	0	44	0	1885	96	636	**5,793**
2018	820	1089		359	400	44	0	2300	192	636	**7,568**

(Source) MTP (2014-2018)

Table 3.1.7-2 Share of Installed Capacity Contributions

Year	Hydro	N. Gas	AGO/ HFO	Import	Bagasse	Kerosene	Geo-therm	Coal	Wind	**Total**
2014	36%	0%	32%	0%	1%	2%	26%	0%	1%	100%
2015	34%	0%	29%	0%	2%	2%	30%	0%	4%	100%
2016	20%	18%	9%	0%	1%	1%	19%	23%	8%	100%
2017	15%	14%	7%	0%	1%	0%	35%	18%	12%	100%
2018	11%	14%	5%	5%	1%	0%	30%	25%	8%	100%

(Source) MTP (2014-2018)



(Source) MTP (2014-2018)

Fig. 3.1.7-1 Demand and Generation Capacity MW by type – Fast-tracked Reference Scenario

Table 3.1.7-3 Demand Supply Balance – Enhanced Reference Scenario

Year		Type	Added (MW)	Total (MW)	System (MW)	Surplus (MW)	Reserve
2014	OLK4	Geothermal	140				
	OK1B	Geothermal	140				
	GULF	MSD	80				
	TRPH	MSD	83				
	OP4C	Geothermal	17.6				
	NG1B	Wind	6.8				
	NGW2	Wind	13.8				
	OWH2	Geothermal	12				
	OWH3	Geothermal	33	2,247	1,606	641	40%
2015	KWLE	Cogen	18				
	MEN1	Geothermal	108				
	KIWP	Wind	60				
	AGRK	Diesel	(30)				
	LNG1	Natural Gas	750				
	OWH4	Geothermal	30	3,183	2,161	1,022	47%
2016	KDP1	MSD	(60)				
	TSVO	MSD	(74)				
	RBA1	MSD	(90)				
	KPD3	MSD	(115)				
	OK1B	Geothermal	70				
	PRUW	Wind	50				
	KIPW	Wind	100				
	MERW	Wind	100				
	COL1	Coal	960	4,123	2,832	1,291	46%
2017	KGT1	Kerosene	(27)				
	KGT2	Kerosene	(27)				
	OLK1	Geothermal	(45)				
	LTWP	Wind	300				
	OLK5	**Geothermal**	**140**				
	SILG	Geothermal	200				
	AGIL	Geothermal	70				
	MEN2	Geothermal	360				
	KD1B	Natural Gas	60				
	TSV2	Natural Gas	77				
	RAB2	Natural Gas	90				
	KD3B	Natural Gas	112				
	SUSG	Geothermal	150				
	OLK6	Geothermal	140				
	AKIG	Geothermal	70	5,793	4,062	1,731	43%
2018	AGIL	Geothermal	70				
	EIMP	Import	400				
	OK1R	Geothermal	70				
	MEN3	Geothermal	100				
	COL2	Geothermal	960				

	SIL2	Geothermal	100				
	EBU2	Geothermal	25				
	SUS2	Geothermal	50	7,568	5,338	2,230	42%

(Source) MTP (2014-2018)

It is indicated in Table 3.1.7-3 that the Olkaria V project is planned to start supplying its generating power to the grid in 2017 and is positioned as one of the important geothermal power plant projects.

3.1.8 Background validity of the project

(1) Geothermal development situation and activity of donors

The current status of geothermal power plant operation and an estimation of geothermal resources in Kenya are indicated in Table 3.1.8-1 and Table 3.1.8-2, respectively. In Kenya surface surveys for geothermal energy began in the 1960's, and were followed by geological, geochemical and geophysical surveys in the region between Lake Bogoria and Olkaria in the 1970's. Based on these surveys, some prospective areas for geothermal development were found, and then deep exploratory wells were drilled at Olkaria by UNDP. Detailed surface surveys have been conducted to date at Suswa, Longonot, Olkaria, Eburu, Menengai, Arus-Bogoria, Lake Baringo, Korosi, Paka and Silali. Basic surface surveys were conducted at Lake Magadi, Badlands, Emuruangogolak, Namatum and Barrier. Based on these surveys, geothermal resource potentials in Kenya were estimated at over 10,000 MW and mainly found along the Kenya Rift Valley that runs through Kenya from north to south. The Olkaria geothermal field is located about 120 km north of Nairobi. The geothermal field has been subdivided into 4 blocks, Olkaria East (Olkaria I: 3units x 15 MW + 2 units x 70 MW=185 MW), Olkaria Northeast (Olkaria II: 3 units x 35 MW= 105 MW), Olkaria West (Olkaria III: 48 MW by IPP) and Olkaria Domes (Olkaria IV: 2 units x 70 MW= 140 MW), as shown in Fig.3.1.8-1. This project, Olkaria V, is located at the east and north of the adjacent development area for Olkaria IV.

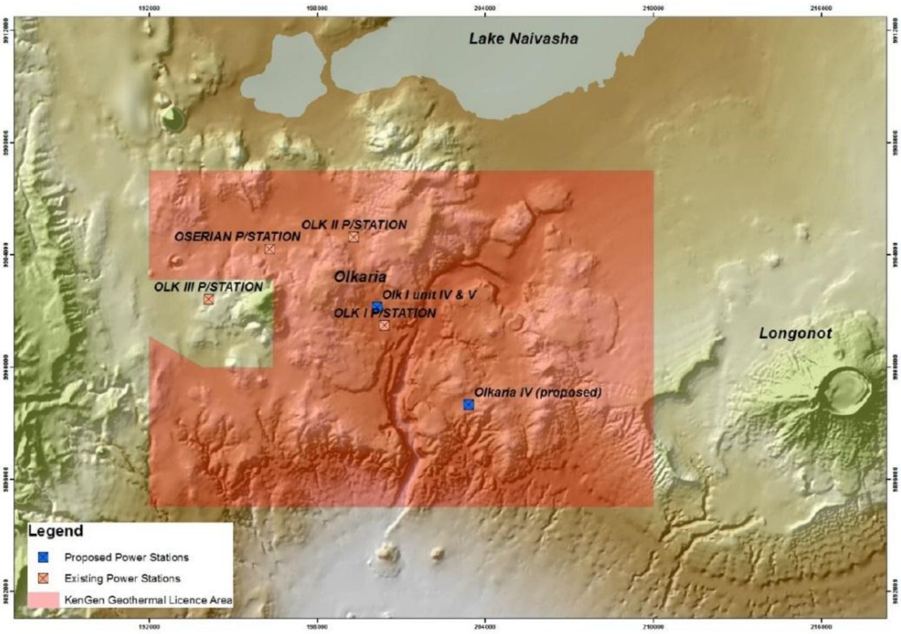


Figure 2. Map of the Greater Olkaria Geothermal Area showing KenGen's concessions area and the location of present power plants and the planned expansion of Olkaria I and the new Olkaria IV.

(Source) Mannvit (2012)

Fig.3.1.8-1 Map of Greater Olkaria Geothermal Area

As geothermal power is a type of base load electricity, the Government of Kenya (Gok) gives high priority to development of geothermal resources. Therefore, a state-owned special company, the Geothermal Development Company Limited (GDC), was established to drill and develop the country's geothermal resources for power generation, and the government provides finance to GDC in order to enhance geothermal development in Kenya. To meet the increasing demand for new power in Kenya, the Ministry of Energy (MoE) has proposed a roadmap to raise the generation capacity by 5,000 MW, in only 40 months, from the current 1,661 MW to slightly over 6,700 MW by 2016. This plan indicated that the installed capacity of geothermal power plants should attain 1907 MW by 2016. Well drilling has been carried out in Olkaria for KenGen and Menengai for GDC. Well drilling is now planned in Baringo and Suswa for GDC. Furthermore, new well drilling is also planned by IPP.

Table 3.1.8-1 Installed capacity of geothermal power plants in Kenya

Field	Developer	Installed capacity	Manufacturer		System
			Turbine	Generator	
Olkaria I (unit 1,2,3)	KenGen	45 MW (15 MW x 3)	Mitsubishi Heavy Industry	Mitsubishi Heavy Industry	Single flash
Olkaria I (unit 4, 5)	KenGen	140 MW (70 MW x 2)	Toshiba	Toshiba	Single flash
Olkaria II	KenGen	105 MW (35 MW x 3)	Mitsubishi Heavy Industry	Mitsubishi Heavy Industry	Single flash
Olkaria wellhead	KenGen	5 MW			
Olkaria III (pilot plant and Unit1,2)	Orpower4	86 MW (12+38+36)	Ormat	Brush, Kato, Ideal	Binary
Olkaria IV (unit 1, 2)	KenGen	140 MW (70 MW x 2)	Toshiba	Toshiba	Single flash
Total		521 MW			

Table 3.1.8-2 Geothermal development plan in Kenya

Field		Developer	Development plan
1	Olkaria I (unit 6)	KenGen	70 MW
2	Olkaria wellhead (unit 1,2,3)	KenGen	70 MW (20+20+30)
3	Olkaria III (unit 3)	IPP (Or power 4)	16 MW
4	Olkaria V	KenGen/JICA	140 MW
5	Olkaria VI	KenGen/IPP	140 MW
6	Eburru	KenGen	30 MW
7	Longonot I, II, III, IV	Concessioned to IPP (AGIL; Africa Geothermal International Limited)	700 MW
8	Akira I	Concessioned to IPP (Marine Power)	350 MW
9	Menengai I, II, III, IV, V, VI	GDC	1,600 MW
10	Suswa	GDC	600 MW
11	Korosi I, II, III	GDC	450 MW
12	Paka I, II, III	GDC	500 MW
13	Silali I, II, III, IV, V	GDC	800 MW
14	Chepchuk	GDC	100 MW
15	Arus	GDC	200 MW

16	Badlands	GDC	200 MW
17	Baringo	GDC	200 MW
18	Bogoria	GDC	200 MW
19	Magadi	GDC	100 MW
20	Emuruangogolak I,II	GDC	650 MW
21	Namarunu	GDC	400 MW
22	Barrier 1&2	GDC	450 MW
Total			7,966 MW

With respect to geothermal development, the community of international donors and lenders have mainly committed to the 6 countries in East Africa (Djibouti, Ethiopia, Kenya, Rwanda, Tanzania, and Uganda) to enhance construction of geothermal power plants. The East Africa donor community consists of AFD (French development Agency), AfDB (African Development Bank), DFID (UK Department for International Development), EIB (European Investment Bank), EU (European Union), ICEIDA (Icelandic International Development Agency), IFC (International Finance Corporation), JICA (Japan International Cooperation Agency), KfW (Kreditanstalt fur Wiederaufbau), UNEP (United Nations Environment Programme), USAID/Power Africa (U.S. Agency for International Development/ Power Africa), WB (World Bank) and so on. In addition, private financing institutions such as CFC Stanbic, Standard Chartered and PTS Bank are also available.

3.1.9 Validity of the project implementation and selection

(1) The current situation and issues of the electricity sector in Kenya

The Kenya electricity sector has increased at an average annual rate of 8% since 1970 and attained 1,463 MW as its maximum demand in 2013. The power source structure in 2013 is hydro power 47.5%, thermal power 36.8%, and geothermal power 14.0%. Although the main power source is hydro power in terms of installed capacity of power plants, shortage of electricity has become more serious due to droughts which frequently occur in Kenya. In order to address this serious issue and stabilize the electric power supply against increased demand, new power development is urgently needed. Thus, the expectations for the development of geothermal energy have been raised, due to the fact that it is not affected by weather conditions, and is a stable power source. Development has been especially highlighted along the Great Rift Valley in East Africa, where a huge geothermal resource is projected.

(2) Development policy in Kenya

The overall goal of the Vision 2030, declared in 2008 as a Kenyan national development plan, is to have international competitive power and attain economic stability by 2030, and the electric power sector is regarded as one of economic foundations of this policy. The Vision suggests that the electric power sector should endeavor to secure the electric power required for maintaining economic growth, increase the rural electrification ratio, and improve the electric power supply. According to the "Vision 2030－Updated Least Cost Power Development Plan 2013-2033 (March 2013)－, which indicates the development plan for each power source and transmission line, the composition of power generation in the year 2033 is estimated as follows: hydro (3%), nuclear (11%), diesel (2%), import (8%), natural gas (16%), geothermal (29%), coal (22%) and wind (9%). In addition the power sector is preparing a Medium Term Plan 2014 – 2018 (MTP 2014 – 2018) which is a more accurately predicative plan based on already committed projects and a Ten Year Power Sector Expansion Plan which builds on the MTP 2014-2018 in light of the government policy to accelerate power generation in the country. The LCPDP expects geothermal power development of 2,095 MW, which would account for 33% of the electric power to be newly developed in the latest medium-term plan. KenGen's share of that

2,095 MW should be about 40%. The development in Olkaria should be given the highest priority in geothermal power development in the three plans. LCPDP is a very important part of the plan to achieve Vision 2030, the blueprint to transform Kenya into a middle-class country in terms of income by 2030. Moreover, according to another plan "5,000+MW by 2016 Power to Transform Kenya" declared by the Ministry of Oil and Energy in 2013, more than 5,000 MW should be newly developed by 2016, with geothermal power's share being 1,640 MW. Against the above background, geothermal development in Olkaria is being heavily promoted, and this development project for Olkaria V therefore matches with the power development policy of the Government of Kenya.

(3) Country assistance policy of Japan

According to country assistance policy of Japan for Kenya (April 2014) building of infrastructure and economy is regarded as an important field, and a stable electric power supply is indispensable for maintaining economic growth, and should be encouraged. This indicates that this project matches with the aid policy of Japan. This project will contribute to the mitigation of the tight condition of the power supply and improve the stability of the power supply in Kenya by constructing a 140 MW power plant in the Olkaria geothermal field. The project will also contribute to the economic growth of Kenya through improvement of investment circumstances. Furthermore, this project will promote the utilization of geothermal energy, a clean and renewable energy source, which will contribute to the reduction of earth's environmental burden.

3.2 REVIEW OF GEOTHERMAL RESOURCES IN OLKARIA

3.2.1 Geology

(1) Review of geological data

Geological documents and reports were collected during the work in Kenya (Table 3.2.1-1). The contents of the collected materials are documents regarding the geological structure, revised by KenGen, describing well geology, summary of well data and geological maps, etc.

Table 3.2.1-1 Collected documents of geological data

No.	Data No.	Document Title	Auther/Contens	List No.
1	KT02	An Update of Geological Conceptual Model of the Greater Olkaria Geothermal Field (2014.4)	Kandie R., Ronoh I., and Mwamia M./ Geological Conceptual Model	10
2	KT06	Geolaogical Summary Olk Ⅳ	Geological summary of wells (OLKⅣ)	13
3	KT07	Geolaogical Summary Olk Ⅴ	Geological summary of wells (OLKⅤ)	13
4	KT08	Olkaria Ⅳ Wells - Stratigraphy: 22 Wells	Geological dicription of wells(OLKⅣ)	13
5	KT09	Olkaria Ⅴ Wells - Stratigraphy: 13 Wella	Geological dicription of wells(OLKⅣ)	13
6	KT10	GeologicalmapGeoRef	Geological map of Olkaria	13

In regards to the geological structure model of Olkaria, it has been reviewed by Gylfadottir et al. (2012). This model follows the geological structure model by WJEC (2009) and the added information regarding the new alteration data that has been obtained from newly drilled wells. Updating of the geological structure model was carried out by KenGen in April 2014.

(a) Outline of Geology

A geological structure map is shown in Fig. 3.2.1-1, geological cross sections are shown in Fig.3.2.1-2 and Fig.3.2.1-3 and generalized stratigraphy of Olkaria is shown in Table 3.2.1-2. The Olkaria V area is situated in eastern portion of the Olkaria geothermal area.

The Olkaria geothermal area is geologically composed of Proterozoic Basement Rocks, Pre-Mau Volcanics, Pre- Mau Volcanics, Plateau Tracytes, Olkaria Basalut, Upper Olkaria Volcanics (Omenda,2000, Laget et al. 2004).

1) Proterozoic Basement Rocks

The “basement” rock in the area is considered to be Proterozoic amphibolite grade gneisses and schists and the associated marble and quartzites of the Mozambiquan group. The rocks outcrop on the far flanks of the rift, more commonly toward the Magadi area in the south. In the south-central sector of the Kenya rift, the rocks are largely composed of gneisses and schists. Reflection seismic, gravity and geological correlation indicate that the depth of the “basement” is about 5-6 km in the central Kenya rift (Lagat, 2004).

2) Pre-Mau volcanic

The Pre-Mau formation is not exposed in the area but outcrops occur on the rift scarps in parts of the southern Kenya rift. The rocks are composed of trachytes, basalts and ignimbrites and are of unknown thickness. These rocks are directly overlain by the Mau tuffs (Lagat, 2004).

3) Mau Tuffs

Mau tuffs are the oldest rocks that crop out in the Olkaria area. These rocks are common in the area west of Olkaria Hill, but are absent in the east due to an east dipping high angle normal fault that passes through Olkaria Hill (Omenda 1994, 1998a). The rocks vary in texture from consolidated to ignimbritic and are the main geothermal reservoir rocks in the Olkaria west field (Lagat, 2004).

4) Plateau Trachytes

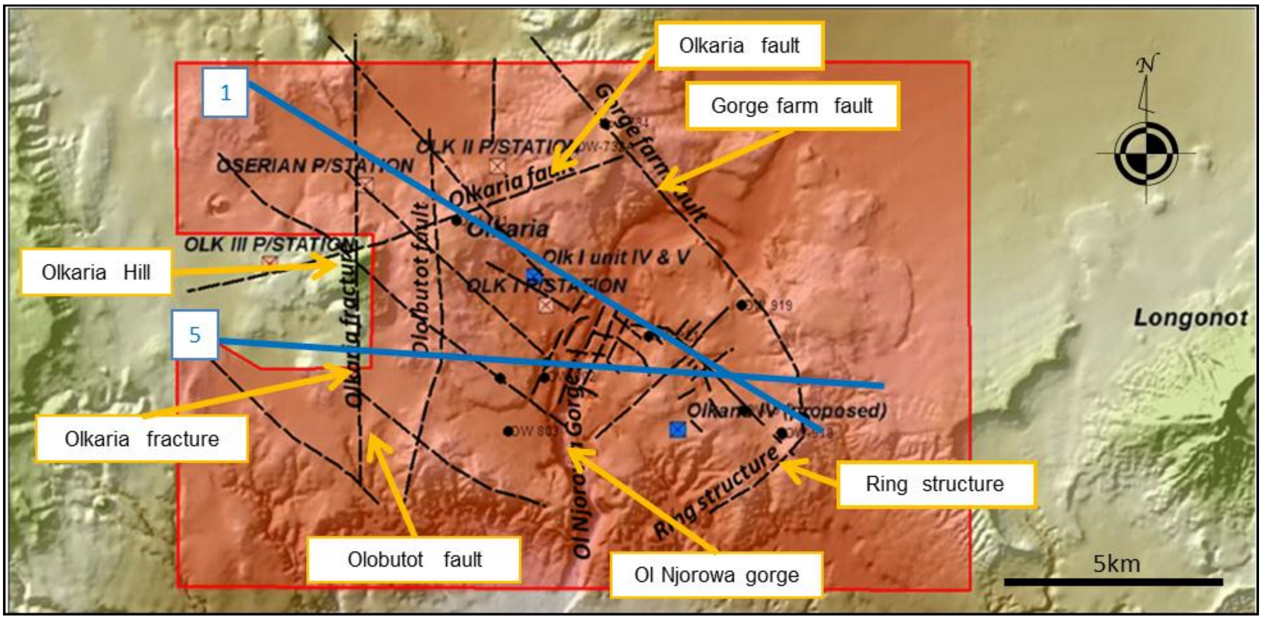
Plateau trachytes encountered in the boreholes in the Olkaria area are part of the Kenya rift floor fissure flows that are well exposed in the south and north of Olkaria area. The formation is of Pleistocene age and occurs from about 1000 m to more than 2600 m in depth. Trachytes are the main rock of the formation but minor basalts, tuffs, and rhyolites also occur. The Plateau trachytes occur in the area to the east of Olkaria Hill where a graben existed prior to their eruptions. These rocks are the host for the geothermal reservoir for the eastern Olkaria geothermal fields (Lagat, 2004).

5) Olkaria Basalt

The Olkaria basalt underlies the Upper Olkaria volcanics in the area to the east of Olkaria Hill while the formation is absent to the west. The formation consists of basalt flows and minor pyroclastics and trachytes. The formation varies in thickness from 100 m to 500 m and is considered to act as cap-rock for the Olkaria geothermal system (Lagat, 2004).

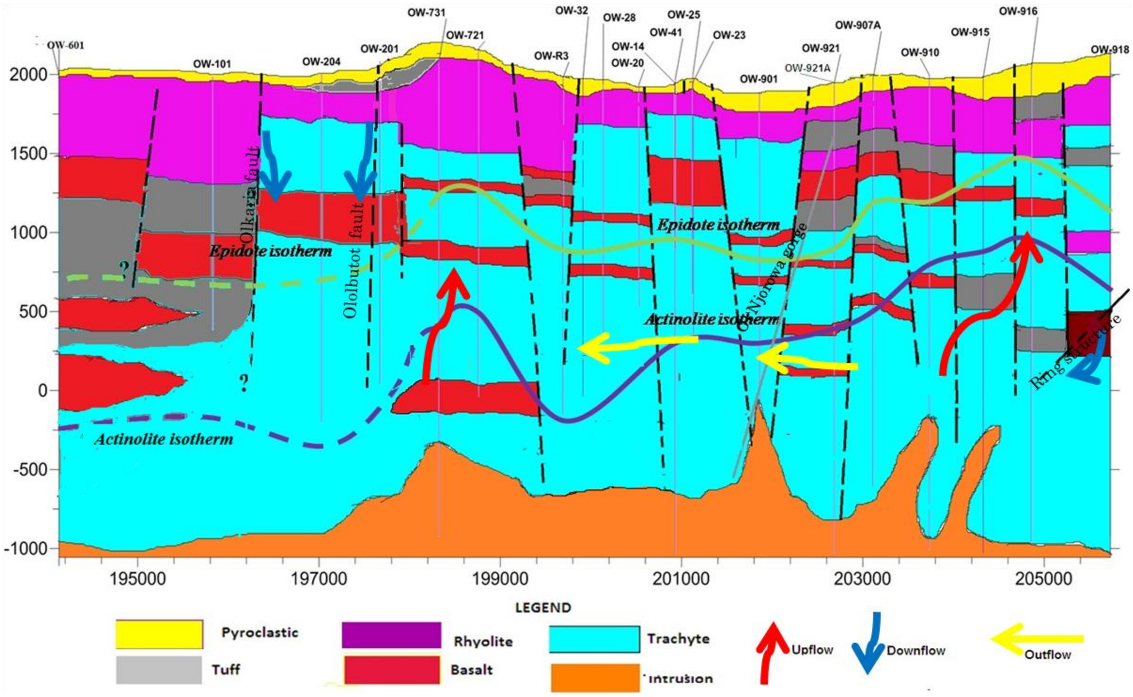
6) The Upper Olkaria Volcanics

The Upper Olkaria formation consists of comendite lavas and their pyroclastic equivalents, ashes from Suswa and Longonot volcanoes and minor trachytes and basalts. These rocks occur from the surface down to about 500 m depth. Comendite is the dominant rock in this formation. The youngest of the lavas is the Ololbutot comendite, which, has been dated at 180±50 yrs. The vents for these young lavas and pyroclastics were structurally controlled with most of the centres occurring along N-S faults/fractures and a ring structure (Lagat, 2004).



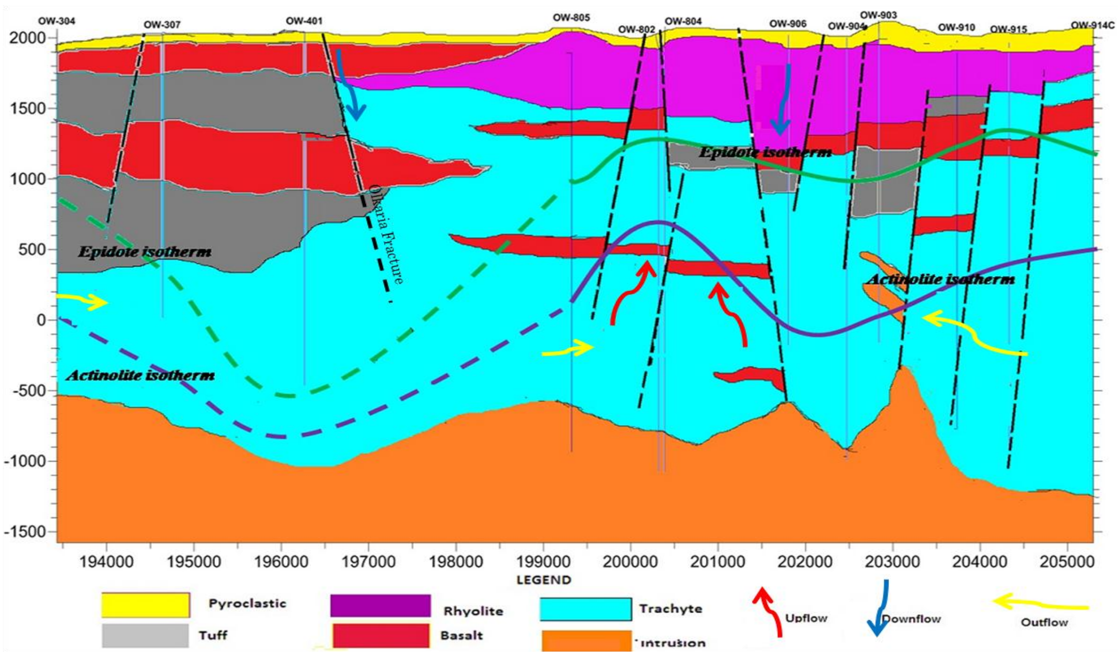
(Source) KenGen(2014)

Fig. 3.2.1-1 Geological structure map of Olkaria geothermal area



(Source) KenGen(2014)

Fig. 3.2.1-2 Conceptualized geological model (Profile 1)



(Source) KenGen(2014)

Fig. 3.2.1-3 Conceptualized geological model (Profile 5)

Table 3.2.1-2 Generalized stratigraphy of Olkaria geothermal area

Formation Name	Lithology	Thickness (m)	Characteristic (Age)
Upper Olkaria Volcanics	Comendite lavas and their pyroclastic equivalents, ashes , minor basalts (Clarke et al.,1990, Omenda, 1998a)	Surface-500m	Superficial (Quaternary)
Olkaria Basalt	Basalt flow, minor pyroclastics and trachytes (Omenda 1998a)	100-500	Cap-rock
Plateau Trachyte	Trachytes with minor basalts, tuffs and rhyolites (Omenda 1994,1998a)	1000-2600	Reservoir (Pleistocene)
Mau Tuffs	Consolidated ignimbrites (Omenda 1994,1998a)	>2600	Reservoir (Late Miocene)
Pre Mau Formation	Trachytes, basalts, ignimbrites	unknown	Reservoir
Proterozoic Basement rocks	Gneisses, schists, marbles and quartzites(Mosley,1993, Smith and Mosley, 1993, Simiyu et al., 1993)	5000-6000	Basement (Proterozoic)
Olkaria Intrusion	Granites, Syenite and Basaltic in composition. They occur as dykes and sills cutting through the basement rocks, tuffs and the trachytic units.	Varying	Intrusive (Late Pleistocene-Holocene

(Source) KenGen(2014)

(b) Geological Structure

There are four (4) fault systems that characterize the field and are associated with fluid movement in the Olkaria geothermal area (Fig. 3.2.1-4). These include ENE-WSW, NW-SE, N-S and E-W structures that are all defined as normal faults from the correlation of lithology and alteration mineralogy zones. These structures include the Ololbutot fault, Olkaria fault, Olkaria fracture, Gorge farm fault, Ring fault structure and Ol Njorowa Gorge. The most prominently recent and active faults from volcanic history, are the Ololbutot fault, Olkaria fracture and the NNE to NE striking faults. The Ololbutot lava flow which emanates from the Ololbutot fault is the youngest lava flow that indicates the latest active fault in the area. The Ol Njorowa Gorge is clearly a structurally controlled feature which has been modified by erosion. The Gorge trends in a near NNE direction and it is controlled by the NNE and the NW striking faults (KenGen, 2014).

Rhyolite, Basalts and Trachyte are distributed in Olkaria V area and the ring structure is situated in eastern end of the area (Fig. 3.1.2-2). This structure is a characteristic geological structure in the area, there is a possibility that the structure controls the fluid flow. Volcanoes are arranged along the ring structure (Photo 3.1.2-1) and distribution of the volcanoes is also clearly in the Landsat image (Fig. 3.1.2-4).

Photo 3.2.1-1 Distant view from southwest side of Olkaria V development area

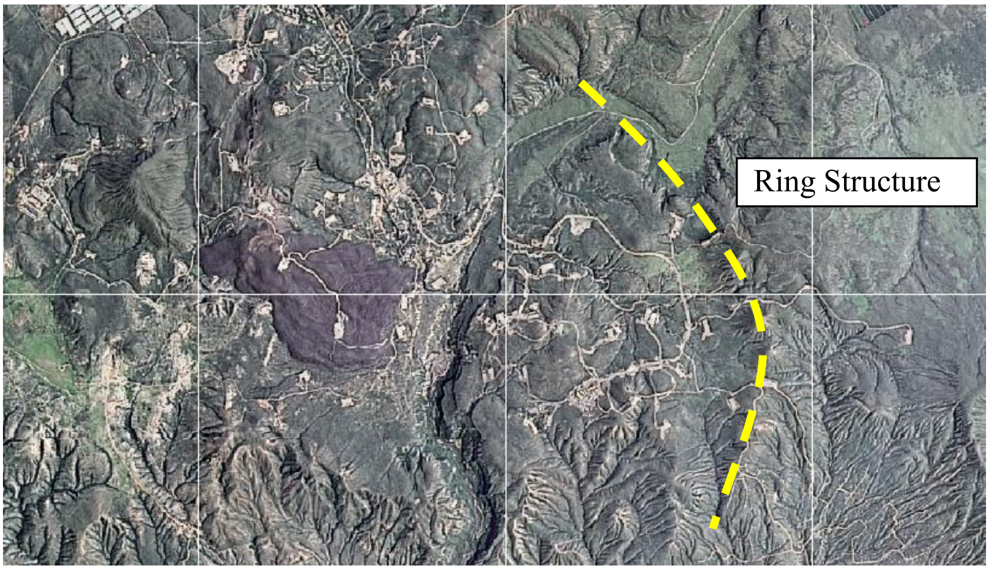
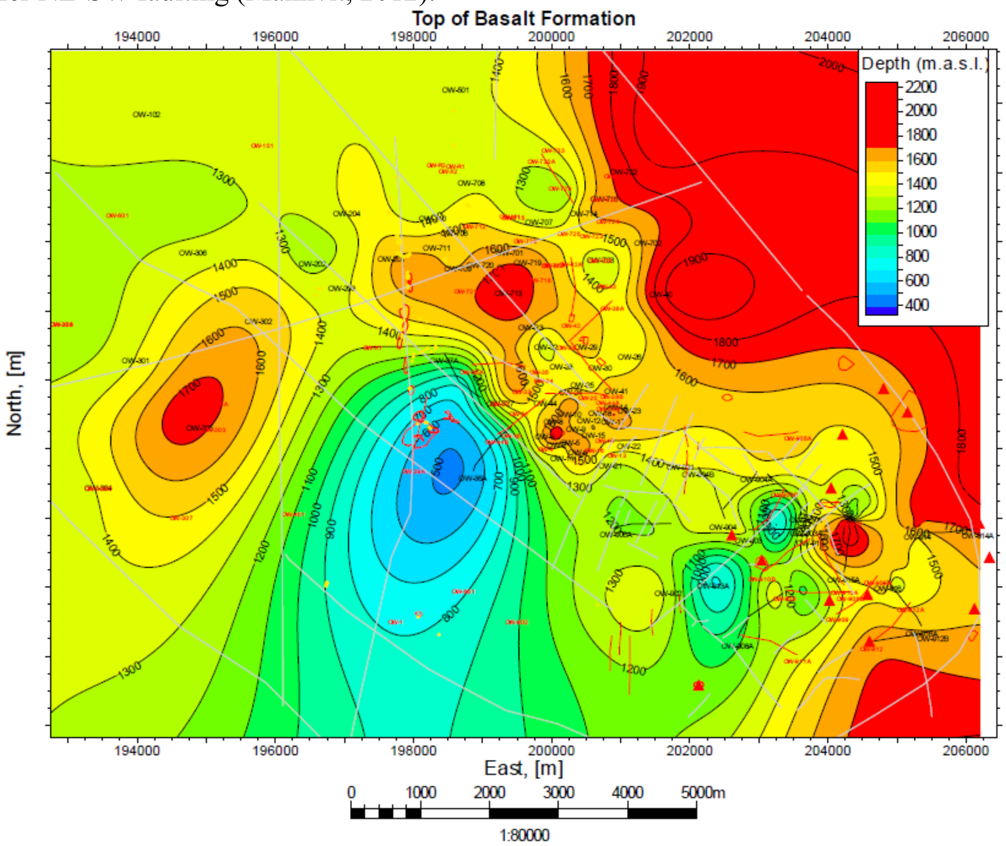


Fig. 3.2.1-4 Landsat Image of Olkaria V area

Olkaria Basalt beds found in the wells are in many ways excellent marker beds. The top of basalt formation is shown in Fig. 3.2.1-5. Big differences are found in the Dome area, which may infer NE-SW faulting (Mannvit, 2012).



(Source) Manvit (2012)

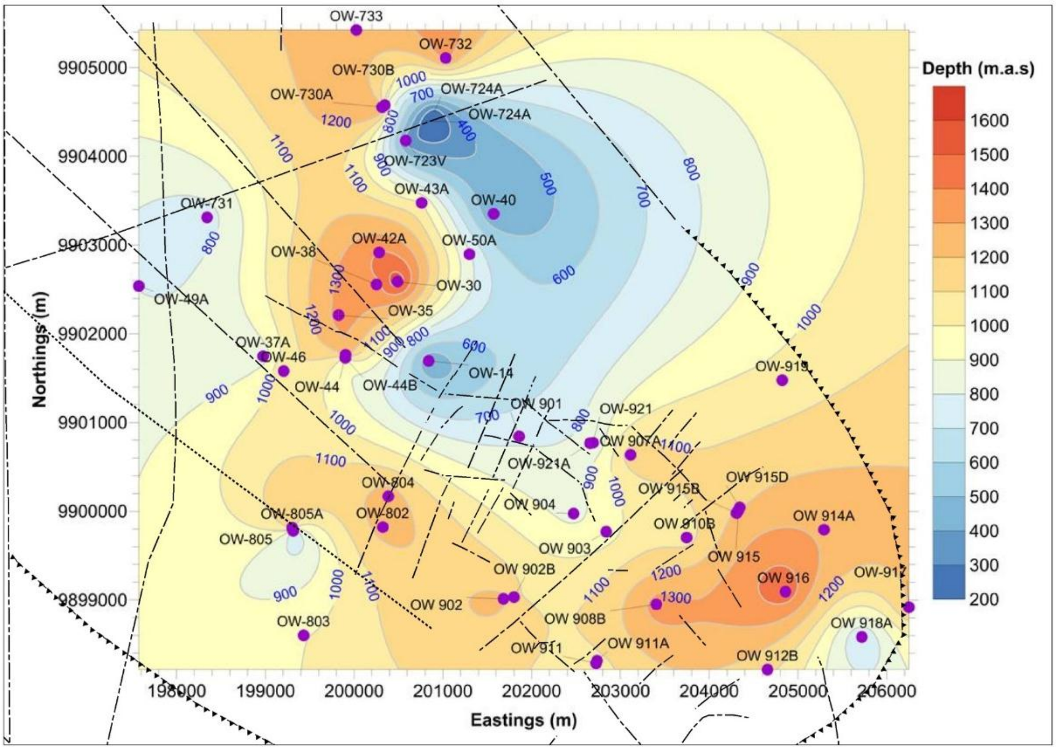
Fig. 3.2.1-5 Top of Basalt formation

(c) Geothermal Alteration Zone

Distribution of hydrothermal alteration minerals are unique and a function of subsurface geothermal structure. Four hydrothermal alteration mineral zones defined by the first appearance of specific index minerals and clays minerals occur in the area (KenGen, 2014).

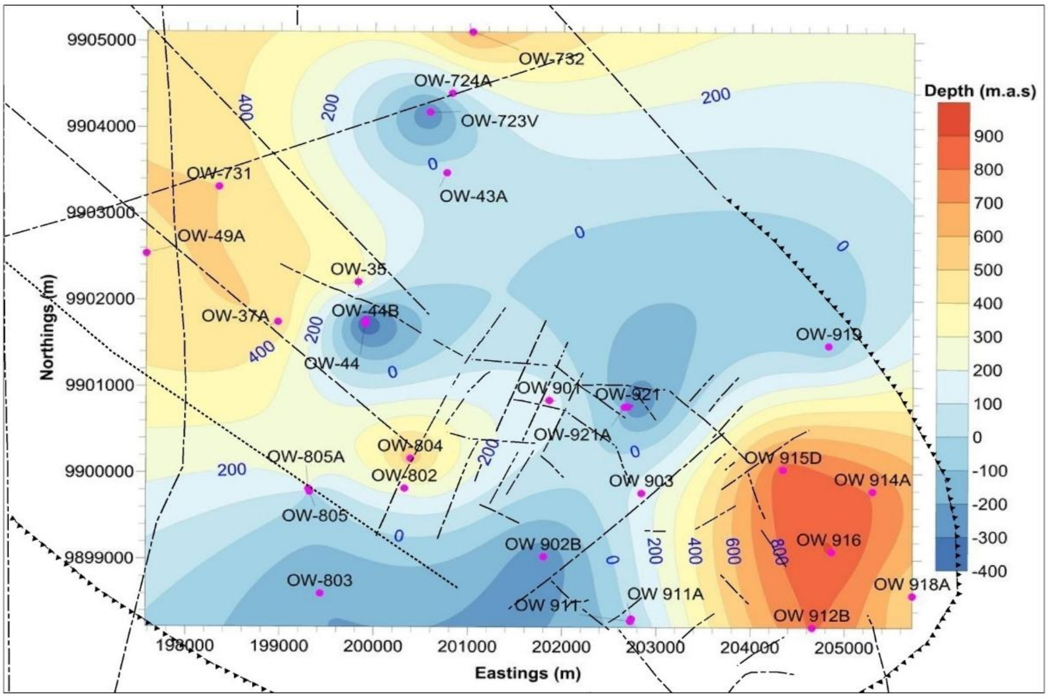
- ✓ Smectite-chlorite-illite zone (<300m.b.g.l)
- ✓ Chlorite-illite zone (300-550m.b.g.l)
- ✓ Epidote-chlorite-illite zone (550-1400m.b.g.l)
- ✓ Actinolite-epidote chlorite-illite zone (1400-3000m.b.g.l)

An Epidote isomap and Actinolite isomap are shown in Fig. 3.2.1-6 and Fig. 3.2.1-7 respectively. Significant hydrothermal alteration is notable at the up-flow zones around wells OW-914, OW-916 and OW-915, a region where the high temperature geothermometer minerals are observed at shallow depth as compared to the down-flow regions around the ring structure. Epidote and actinolite, which form under high temperature geothermal fluid, are distributed in the shallow layers around OW-914, OW-915, OW-916, alteration minerals indicating high temperature are not observed in OW-917. A comparison of alteration and measured temperatures reveal that the system is heating up in the vicinity of wells OW-916, OW-914 and OW-915 and possible cooling is evident around the ring structure, and at the Ol Njorowa Gorge (KenGen, 2014).



(Source) KenGen (2014)

Fig. 3.2.1-6 Epidote isomap of the Olkaria geothermal area



(Source) KenGen (2014)

Fig. 3.2.1-7 Actinolite isomap of the Olkaria geothermal area

(2) Geological Structure Model of Olkaria V area

A geological structure map of the Olkaria V area is shown in Fig. 3.2.1-8, and a geological cross section of the Olkaria V area is shown in Fig. 3.2.1-9. Borehole geology of the study area is composed of the Upper Olkaria Volcanics, Olkaria Basalt, Plateau Trachytes and Olkaria Intrusion. The Upper Olkaria Volcanics consist mainly of pyroclastics, rhyolite, trachyte and tuff, and are distributed from the surface to an altitude of 1500masl (m above sea level) - 1600masl causing numerous instances of circulation loss during drilling. Olkaria basalt is mainly composed of basalt lava with minor amounts of trachyte and tuff, and is distributed from an altitude of 1100masl to 1500masl. Plateau Trachytes is mainly composed of trachyte with minor rhyolite, basalt, tuff, and is distributed at altitudes below 1500masl. Olkaria Intrusion is mainly composed of syenitic intrusive rocks.

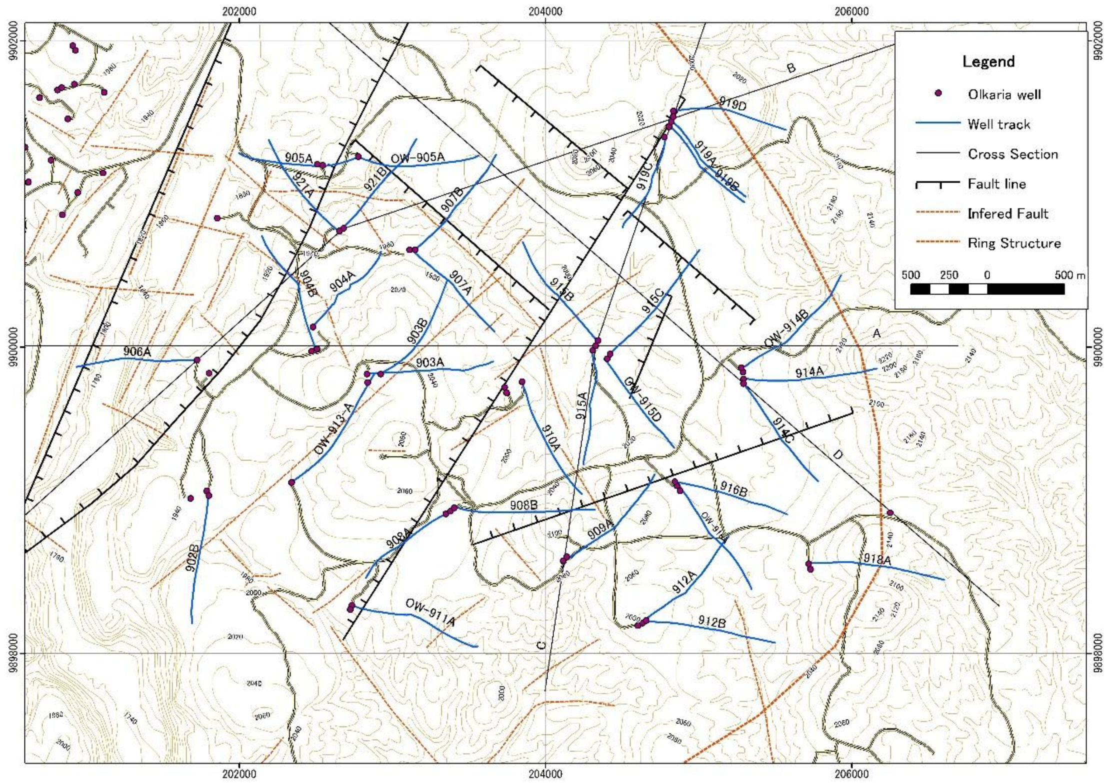
The Olkaria V area is located inside of the Ring Structure. Considering the geological structure from the distribution of Olkaria basalt (Fig. 3.2.1-10), it is estimated that the geological structure is depressed toward the west region and divided into several blocks by the fault system inside of the Ring Structure. It is estimated that the fault system of NE-SW and NW-SE are dominant inside of the Ring Structure. Olkaria basalt is distributed from an altitude of 1250masl to 1550masl in OW-917, which was drilled outside of the Ring Structure and located in the highest elevation. In contrast, it is estimated that OW-914 and OW-915 are more depressed than the surrounding region. In the E-W cross section (A), it is presumed to have depressed the formation towards the west region. In addition, the block of OW-915 is depressed in relation to the surrounding region.

Olkaria Intrusions are distributed in OW-915C, OW-915D, OW-916B, OW-917, OW-919A and OW-919D. Most of the Olkaria intrusions which are distributed at below 2000m are composed of syenitic and rhyolitic intrusion and strongly altered with epidote or actinolite. Circulation loss occurs around the intrusive rocks, therefore it is estimated the permeability at their depth is high.

Alteration minerals of epidote and actinolite are distributed in the shallow layers around OW-914, OW-915 and OW-916 in the Olkaria V area (Fig. 3.2.1-11). It is indicated that high temperature hydrothermal activity is dominant around these regions. On the other hand, to the north of OW-915 to OW-921 and outside of the Ring Structure, distribution of high temperature geothermometer minerals are deep or actinolite is absent. Therefore, it is indicated that the temperature of the hydrothermal fluid is low.

Based on the above, the characteristics of the geological structure model in the Olkaria V area is as follows:

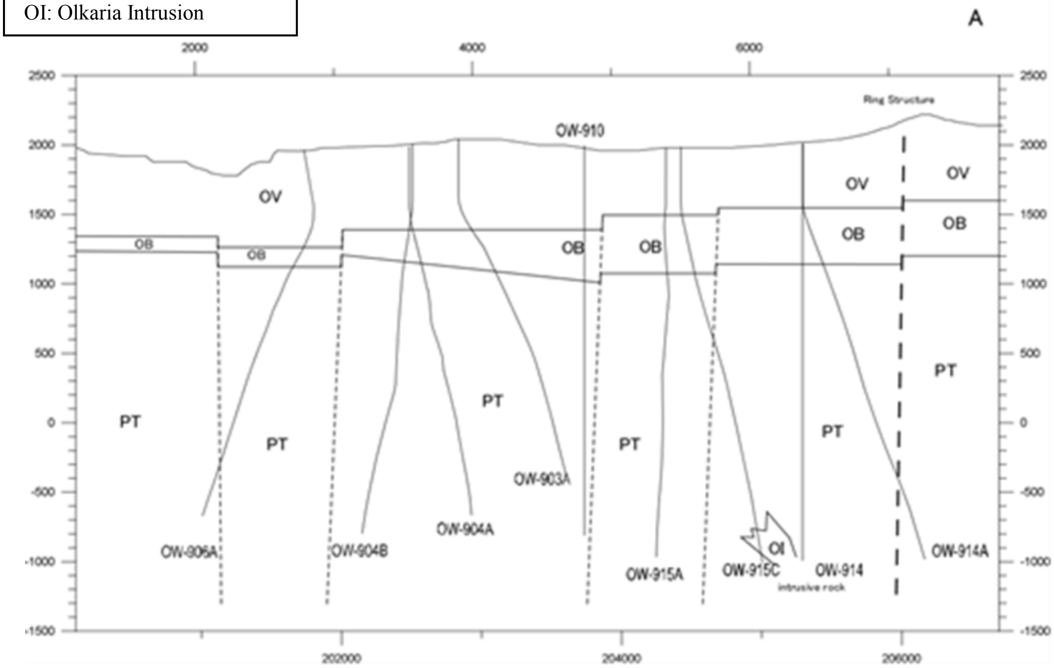
- ✓ The Olkaria V area is located inside of the Ring Structure, and it is estimated that the NE-SW and NW-SE fault system developed and is divided into several block, formations are depressed toward the west region.
- ✓ Actinolite is distributed in the shallow layers around OW-914, OW-915 and OW-916 in the Olkaria V area. It is indicated that high temperature hydrothermal activity is dominant around this region. Olkaria Intrusions composed of syenitic and rhyolitic, are distributed in OW-915C, OW-915D and OW-916 at the deeper part of the wells (Fig. 3.2.1-12). Circulation loss during drilling occurred around the intrusive rocks, therefore it is estimated the permeability of that depth is high.
- ✓ On the other hand, to the north of OW-915 to OW-921 and outside of the Ring Structure, distribution of high temperature geothermometer minerals are deep or actinolite is absent. It is indicated that the temperature of hydrothermal fluid is low. Decrease of the temperature may be due to inflow of cold fluid from the Ring Structure of the northern region. It is predicted that fluid flow from the north region is associated with the NW-SE or NE-SW permeable fracture system.



(Source) JICA Study Team

Fig. 3.2.1-8 Geological structure map of Olkaria V area

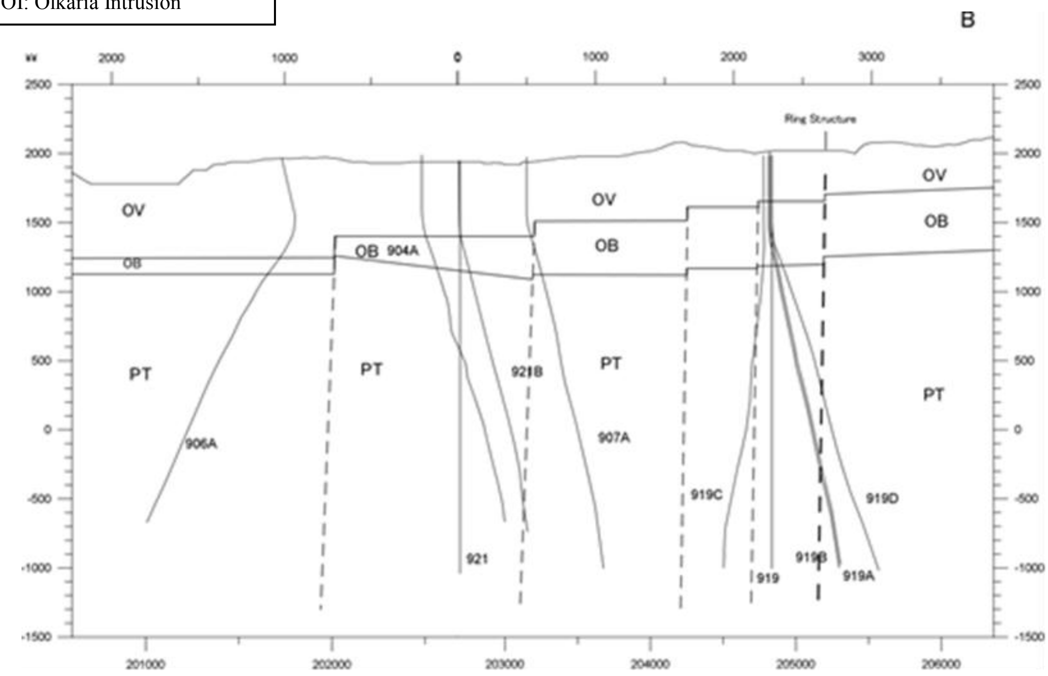
OV: Upper Olkaria Volcanics
OB: Olkaria Basalt
PT: Plateau Trachyte
OI: Olkaria Intrusion



(Source) JICA Study Team

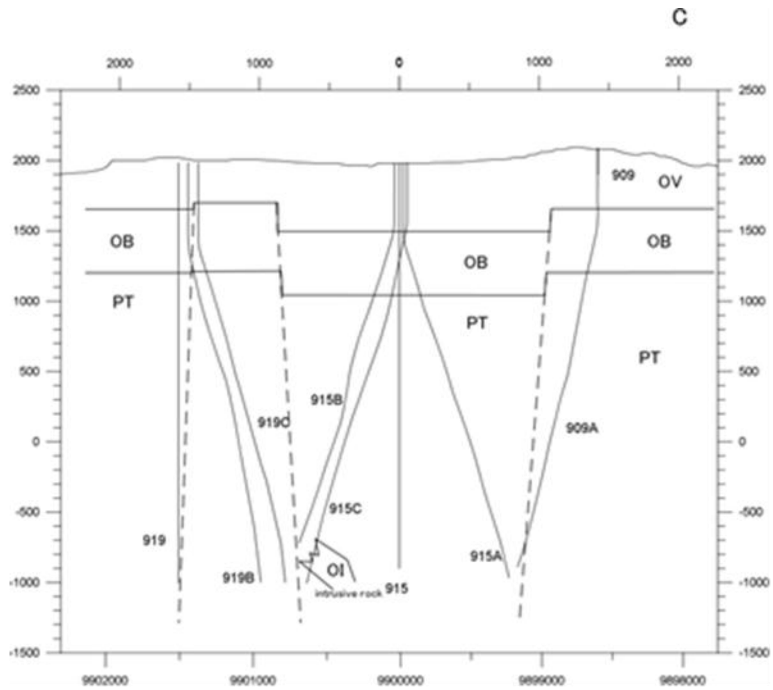
Fig. 3.2.1-9(a) Geological cross section of Olkaria V area A

OV: Upper Olkaria Volcanics
OB: Olkaria Basalt
PT: Plateau Trachyte
OI: Olkaria Intrusion



(Source) JICA Study Team

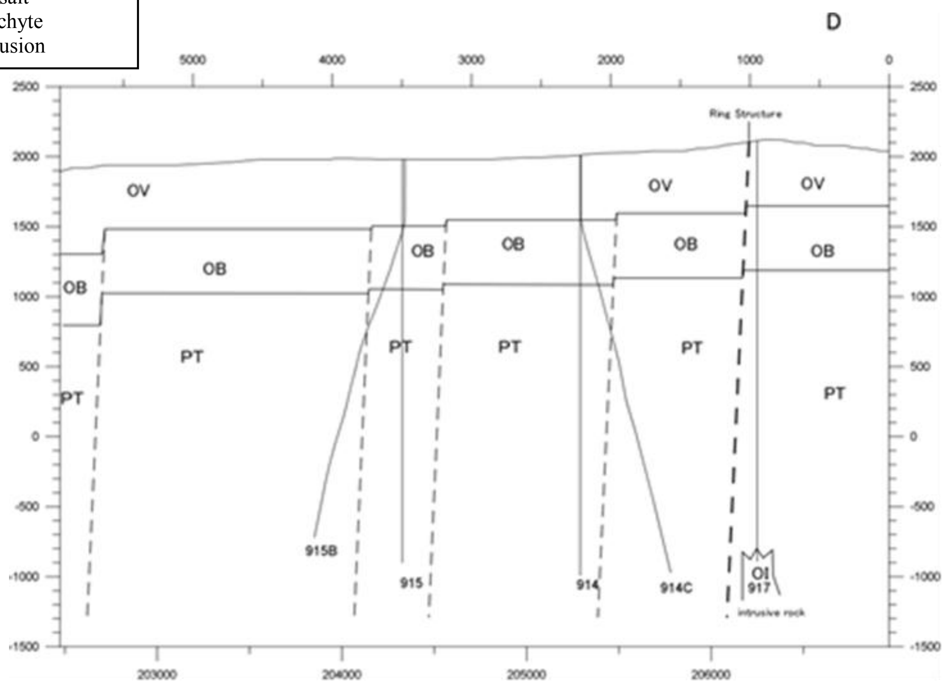
Fig. 3.2.1-9(b) Geological cross section of Olkaria V area B



(Source) JICA Study Team

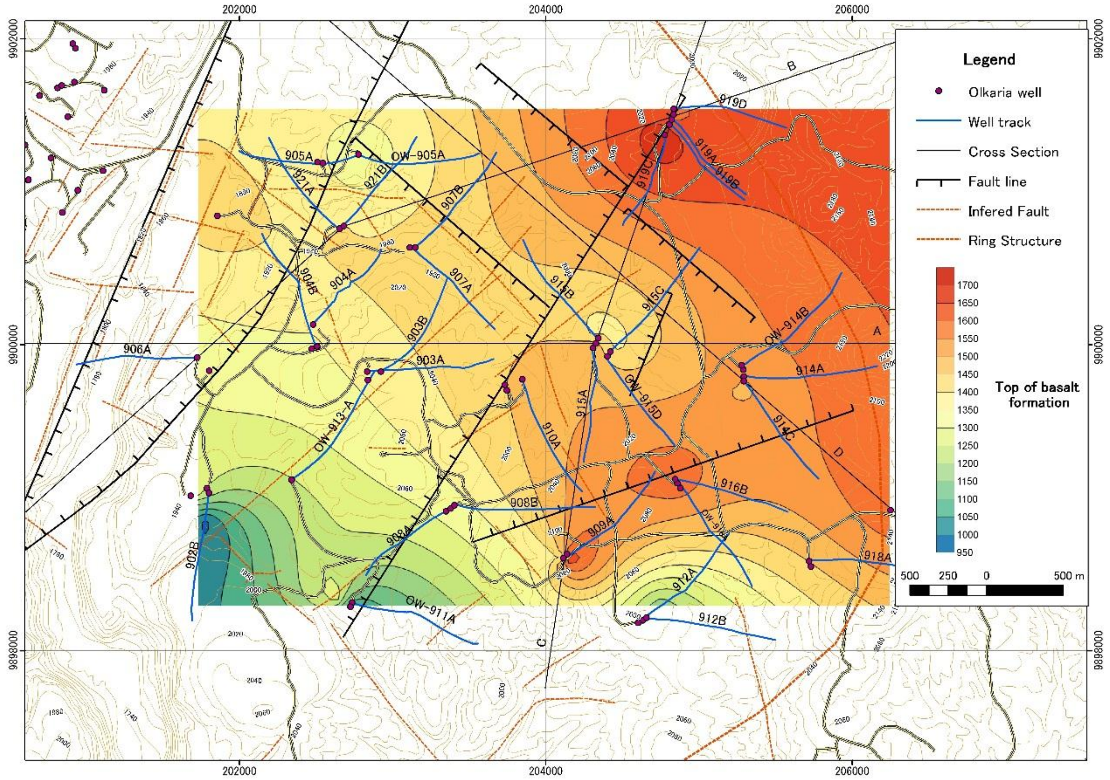
Fig. 3.2.1-9(c) Geological cross section of Olkaria V area C

OV: Upper Olkaria Volcanics
OB: Olkaria Basalt
PT: Plateau Trachyte
OI: Olkaria Intrusion



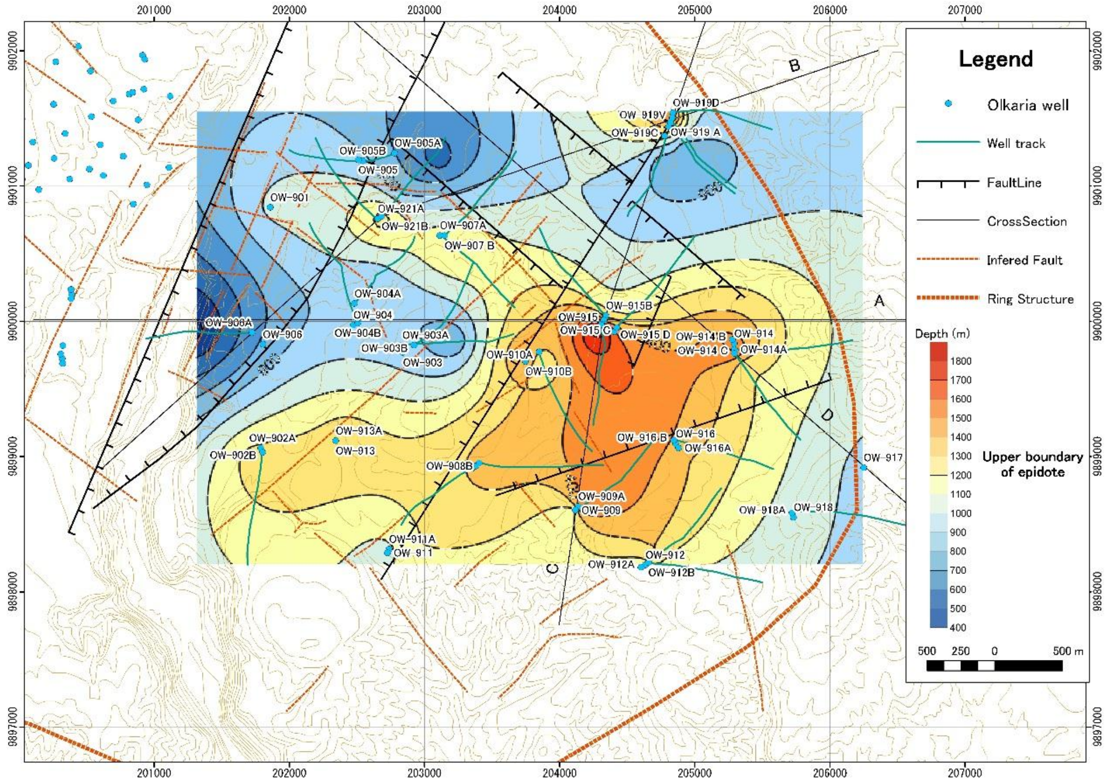
(Source) JICA Study Team

Fig. 3.2.1-9(d) Geological cross section of Olkaria V area D



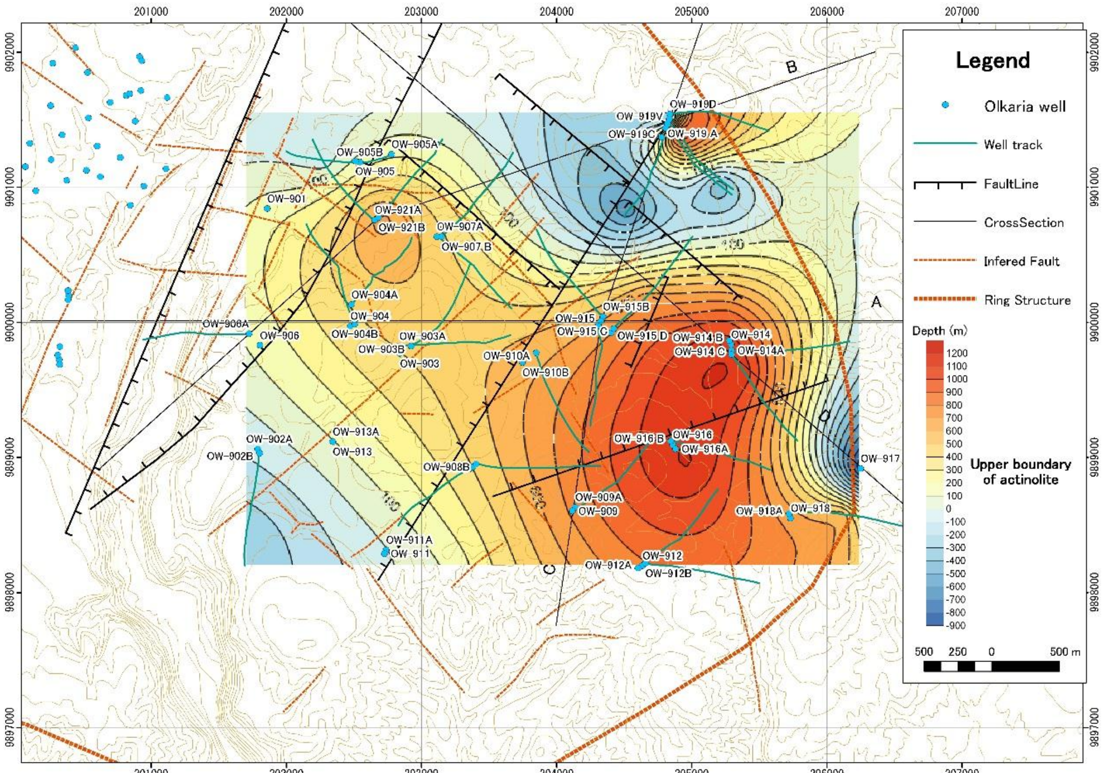
(Source) JICA Study Team

Fig. 3.2.1-10 Distribution map of Olkaria Basalt



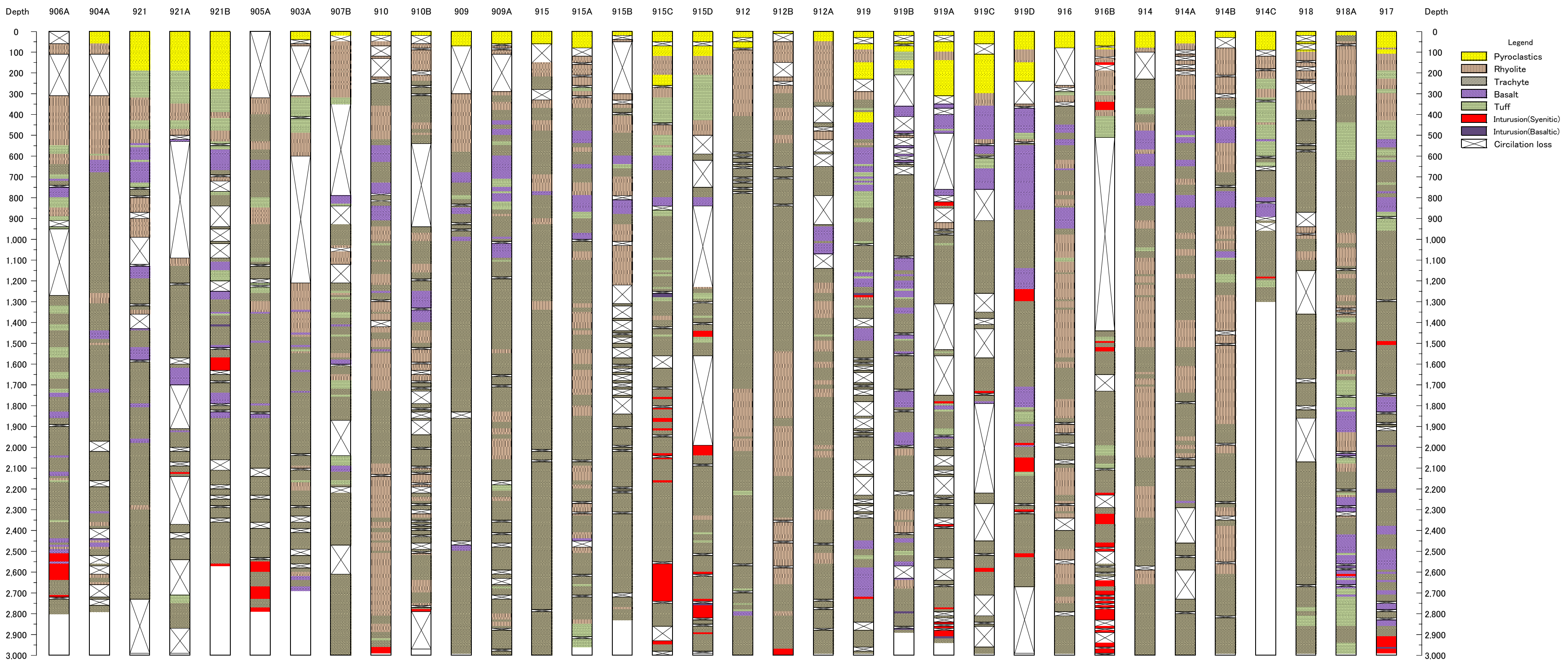
(Source) JICA Study Team

Fig. 3.2.1-11(a) Distribution map of epidote in Olkaria V area



(Source) JICA Study Team

Fig. 3.2.1-11(b) Distribution map of actinolite in Olkaria V area



(Source) JICA Study Team

Fig. 3.2.1-12 Geological section column

3.2.2 Geophysics

The geophysical data collected in the first work in Kenya is summarized in Table 3.2.2-1

Table 3.2.2-1 List of collected geophysical data

No.	Date	Title	Contents	Year
1	2014/8/14	GoGA-Gravity	Gravity data	
2	2014/8/14	Olkaria-Gravity	Gravity data	
3	2014/8/14	Induced Micro-Seismicity During Discharge of Olkaria Well-719	S. M. Simiyu, E. O. Oduing and T. K. Mboya/ Seismic Report	1999
4	2014/8/14	Seismic Monitoring of The Olkaria Geothermal Area, Kenya	S. M. Simiyu, T. K. Mboya, E. O. Oduing and H. I. Vyele/ Seismic Report	
5	2014/8/15	MT data	MT data	
6	2014/8/15	TEM data	TEM data	
7	2014/8/15	Micro - Gravity Measurement Olkaria East Production Field	Charles Ogada/ Micro gravity Report	2009
8		Geophysics Report of the Great Olkaria Geothermal Area (GOGA)	Anastasia W. Wonjohi/Geophysics report	2014

The apparent feature of geological structure in the Olkaria field is the alignment of lineaments trending in NW-SE direction, and the ring-shaped chain of volcano that is located at the south-eastern end of the alignment of lineaments. (Fig. 3.2.2-1)

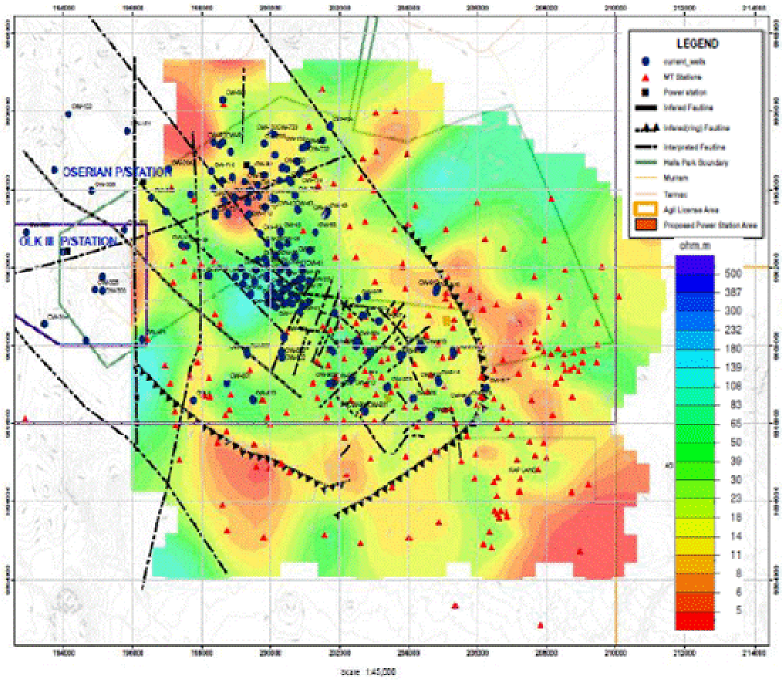
(Source) Wanjohi, 2014

Fig. 3.2.2-1 Geological structure and volcano alignment in Olkaria area

In the Olkaria field, various geophysical observations such as micro-earthquake observations, gravity measurements, and electromagnetic explorations have been collected. The data collected during the first visit to Kenya includes raw data of MT method and gravity measurements. The result of MT data analysis was summarized in a report (Wanjohi, 2014) together with the existing exploration results.

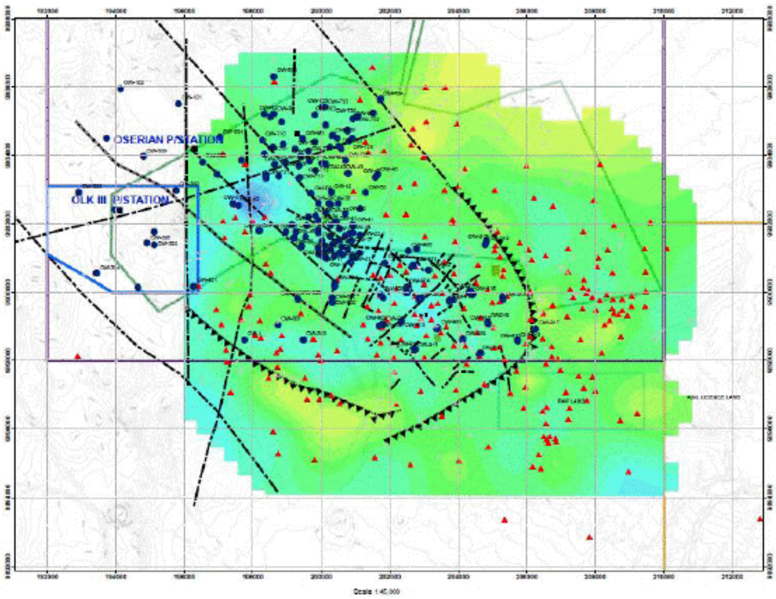
The report (Wanjohi, 2014) showed the results of 1-dimensional joint inversion of MT and TEM methods. Fig. 3.2.2-2 shows the resistivity distribution at a level of 1,500m a.s.l. Also, Fig. 3.2.2-3 shows the resistivity distribution at sea level.

In general, the features of resistivity distribution suggesting the existence of a high-temperature reservoir are; (1) conductivity layer in the shallow region, (2) relatively high resistivity region beneath the conductive layer. The conductive layer in the shallow region suggests the existence of cap rocks that contain clay minerals stable under relatively low temperature environment, and the relatively high resistivity zone beneath the conductive layer indicates the existence of a hydrothermal alteration zone that contains altered minerals which are stable under a high temperature environment.



(Source) Wanjohi, 2014

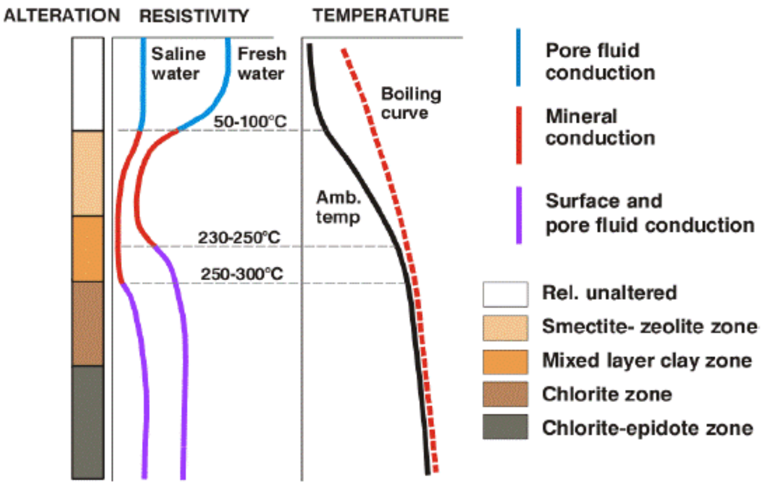
Fig. 3.2.2-2 Resistivity distribution at a level of 1,500m a.s.l



(Source) Wanjohi, 2014

Fig. 3.2.2-3 Resistivity distribution at sea level

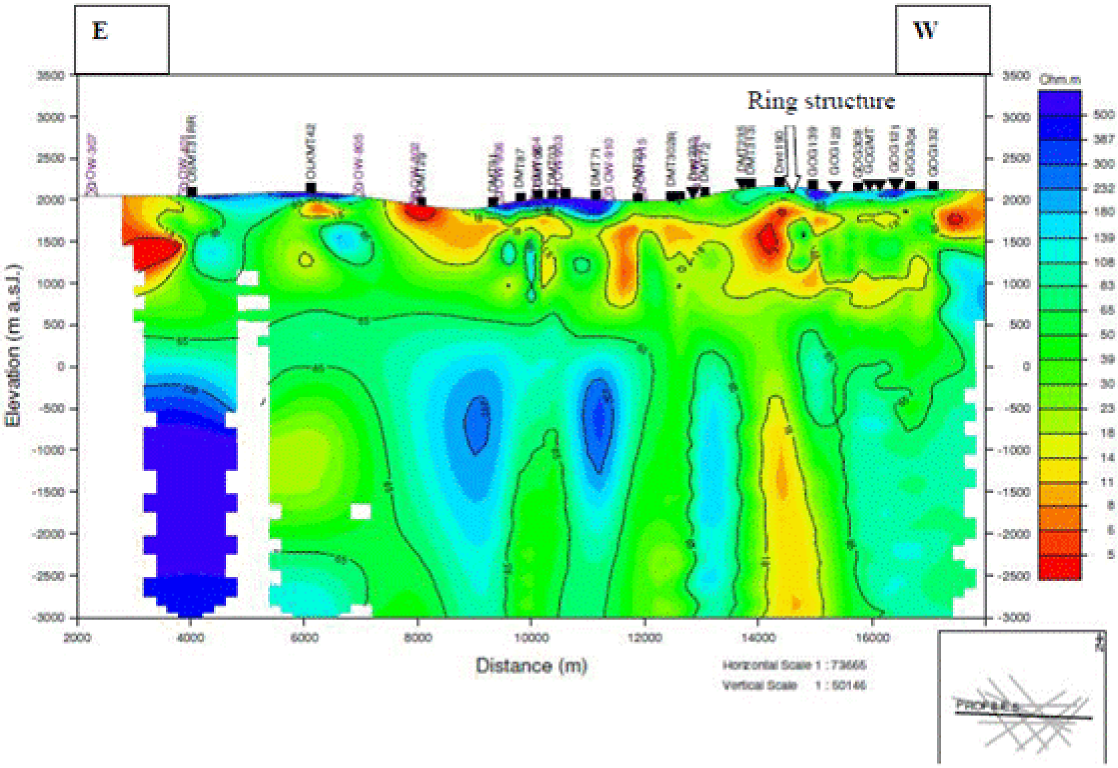
In the resistivity distribution shown in Fig. 3.2.2-2 and Fig. 3.2.2-3, such an indicative feature (schematically shown in Fig. 3.2.2-4) is found at the internal region bounded by the NW-SE alignment of lineaments and the ring chain of volcanos. As the exploitation area of Olkaria V is located in the internal region, bounded by the volcano ring, the promising region for steam production would be the region elongated from the NW-SE trending lineaments inside the volcano ring. Actually, the boreholes drilled outward (toward east or north-east direction) through the ring structure such as OW-917 and OW-918 showed relatively low temperature comparing with those drilled inside of the ring structure.



(Source) Wanjohi 2004

Fig. 3.2.2-4 The typical feature of resistivity distribution in a promising geothermal field

Fig.3.2.2-5 shows the resistivity section that traverses the whole Olkaria field in an E-W direction. In the figure, the existence of a shallow conductive layer and a relatively high resistivity zone can be apparently seen. On the other hand, a low resistivity zone that elongates toward the deep region can be seen in the sites located outside of the ring structure. Beside this area, the existence of vertical structures are apparent, especially in the region deeper than sea level. Furthermore, the thickness of the cap rock varies from site to site. These features are artifacts caused by the inconsistence of the analysis method (1-D Occam inversion) that cannot take into account topographic effect, or, the actual structure which is three-dimensional. Re-analysis by 3-D inversion is necessary to completely remove such artifacts.



(Source) Wanjohi, 2014

Fig. 3.2.2-5 Resistivity section in Olkaria field in E-W direction

Although there are some issues with the methodology of the data analysis, it could be concluded that there are indications suggesting the existence of high temperature resources beneath the whole Olkaria area. Also, it is almost certain that the ring structure is a key structure that controls the flow of high temperature fluid.

The areal distribution of Bouguer anomaly collected in the first work in Kenya is shown in Fig. 3.2.2-6. The spatial distribution of the Bouguer anomaly in Fig. 3.1.2-12 hardly can be interpreted that it was originated from natural density distribution in subsurface. Thus we have asked KenGen to provide the details of data reduction used to derive the Bouguer anomaly. However, the information was lost except the fact that the gravity measurement was conducted by an Italian consultant. Further investigation of the Bouguer anomaly showed that a large fraction of the Bouguer anomaly was the same one we were given by KenGen in the study conducted in 2009. Only part of the new data is inconsistent with the existing gravity data. It can be concluded that no new information could be extracted from the newly added gravity data, and the analysis of consistent gravity data would give an identical result as the previous study. However, the gravity data obtained in the 2009 study covered the whole Olkaria region, and the result of the data analysis was consistent with the geological information. Also, the geothermal conceptual model was devised considering the gravity data analysis. Thus, the lack of newly added gravity data would leave almost no impression on the resource evaluation in the Olkaria region.

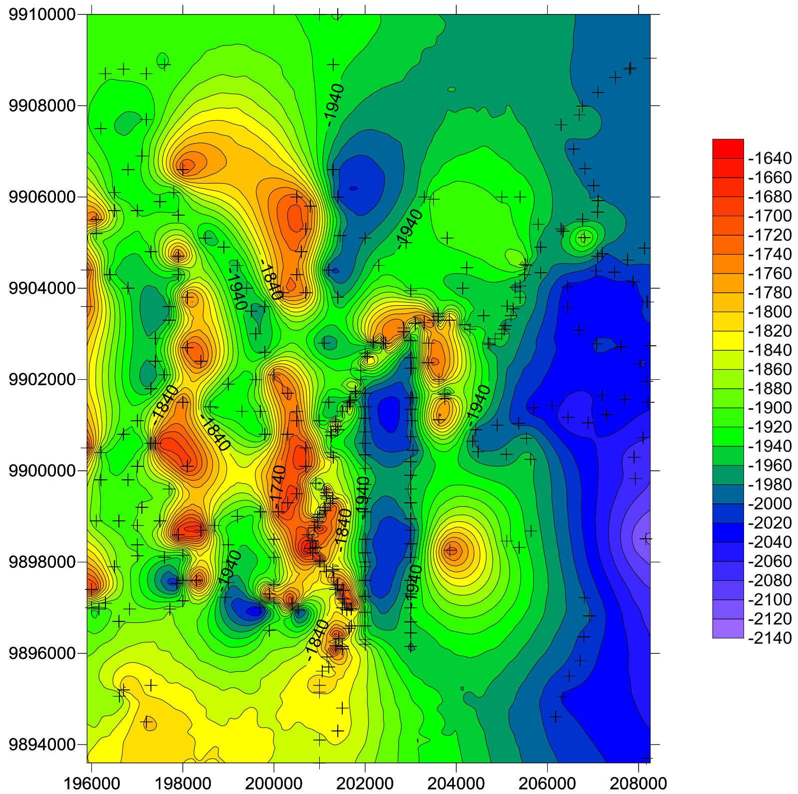


Fig. 3.2.2-6 Newly collected Bouguer anomaly distribution in Olkaria area

The micro-earthquake data itself was not provided by KenGen, however a report of the analysis results was provided. In general, the strength of rocks is greatly reduced and broken when pore water exist, and when the temperature pressure become higher beyond a certain value, rocks become plastic that are deformed plastically. Because of this nature, there exist clouds of micro-earthquake hypocenters where water penetrates down to the high temperature intrusions, and few hypocenters could be found beneath the hypocenter cloud. In the hypocenter distribution of the Olkaria field (Fig. 3.2.2-7), the upheaving of the hypocenter cloud and almost no seismicity area beneath the clouds. Such regions were well correlated with the upflow zones of high temperature fluid in the Olkaria field. Such hypocenter clouds can be seen beneath the exploitation area for Olkaria V. It suggests the existence of a promising area for steam production in the exploitation area for Olkaria V.

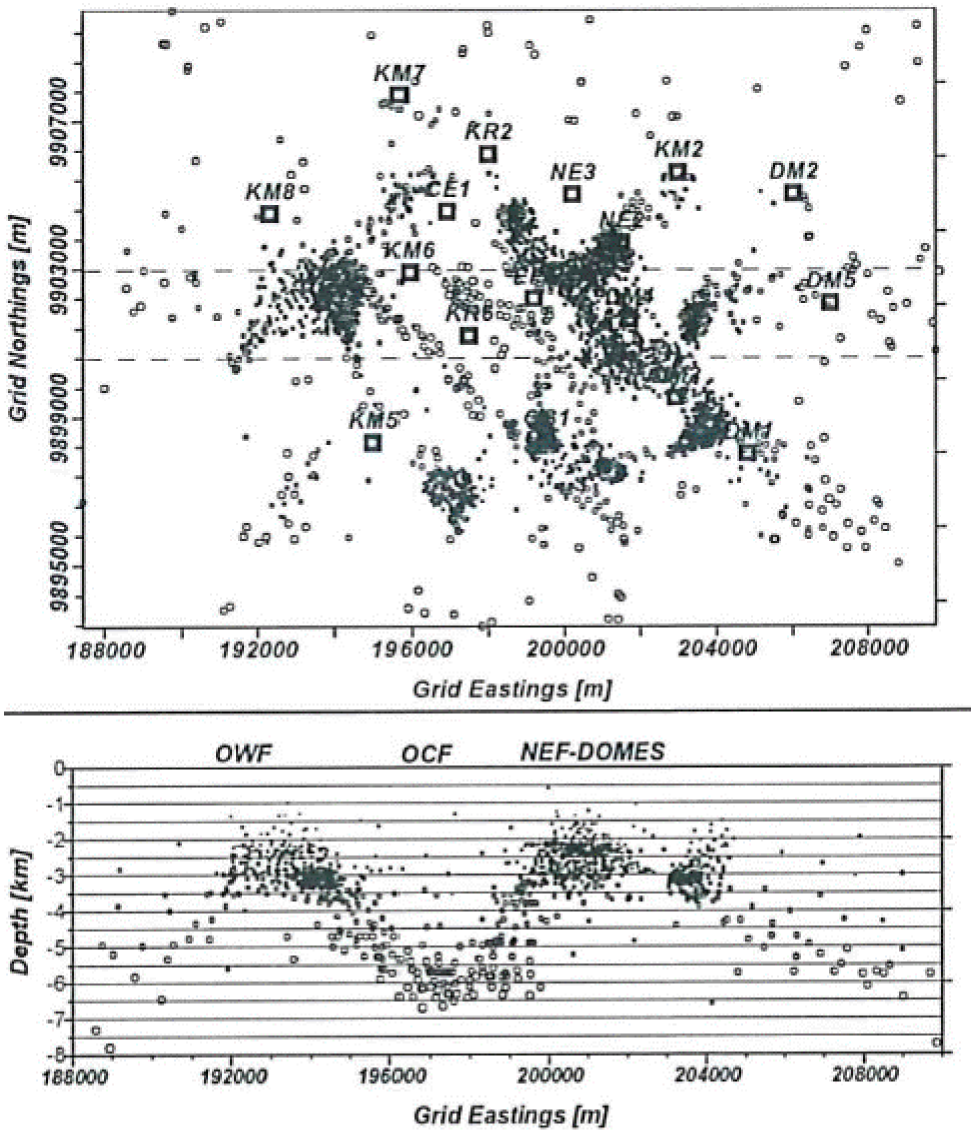


Fig. 3.2.2-7 Distribution of micro-earthquake hypocenters in the Olkaria area

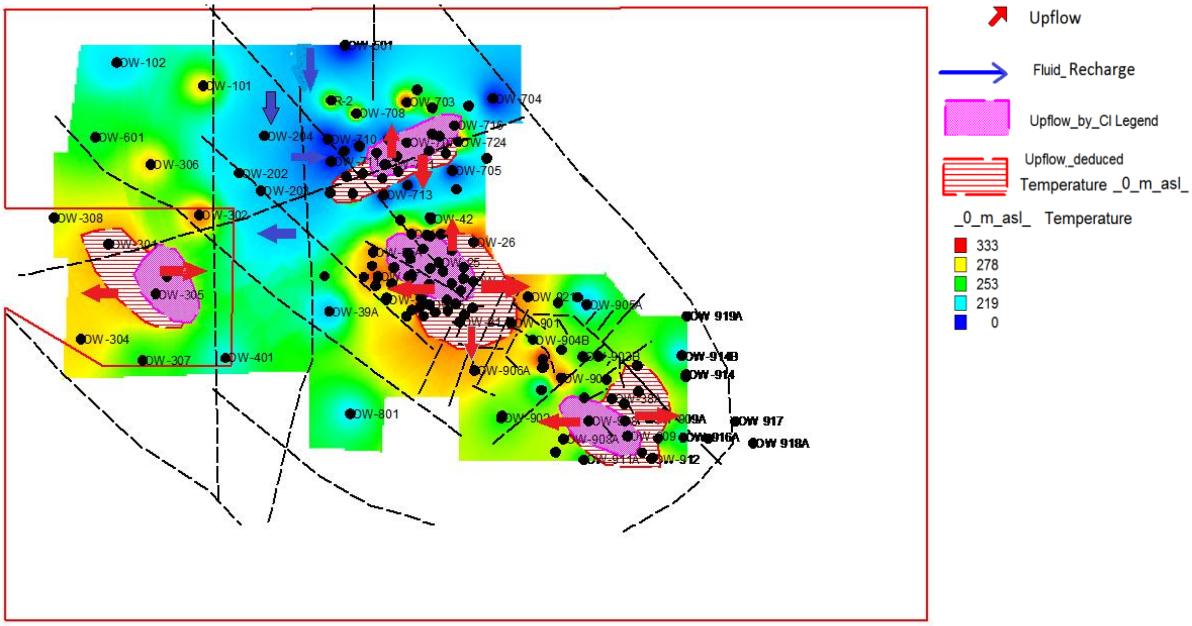
3.2.3 Geochemistry

KenGen provided chemical data of the steam and water in existing wells which are planned to supply the steam for the Olkaria V project. In addition, a KenGen internal report (2014) on the regional geochemical model of the Greater Olkaria area and other reports on well discharge chemistry (relating to Non-condensable Gas (NCG) content in steam and scaling potential in brine) have been also collected from KenGen.

Some studies on the geothermal resources in the Greater Olkaria area including the Olkaria V project have been carried out by KenGen and consultants (Mannvit and other companies) based on the chemical data obtained in the production test of some wells.

(a) Regional geochemical model

The regional geochemical model constructed by KenGen of the Greater Olkaria area is shown in Fig. 3.2.3-1. In the Olkaria area, recharge into the system is mainly occurring from the north-west of the geothermal area. The deep circulating water is heated by the magmatic heat source and likely provides upflows of hot fluid at four distinct areas. From the spatial distributions of chloride (Cl) concentration in brine and sodium/potassium (Na/K) geochemical temperature, one of the upflows may exist in the center of Olkaria Domes, where geothermal resources have been developed for the Olkaria IV and V projects.



(Source: KenGen internal report (2014))

Fig. 3.2.3-1 Regional geochemical model of the Greater Olkaria area

(b) Discharge fluid chemistry of wells for Olkaria V

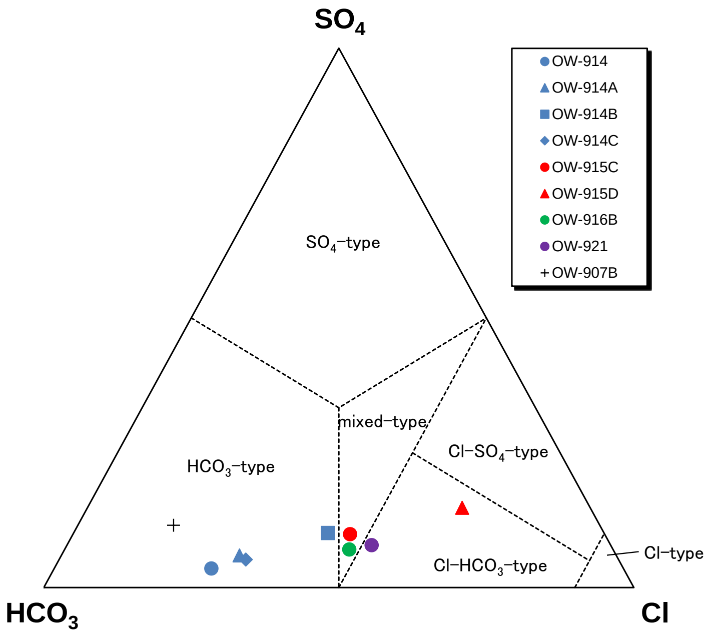
The chemistry of the water and gas in the steam of existing wells which are planned to supply the steam for the Olkaria V is shown in Table 3.2.3-1. The chemistry is similar to that of fluids from production wells in the developed fields in Olkaria; namely the fluids are relatively low in Cl and high in bicarbonate (HCO_3; indicated as 'Total-CO_2' in Table 3.2.3-2) as hot reservoir fluids. The main component of non-condensable gas (NCG) in the steam is carbon dioxide (CO_2), and the content of hydrogen sulfide (H_2S) is relatively small.

Table 3.2.3-1 Water and gas chemistry of production wells for Olkaria V

Well	Sampling Date	Well Head Pressure	Gas Sampling Pressure	Discharge Enthalpy	Water (after steam separation; at atmospheric pressure)													Gas in Steam					
					pH	Na	K	Li	Ca	Mg	Cl	SO_4	Total-CO_2	F	SiO_2	B	H_2S	CO_2	H_2S	CH_4	H_2	N_2	NCG in steam
		BarG	BarG	kJ/kg	@20deg.C	mg/kg												mmoles/100 mole					mole%
OW-914	2010/5/20	6.9	3.8	2111	10.06	1569	461	2.75	ND	0.01	514	87.5	1400	270	650	3.39	2.99	498	0.91	0.61	12.3	18.1	0.53
OW-914A	2010/12/6	14.0	3.5	1841	7.43	891	217	1.26	0.91	0.04	381	51.6	877	-	685	2.89	2.14	648	1.80	0.08	13.5	11.7	0.67
OW-914B	2011/5/26	12.8	5.7	2225	10.10	776	158	0.87	1.86	0.05	324	79.8	356	275	293	3.01	2.38	328	1.57	0.71	6.8	5.9	0.34
OW-914C	2013/5/20	11.7	11.0	-	9.51	896	278	1.57	ND	ND	386	47.1	706	234	997	0.96	4.08	631	2.56	3.75	10.8	7.3	0.66
OW-915C	2013/7/25	16.0	16.0	2424	10.16	1338	264	1.63	ND	ND	619	110.6	847	235	1832	1.19	11.56	137	1.30	0.07	27.8	5.9	0.17
OW-915D	2013/7/24	12.0	11.0	2326	10.28	918	337	1.61	ND	ND	698	137.0	342	264	1535	1.20	4.62	94	2.40	0.42	22.1	10.6	0.13
OW-916B	20134/17	10.0	9.8	2253	9.69	711	171	1.89	ND	ND	352	83.1	434	230	1161	0.98	3.74	494	5.46	3.13	38.8	6.7	0.55
OW-921	2014/3/14	14.5	14.0	1882	9.76	563	153	1.77	0.36	0.084	339	79.8	273	70.6	1117	2.03	2.04	394	2.71	0.87	6.4	22.3	0.43

(source) KenGen internal report (2014)

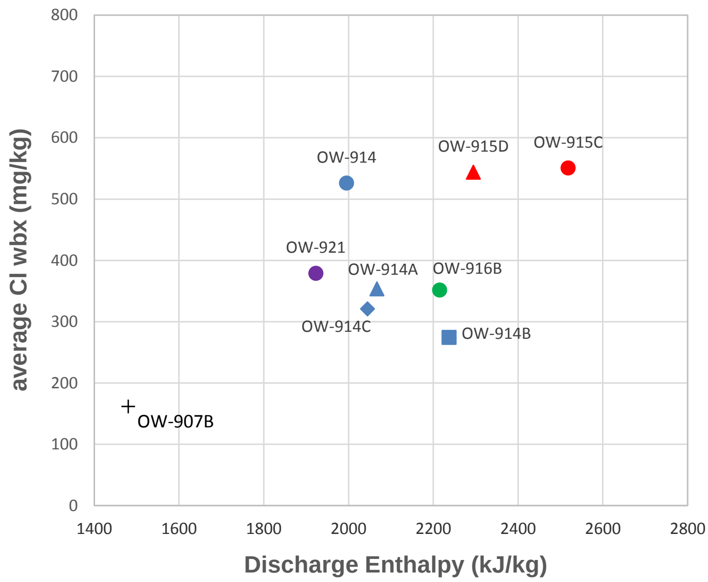
The major anion composition of well discharge water exhibits a fairly wide variety (Fig. 3.2.3-2). Since the ratios of Cl and sulfate (SO_4) are almost constant, the variety is attributed mainly to difference of bicarbonate (HCO_3) concentration in the water.



(Source) JICA Study Team

Fig. 3.2.3-2 Major anion composition of water of production wells for Olkaria V

A cross plot of discharge enthalpy vs. average Cl concentration in water of production wells is shown in Fig. 3.2.3-3. When we consider also the data of well OW-907B (which is probably not available to supply steam due to the low discharge pressure) the water from wells having a higher enthalpy tends to exhibit a higher Cl concentration in water. This suggests that the hotter water presumably ascending from the depths is relatively high in Cl. This tendency is consistent with the current interpretation on chemical characteristics of deep reservoir water in the Olkaria field.



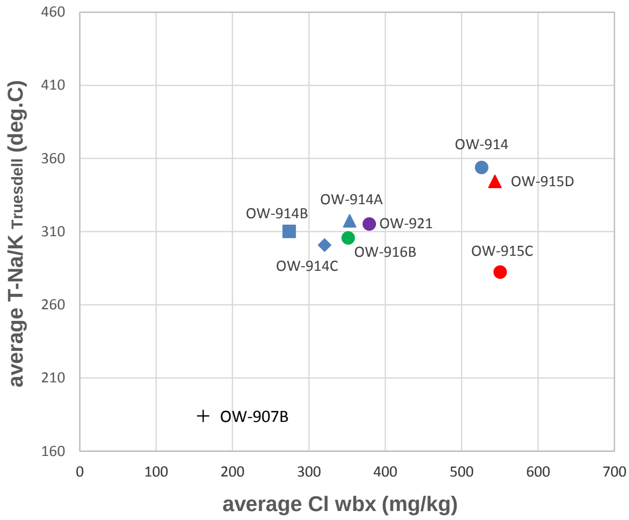
(Source) JICA Study Team

Fig. 3.2.3-3 Cross plot of discharge enthalpy vs. average Cl concentration in water

(c) Reservoir fluid temperature

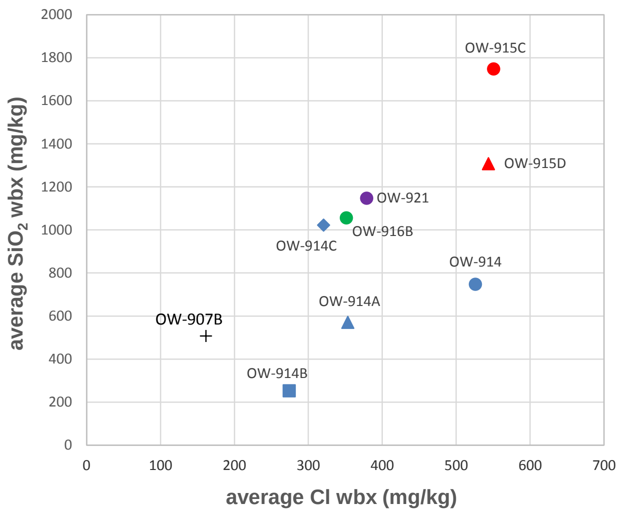
The Na/K geochemical temperature (calculated from the ratio of sodium (Na) and potassium (K) concentrations of water) for the high Cl water from wells OW-915D and OW-914, is high temperature at around 360°C (Fig. 3.2.3-4). This temperature is close to the maximum temperature measured in the boreholes at the Olkaria V field. The Na/K temperature for other production wells in Olkaria V is calculated to be around 300-320°C. It is suggested that the deep hot fluids having a temperature higher than 300°C contribute the discharge fluids of most of the (existing) production wells in the Olkaria V. On the other hand, the average Na/K temperature for OW-907B is 184°C, suggesting the contribution of cooler water being separated from the deep hot fluids.

Solubility of silica (SiO_2) in geothermal water increases with increase of the reservoir temperature. The high-Cl discharge water from production wells in the Olkaria V tends to be high in SiO_2 concentration (Fig. 3.2.3-5) as well as high Na/K temperature. However, we should note that SiO_2 concentration in water separated from steam at the surface is affected by the difference of degree of boiling (steam separation), so the SiO_2 concentration in water is not linearly proportional to the reservoir temperature.



(Source) JICA Study Team

Fig. 3.2.3-4 Cross plot of average Cl concentration vs. average Na/K temperature

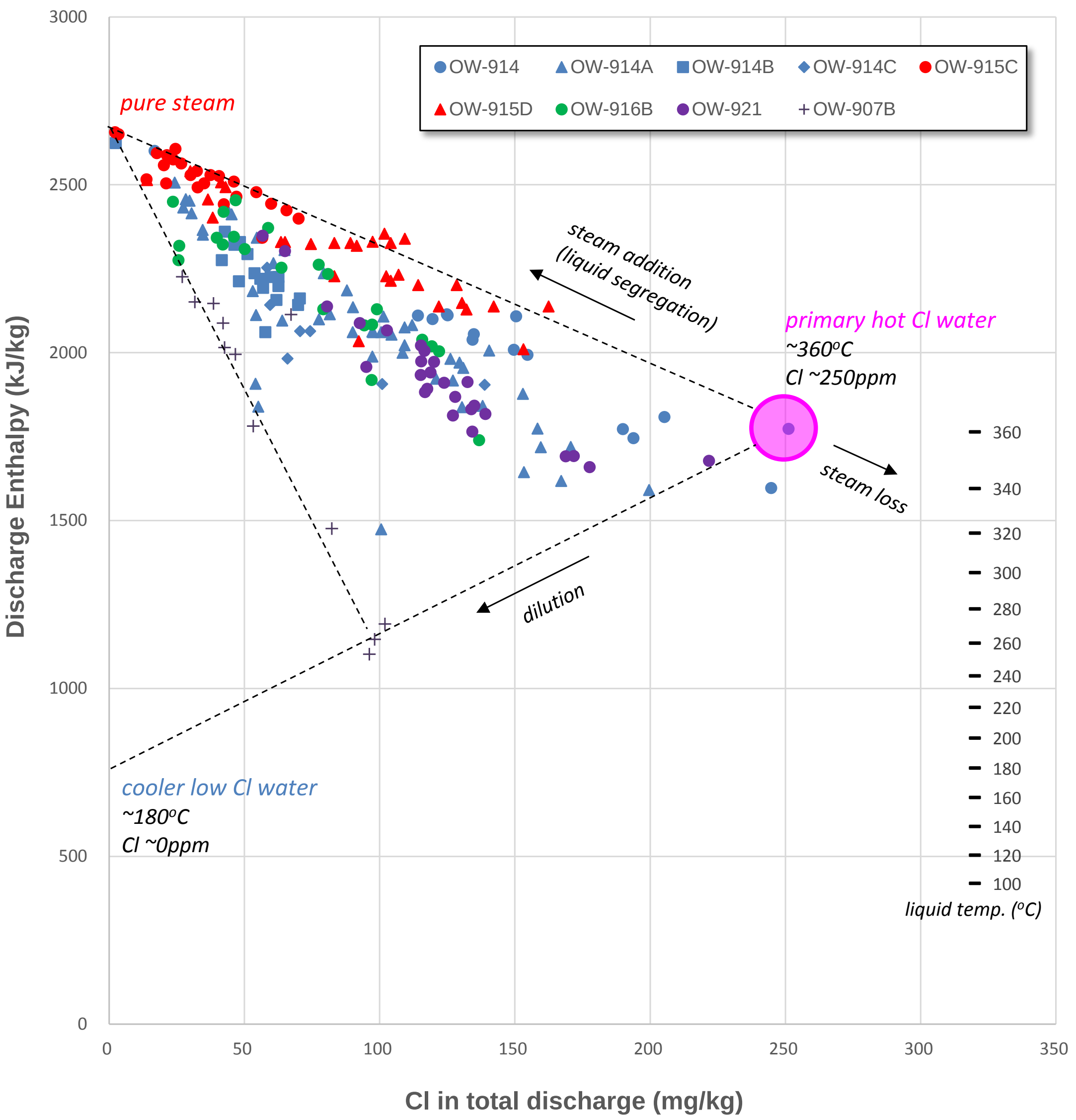


(Source) JICA Study Team

Fig. 3.2.3-5 Cross plot of average Cl concentration vs. average SiO_2 concentration

(d) Primary water and mixing model in Olkaria V

A cross plot of Cl concentration in total discharge fluids (water and steam) vs. discharge enthalpy of production wells for the Olkaria V project is shown in Fig. 3.2.3-6. This diagram of cross plot is generally utilized for assessing the mixing relations of several kinds of subsurface fluids. From the distribution of plotted data in the diagram, it is possible to delineate mixing lines and to estimate chemical/physical properties of end members of subsurface fluids.

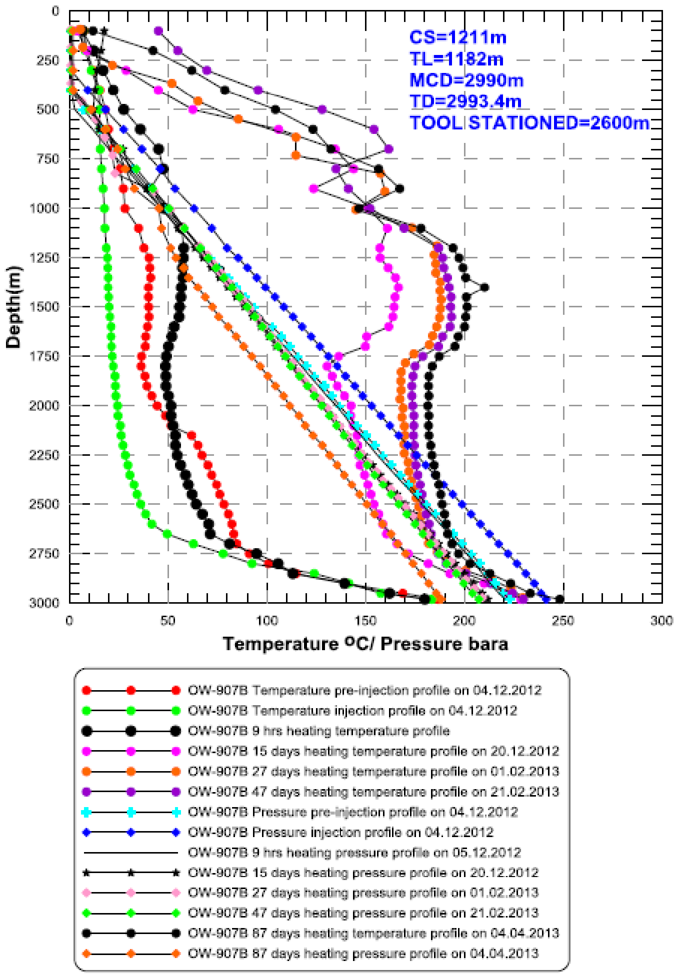


(Source) JICA Study Team

Fig. 3.2.3-6 Cl-Enthalpy mixing model

The distribution of plotted data in the above diagram suggests that the primary deep hot water in the Olkaria V sector has a temperature around 360°C and a Cl concentration of around 250ppm. The estimated temperature is comparable with the maximum measured temperature and Na/K temperatures of the production wells in the Olkaria V field. The discharge fluids from wells in the drilling pad OW-915 (OW-915C and OW-915D) is thought to be mixture of the steam from boiling of the primary water and a part of remaining liquid water. Some of the discharge fluids from well OW-914 appear to be a similar mixture of fluid.

On the other hand, the plotted data of OW-907B indicates the contribution of water having a considerably lower temperature and Cl concentration compared with the primary water. Such cooler water is likely to have a temperature around 180°C and a Cl concentration nearly 0ppm. Considering the Na/K temperature of OW-907B near 180°C and the measured borehole temperature suggesting the formation temperature around 180°C at OW-907B (Fig. 3.2.3-7), the cooler water may possibly exist at relatively shallow levels.



(Source) KenGen internal data

Fig. 3.2.3-7 Temperature and pressure profiles of well OW-907B

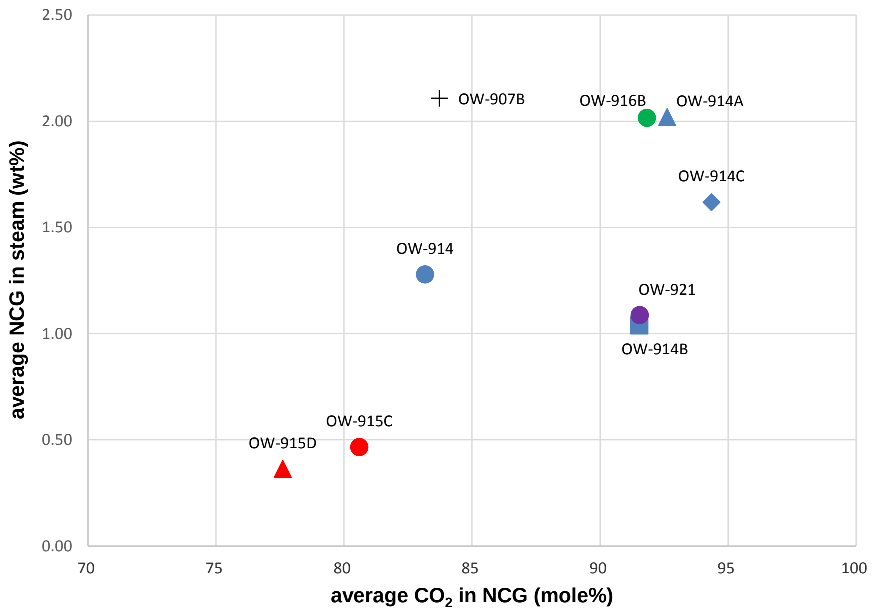
The plotted data in Fig. 3.1.2-6 suggest that the discharge fluids from wells OW-914A, OW-914B, OW-914C, OW-916B and OW-921 are composed of not only the primary water and the steam from it but also some of the cooler water having a temperature around 180°C.

From the discussions described above, it is inferred that the main upflow of primary hot water exists close to the area around the well pads of OW-915 and OW-914, where is at the center of Olkaria V project area. At the surrounding areas, the cooler water having a temperature around 180°C may occur locally at relatively shallow levels and contribute to the discharge fluids at some production wells. The cooler water aquifer likely extends widely around the well OW-907B, and this may result in the low productivity of the well.

(e) Fluid chemical constraints for power generation

Generally it seems that the drilled wells in the Olkaria V project area are not in any great danger from corrosion at the surface facilities including pipelines. The salinity of water from the wells is moderate and the pH is relatively basic and not acidic.

Non-condensable gas (NCG) content in the steam from production wells is in a range of 0.4-2.0wt% (Fig. 3.2.3-8), and the average is 1.2wt%. This NCG content is higher than that of the steam supplied for the existing power plants in Olkaria, but it is still benign and will not cause significant obstacles for power generation utilizing a condensing-type turbine.

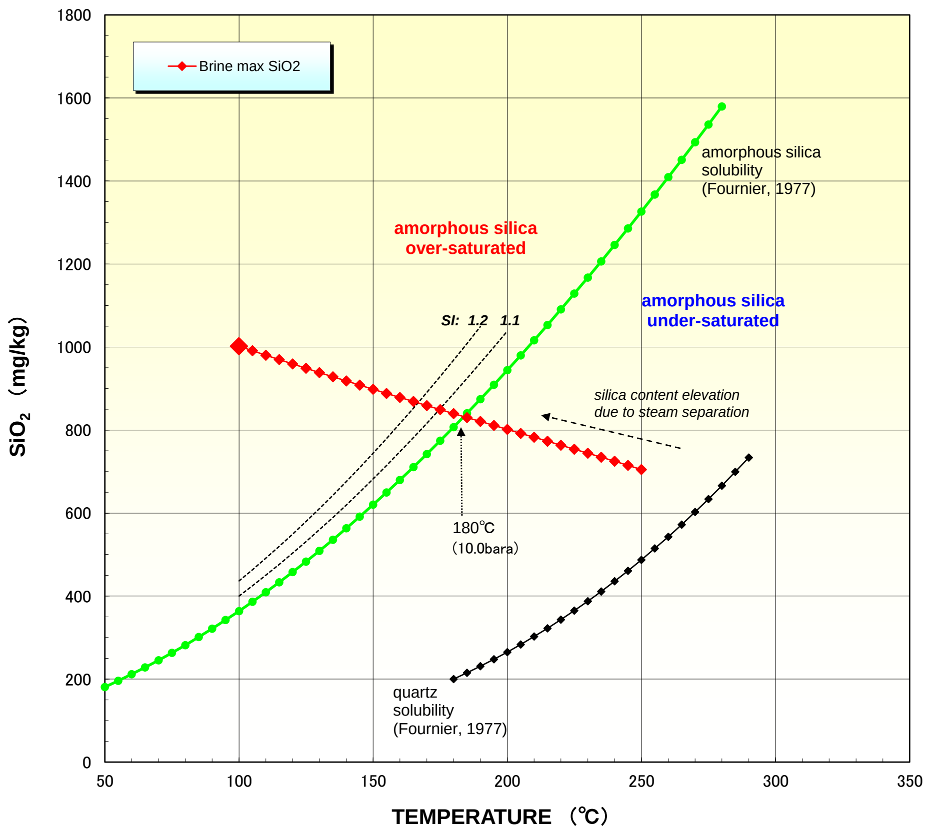


(Source) JICA Study Team

Fig. 3.2.3-8 Cross plot of CO_2 content in NCG vs. NCG content in steam

As the water from drilled and tested production wells in the Olkaria V area is relatively high in silica, it is imperative to avoid silica scaling from the water separated from steam. The weighted average silica concentration is calculated to be 1,000ppm in the water with the maximum steam separation at the atmospheric pressure. To keep the undersaturation condition in terms of amorphous silica (silica scale) for such water, the steam separation temperature shall be set at 180°C or higher (pressure: around 10 bara or higher) and the separated water shall be directly reinjected without cooling (Fig. 3.2.3-9).

However, the silica concentration in the water is significantly different from well to well (Refer to Fig. 3.2.3-5). For the utilization of wells discharging water high in silica (wells in the pad OW-915), special care must be taken to avoid scaling. No silica scaling problems have been reported in the production tests of wells in the pad OW-915 (personal communication from a KenGen engineer). This is possibly because of the slow reaction rate of silica polymerization (kinetic effect) and/or the high brine pH (~10) of the wells. In the power plant operation stage, in regards to steam production from the wells on pad OW-915, it is recommendable to use high wellhead pressures, as much as possible, in order to lower the degree of silica oversaturation in the brine from the OW-915 wells with a higher pressure and temperature at the two-phase line up to the separator station in where the brine is diluted by mixing with brines from other wells. In regards to setting the separator temperature (pressure) and designing the reinjection water line, it is desirable to review them for optimization at the stage when the production test data of all the wells required for the project has been obtained.



(Source) JICA Study Team

Fig. 3.2.3-9 Relation of SiO_2 concentration and amorphous silica solubility in water

3.2.4 Review of the Existing Geothermal Resource Evaluation Model and Situation of the Model Update

(1) The existing wells

Fig.3.2.4-1 shows the location of wells around the development area for Olkaria V. The number of existing wells drilled outside of the National Park is 17 (OW-905, 905A, 907B, 912B, 914, 914A, 914B, 914C, 915C, 915D, 916B, 917, 918, 918A, 921, 921A and 921B) in total. Drilled depths have a range of approximately from 2,000 m to 3,000 m. Most of the wells reached the depth of 3,000m. Injection tests for measuring formation permeability and well-loggings for measuring formation pressure and temperature have been done in these wells. In addition, production tests have already been conducted for 9 wells of the existing wells located outside of the National Park. It has not been decided yet which wells should be utilized for Olkaria V. KenGen is willing to distinguish which wells should be connected to the power plant of Olkaria V, taking results of drilling into consideration. Accordingly allocation of production or reinjection wells will be decided by the bidding for steam-gathering construction. Candidates of production wells to connect to the Olkaria V power plant is shown in Table 3.2.4-1.

Table 3.2.4-1 Candidates of wells to connect to the Olkaria V power plant

No.	Well pad	Well No.	Wellhead pressure (bara)	Steam (t/h)	Water (t/h)	Total (t/h)	Enthalpy (kJ/kg)	Completion depth (m)	Production casing depth (m)	Output (MWe)
1	OW-914	OW-914	14.5	86.3	30.2	116.5	2120	3000	952	12.5
2		OW-914A	15.1	54.9	35.6	90.5	1841	3000	858.53	8
3		OW-914B	13.6	50.4	12.6	63	2246	3000	754.49	7.1
4		OW-914C	12.87	48	25	73	1946	3000	951.36	6.6
5	OW-915	OW-915C	11.7	63.6	10.7	74.3	2364	3010	836.23	8.8
6		OW-915D	13.8	45.3	18.4	63.7	2059	3000	847.61	6.3
7	OW-916	OW-916B	12	37.2	16.6	53.8	2088	3000	942.25	5.7
8	OW-921	OW-921	NA	NA	NA	NA	NA	NA	NA	6.5
9		OW-921A	24.1	177.9	206.5	384.4	1547.5	3000	1084.46	24.7
				563.6	355.6	919.2			sub-otal	86.2

The total number of the existing wells in the entire Olkaria area reaches over 100, as geothermal power plants for Olkaria I to IV have been already constructed. Based on this accumulated well data, KenGen is going to expand the exploitation area to the surrounding new fields such as Olkaria VI and VII, where well data has not yet been accumulated.

(2) Geothermal resource potential evaluation model

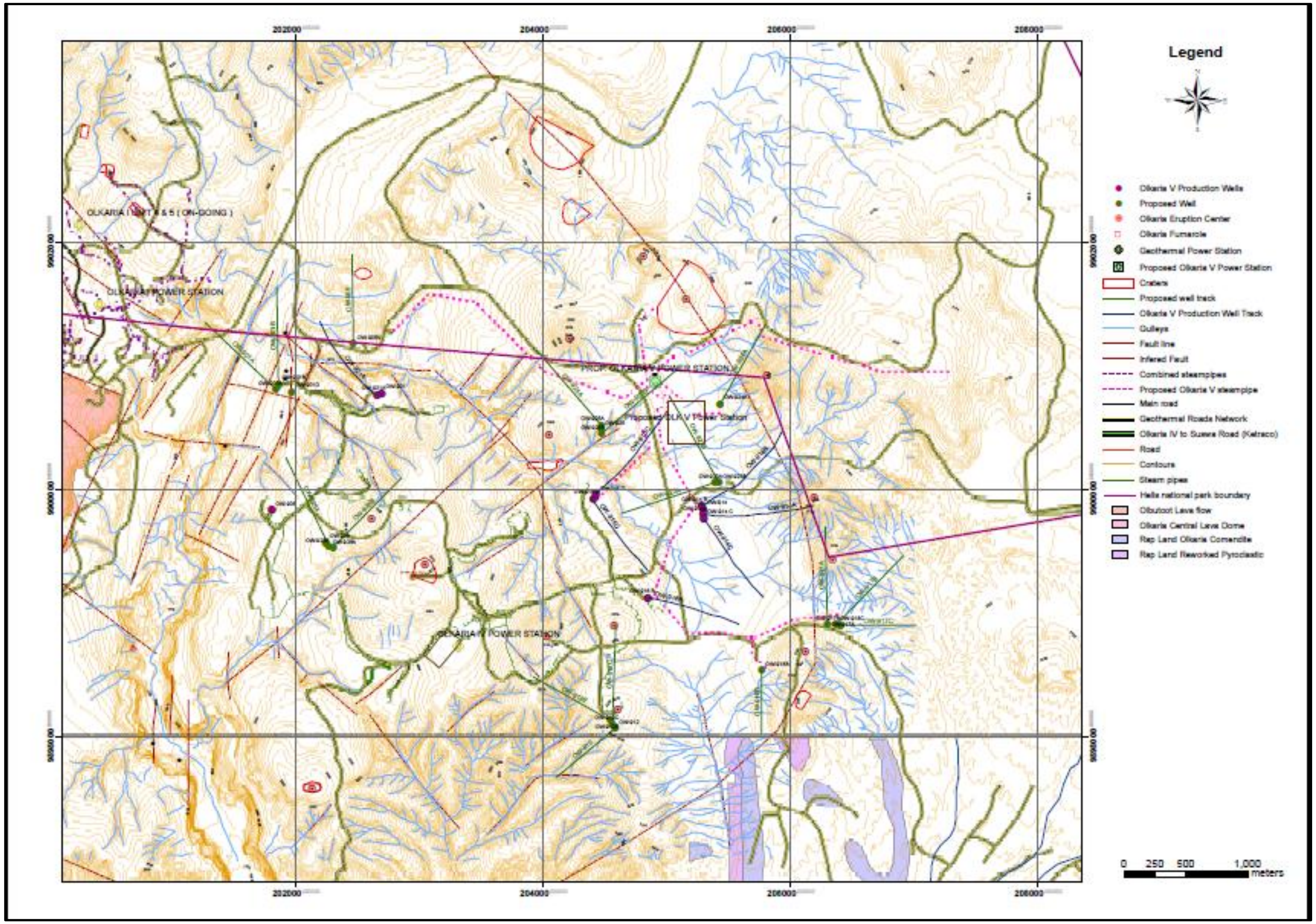
Reports relating to the geothermal resource evaluation which were collected during the first survey in Kenya are shown in Table 3.2.4-2. According to the report, "Feasibility Study for Development of KenGen's Geothermal Concession Area in Olkaria Beyond 430 MW (Revised September 2012)", the objective of the report was to evaluate geothermal resources in the entire Olkaria development area of 204 km^2, which is KenGen's concession area.

A conceptual model of the entire Olkaria geothermal system is shown in Fig.3.2.4-2. The heat source of the Greater Olkaria Geothermal System is assumed to be a deep-seated magma chamber or chambers. Three main intrusions are believed to extend up from the magma to shallower depths of 6,000-8,000 m. These heat source bodies are proposed to lie beneath Olkaria Hill (Olkaria III), in the northeast beneath the Gorge Farm volcanic centre, and in the Domes area. Four major geothermal up-flow zones are identified. First, 1) an up-flow zone feeding the West field seems to be associated with the Olkaria Hill heat source body. Second, two up-flow zones, 2) one feeding the Northeast field and 3) another feeding the Eastern field and the northwest corner of the Domes, are probably both associated with the heat source body beneath the Gorge Farm volcanic centre. Finally, 4) an up-flow zone appears to be associated with the ring structure in the southeast corner of the Domes field, related to the heat source proposed beneath the Domes area. The existence of these up-flow zones is predicted by Cl^- concentration data, reservoir temperature estimates, as well as resistivity data. It is considered that high temperature fluids of around 340°C ascend from the depth at the up-flow zones to the shallower depth through dominant permeability structures such as faults, then form geothermal reservoirs at the depths of 1,000 m - 2,000 m.

The reservoir numerical model for evaluating geothermal resource potential was also established so as to cover the whole Olkaria development area, as indicated in Fig.3.2.4-3. This reservoir numerical model is very large, covering 720 km2 and its thickness is 3,600 m, ranging between 1900 m above sea level and 1,700 m below sea level. The model has 15 layers, each containing 2,463 elements. In total there are 36,945 elements. The model is constrained by boundary conditions that are implemented so as to maintain a constant pressure and temperature as the initial setting values in the top and bottom layers. These layers are relatively impermeable and the flow of fluids into or from adjacent layers is limited. In order to attempt capturing the North-South flow of cold water in the Ololbutot fault, the north and south boundaries in the layer at 400 m above the sea level are open to flow. Each element in the model has a certain rock type with specific properties (rock density, porosity, permeability, heat capacity and thermal conductivity). The model is set up with the dominant permeability for the Ololbutot fault running from North to South, dividing the Western and Eastern parts, and the Olkaria fault running from WSE to NEN to capture the main structural features and fluid behavior of the Olkaria system. The outermost elements of the grid are all of the same rock type and have very low permeability in order to keep stable pressure and temperature. On the other hand, the innermost part of the grid, inside the outer ring structure, has the highest permeability.

Table 3.2.4-2 Reports for geothermal resource evaluation

No.	Report Title
1	Preliminary Status Report 11 Mar 2012. Development of a numerical model of the Greater Olkaria Geothermal System Phase II (11 Mar 2012)
2	Preliminary Assessment of the electrical generating capacity of the Greater Olkaria Geothermal System (September 2011)
3	Volumetric resource assessment and lumped parameter pressure response modeling for the Greater Olkaria Geothermal System (December 2011/March 2012)
4	Chemical constraints on geothermal power production in the Greater Olkaria Geothermal Area: Scaling and corrosion potential and non-condensable gases (February/May 2012)
5	Report No.6 Task2 Feasibility study for stabilizing power generation with an optimized capacity of the existing plants (Revised September 2012)
6	Report 7 Development of a numerical model of the Greater Olkaria Geothermal System Phase II (June 2012)
7	Report 8- Revised Proposed field development plan for the Greater Olkaria Geothermal Field (Revised September 2012)
8	Report no.9- Feasibility study for development of KenGen's geothermal concession area in Olkaria beyond 430 MW (Revised September 2012)
9	Preliminary assessment of the electrical generating capacity of the Greater Olkaria Geothermal System (September 2011)
10	Revision of the conceptual model of the Greater Olkaria Geothermal System Phase I (October 2011)



(Source):JICA study team

Fig. 3.2.4-1 Location of wells around the development area for Olkaria V

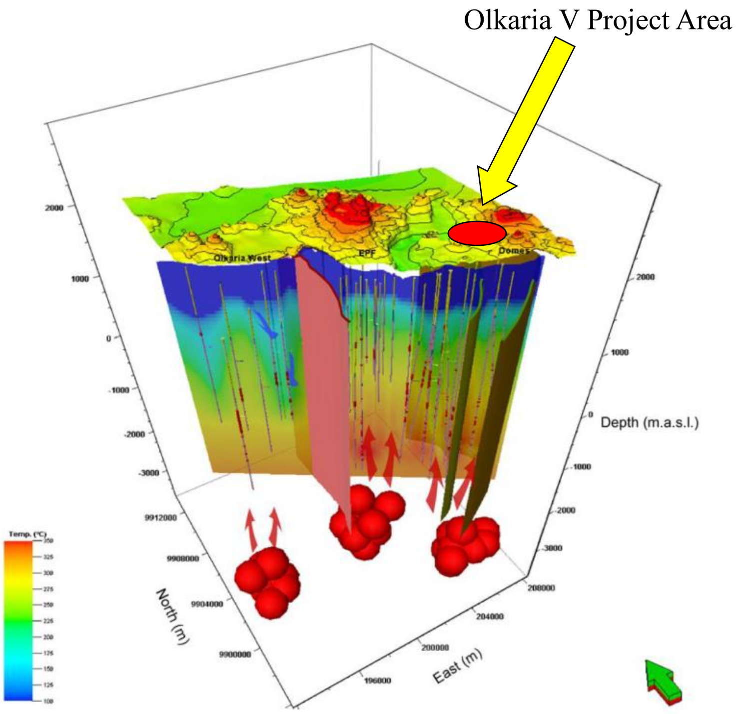


Figure 4. A schematic sketch of the present revision of the conceptual model of the Greater Olkaria Geothermal System. The green arrow in the bottom right corner is directed north. The top layer shows the topography and the Ololbutot fault is shown along with parts of the ring structure. A temperature cross section is also shown and at the bottom the postulated heat sources and up-flow zones (Mannvit/ÍSOR/Vatnaskil/Verkís, 2011c).

(Source) Mannvit (2012)

Fig. 3.2.4-2 Proposed field development plan for the Greater Olkaria Geothermal Field

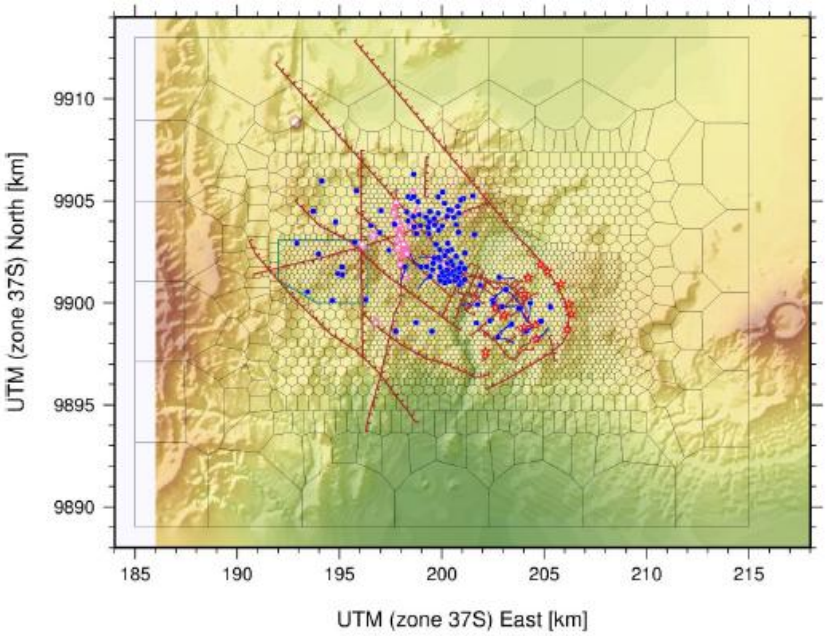


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Figure 17. Plan view of the model grid and main structures in the Greater Olkaria geothermal system. Well locations are shown with blue dots, surface manifestations with pink triangles and rhyolite eruption centres with red stars.

(Source) Mannvit (2012)

Fig. 3.2.4-3 Plan view of the reservoir numerical model grid of the Greater Olkaria Geothermal System

The report, "Development of a Numerical Model of The Greater Olkaria Geothermal System – Phase II (June 2012) " introduces results of forecasting simulation which assess the response of the whole Olkaria geothermal system to future production to estimate its sustainable capacity, while setting up several scenarios. Among these scenarios, the most referable case to the development of 140 MW for Olkaria V is Scenario 6, which assumes an additional 250 MW of development for Olkaria IV and V in the Domes area, while the actual development plan is 280 MW for Olkaria IV (140 MW) and V (140 MW). The actual development plan has not yet adapted to the forecasting simulation. As shown in Fig. 3.2.4-4 and Fig.3.2.4-5, the results of the forecasting simulation for Scenario 6 indicate that most of the production area has a drawdown of over 40 bar and around the production wells the drawdown is above 50 bar, and steam fraction expands widely, reflecting extensive boiling in the production layers in the Domes area within 30 years due to development of 250 MW, compared to the current condition. The reservoir usually tends to change significantly after beginning production, which is known as an initial pressure decline from the natural state. Since temperature in the reservoir at Olkaria V is very high, over 300°C, pressure drawdown will easily induce vaporization in the reservoir, which is a reason of for the expanding steam-rich zone. Reflecting an increase of the steam fraction, specific enthalpy in the reservoir, which indicates thermal energy per unit mass, is also forecasted to increase. While the reservoir simulation conducted in 2012 forecasts these kinds of changes in the reservoir, the production rate and power output of the power plants are forecasted to be mostly stable during the plant operation of 30 years, as shown in Fig.3.2.4-6. It suggests that power generation of 250 MW could be sustained for 30 years in the Domes area.

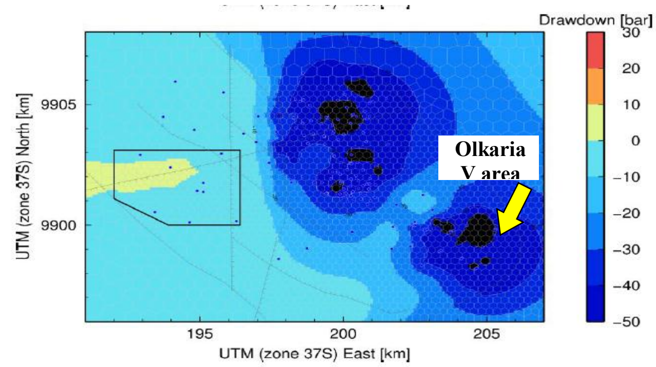


Figure 54. Drawdown in the main production layers (E top, H centre, J bottom) at the end of the forecasting period for Scenario 6 with injection.

(Source)
Mannvit 2012

Fig. 3.2.4-4 Forecasted pressure drawdown in the main production layers at 30 years

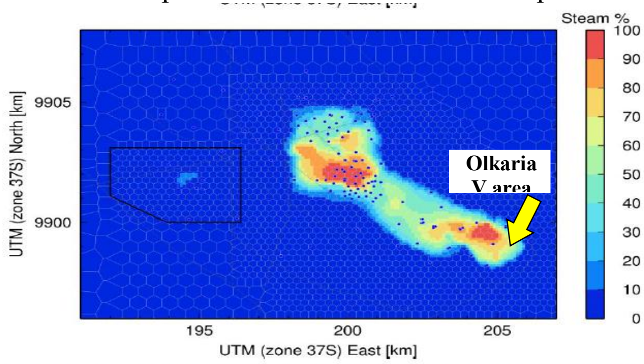


Figure 55. Steam fraction in the main production layers, E (top, EPF), H (centre, NEPF) and J (bottom, Domes) at the end of the forecasting period for Scenario 6 with injection.

(Source) Mannvit 2012

Fig. 3.2.4-5 Forecasted steam fraction in the main production layers at 30 years

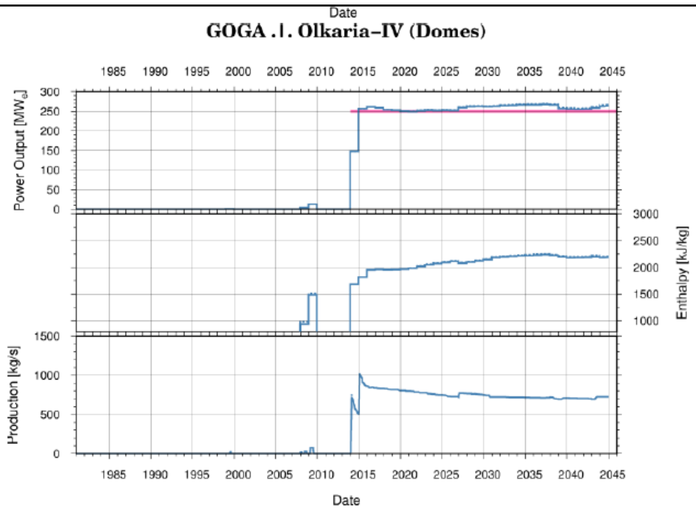


Figure 53. Evolution of mass extraction, enthalpy and power output for scenario 6. The red lines show measured values, the blue lines model calculated values and pink lines show the target production for the scenario.

(Source) Mannvit 2012

Fig. 3.2.4-6 Forecasted changes over time of power output, enthalpy and steam production rate during plant operation for 30 years

According to the results of well drillings in Olkaria V, KenGen had drilled 17 wells, and succeeded in steam discharge for 9 wells to date (among those outside the National Park). The total steam flow rates produced by the 9 wells in the production tests is estimated to be about 90MW, which is equivalent to more than 60% of the planned 140 MW power output of Olkaria V. It is considered that there is an up-flow zone of high-temperature fluids of over 300°C in the Olkaria V area, where a prospective high-potential geothermal reservoir is formulated. The power output of a well in the Olkaria V area is estimated to be about 9 MW in average, much higher than other wells in Olkaria. KenGen is planning to drill 8 more production wells to secure the steam required for 140 MW, assuming that the averaged power output is around 5 to 7 MW as a conservative prospect. With regards to reinjection, allocation of reinjection wells affects the reservoir in pressure or temperature, depending on interferences between production and reinjection zones. While reinjection has good effects in terms of pressure support, it has bad effects in terms of cooling in the reservoir. KenGen is going to finalize allocation of wells by taking the results of future well drillings into consideration. They have decided to drill 11 additional reinjection wells.

(3) Review of the forecasting simulation

The current geothermal reservoir model was updated based on the previous model West JEC created in 2009, by adding well data provided for the years after 2009, and utilizing the data of wells OW-901 to OW-916 for the Domes field. Therefore, the concept of the model is basically the same as the previous model, and the model is calibrated to fit pressure and temperature profiles in natural state in the wells drilled so far. In addition, the model fits measured enthalpy of well fluids and pressure drawdown in wells throughout the production period, which began in 1981. This model forecasts that the reservoir will produce the steam required for power generation of 250 MW for 30 years in the Domes field, if make-up wells are added at the appropriate time.

It should be noted that some of the existing wells in the Domes field already succeeded in steam production and the total amount of the steam produced from these wells is estimated to be over

60% of the required steam for 140 MW power generation. Furthermore, the Olkaria V development area is located around an up-flow zone of high temperature fluids of over 300°C, and the average productivity of the wells doubles that of many of the wells in Olkaria I or II, which reflects a higher reservoir temperature. Accordingly by drilling the 8 additionally planned production wells, the steam required for 140 MW power generation can be sufficiently secured.

Integrated discussion indicates that the geothermal reservoir in Olkaria V will sustain 140 MW for 30 years with the addition of appropriately timed make-up wells, after the commissioning of power plant operation.

3.3 REVIEW OF SURFACE FACILITIES

3.3.1 Review of Power Plant

(1) Type of Power Plant

The results of the resource evaluation suggest that the generated output will be 140 MW (net). The geothermal fluid will be two-phase, and the non-condensable gas (NCG) content in the steam will be less than 2.0 % by weight. Since the power plant will be located at the north-east end of the project area, the distance from the westernmost wellpad OW-921 to the power plant is about 2.5 km. Among the geothermal energy conversion technologies listed in Table 3.3.3-1, a single-flash steam cycle with condensing turbine is advisable for the Olkaria V project for the following reasons.

- With a single flash cycle system, the transportation cost of brine (costs of pipeline and pump and power consumption of the pump) is cheaper than that of double flash cycle and two-phase binary cycle systems because the separated brine can be directly sent to the reinjection wells.
- In a single flash cycle system, the brine can be reinjected at higher temperature compared to double flash cycle and binary cycle systems. The higher reinjection temperature in a single-flash cycle system results in less stress to the reservoir and less risk of trouble due to silica scaling in the reinjection pipeline and wells.
- A single flash cycle system is simple and is the most popular type of geothermal power plant, with well-proven technology and a wide range of applicable design conditions. In Olkaria, where the steamfield and the power plant are designed based on data from a limited number of wells (in other words, the production wells are drilled during the construction of the surface facilities in order to shorten the project period), the single flash cycle is preferable.

Table 3.3.1-1 Comparison of Geothermal Energy Conversion Technologies

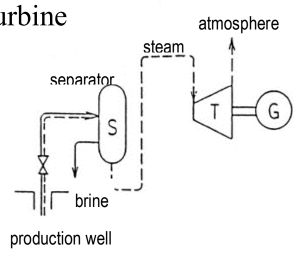
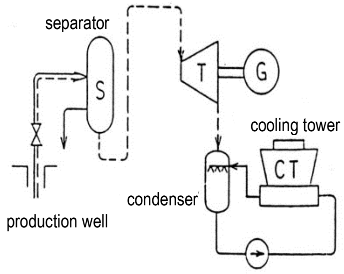
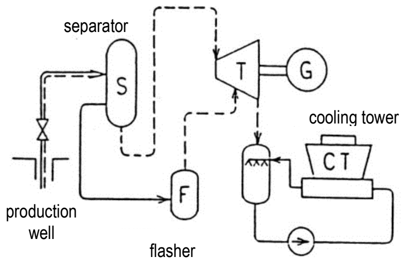
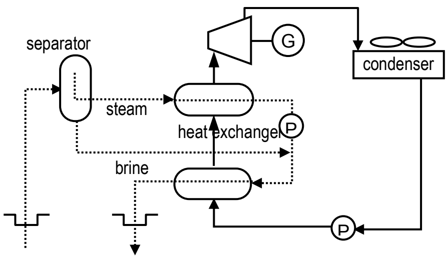
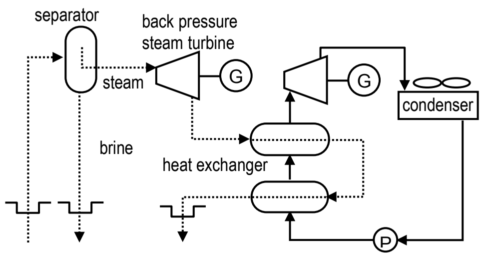
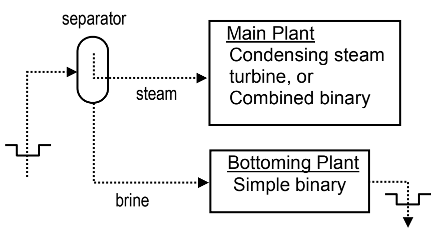
Cycle		Type of Process	Features
Flashed Steam Cycle	Not recommended	Single Flash with Back Pressure Steam Turbine  	• Suitable for two-phase resources of high NCG content. • Small capacity - Usually installed as a wellhead generating pilot plant. • Lower efficiency (i.e. high steam rate) compared to condensing steam turbine • Low construction cost. • High exhaust noise level.
	Recommended	Single Flash with Condensing Steam Turbine  	• Suitable for two-phase resources of low NCG content. • Large capacity • The brine is reinjected without utilizing its thermal energy. • Simple configuration allows a wide range of applicable design conditions. • Single flash is favored over double flash for preventing silica scale in reinjection line. • Brine booster pump may be eliminated by installing the separators at higher elevation than that of the reinjection pad.
	Not recommended	Double Flash with Condensing Steam Turbine  	• Suitable for water-dominated resources of low NCG content. • Large capacity • 10 to 25 % more output than single flash depending on quantity of brine. • Construction cost is about 6 % higher than for single flash. • Less amount of brine for reinjection. • Low temperature brine from flasher would cause silica scale problems in reinjection line unless an anti-scaling measure is taken. It would also cause extra stress to the reservoir. • Costs for transporting brine will be higher than that of single-flash cycle.

Table 3.3.1-1 Comparison of Geothermal Energy Conversion Technologies (continued)

<table>
<tr><th>Cycle</th><th></th><th>Type of Process</th><th>Features</th></tr>
<tr><td rowspan="3">Binary Cycle</td><td>Inconceivable</td><td>Two-phase (Biphase) Binary

</td><td>• Suitable for water-dominated resources of moderate to medium specific enthalpy.
• No gas extraction system (ejector and vacuum pump) is needed.
• Unit capacity is up to around 10 MW.
• Middle size capacity can be achieved by installing many units.
• It utilizes thermal energy of both steam and brine.
• Low temperature brine would cause silica scale problems in reinjection line and heat exchangers unless an anti-scaling measure is taken. It would also cause extra stress to the reservoir.
• Both the steam and brine must be brought to the power plant.</td></tr>
<tr><td>Inconceivable</td><td>Combined Binary Cycle

</td><td>• Suitable for high-pressure, mid to high specific enthalpy resources.
• No gas extraction system is needed.
• Usually, a few binary units will be connected to the back pressure steam turbine.
• Large capacity is possible.</td></tr>
<tr><td>Conceivable</td><td>Hybrid Type (Bottoming Cycle)

</td><td>• Suitable for water-dominated, medium specific enthalpy resources.
• High efficiency since it utilizes both steam and brine.
• The bottoming plant can adjoin the separator station and be monitored / controlled from the main plant.
• The bottoming plant can be constructed along the reinjection line in the future.
• Low temperature brine causes silica scale problems in reinjection line and heat exchanger unless an anti-scaling measure is taken. It would also cause extra stress to the reservoir.
• Higher cost because the main plant and the bottoming plant will be constructed separately.</td></tr>
</table>

(2) Ground condition of Olkaria V planned area and layout of the facility

The proposed site for the Olkaria V power plant is the flatland on the west of the proposed wellpad OW-924 (Figure 3.3.3-1). Although a long pipeline is needed to bring steam from the production wells, this place has several advantages such as requiring less civil work, no tree felling, and being besides the existing road.

With respect to the ground conditions around the proposed power plant site, there is a cliff (H=15m~25m) with clearly observed geologic strata on the encroachment wall, located besides a small river running near the planned location for plant (OLK-V) construction (about 450m in a straight line from the OLK-V planned area). Sequence (panoramic) photographs were taken during the second trip for the preparatory survey. The planned well-drilling point for OW-925 is located at the opposite shore of the above-mentioned cliff, and the elevation (altitude) of the location appears to be nearly same as the altitude of the cliff bottom (see below-attached photographs).

The above-mentioned circumstance was almost confirmed on the contour map; also the information regarding elevation for the OW-925 drilling point was obtained from KenGen. Then, these locations, together with boring data from OLK-IV (already obtained during the first trip for preparatory survey), were added to the cross sectional drawing as shown in Fig. 3.3.1-2 “Geological Cross Section A-A”. The information regarding well-head elevation for the OW-915 drilling point between OLK-IV and V has also been obtained as another relevant piece of data regarding the ground condition; and the location was added to the cross section. The OW-915 drilling point is located about 900m from the planned OLK-V area and its well-head elevation is about 25m lower than the OLK-V area. These locations are plotted on the plan drawing shown in Fig. 3.3.1-3 “Geological Plan”.

The geological data for OLK-IV is shown in the “Soil Investigation Report” which was written and submitted to KenGen by the EPC contractor of OLK-IV (Hyundai Engineering), and 13 boring investigations were carried out at the plant location during the investigation. Each boring was carried out down to a depth of 25m, and result indicated similar composition of soil strata and soil strength (N value by SPT) with little difference among all the boring logs. Therefore, it was concluded that there was no particular difference among all the boring logs. The boring log of BH-1, which was carried out at the location of the west cooling tower, is a typical boring log. It is shown on the right-hand side of Geological Cross Section A-A, (Fig. 3.3.1-2). The location of BH-1 in circled on a diagram of the plant, which is shown just to the left of the BH-1 boring log, in the same figure, Geological Cross Section A-A, (Fig. 3.3.1-2).

In regards to the strength index for soil, N-value, “Specifications for Highway Bridges Part IV Substructures” published by the Japan Road Association” indicates that “A sandy and a gravel stratum which N-value is more than 30 can be deemed as a good bearing layer”. At BH-01, the N-value at the lower part of piles is determined to be about 25~40 in the sandy stratum of “Fine Silty Sand (Volcanic ASH)”. Therefore, it can be determined to be a good bearing layer.

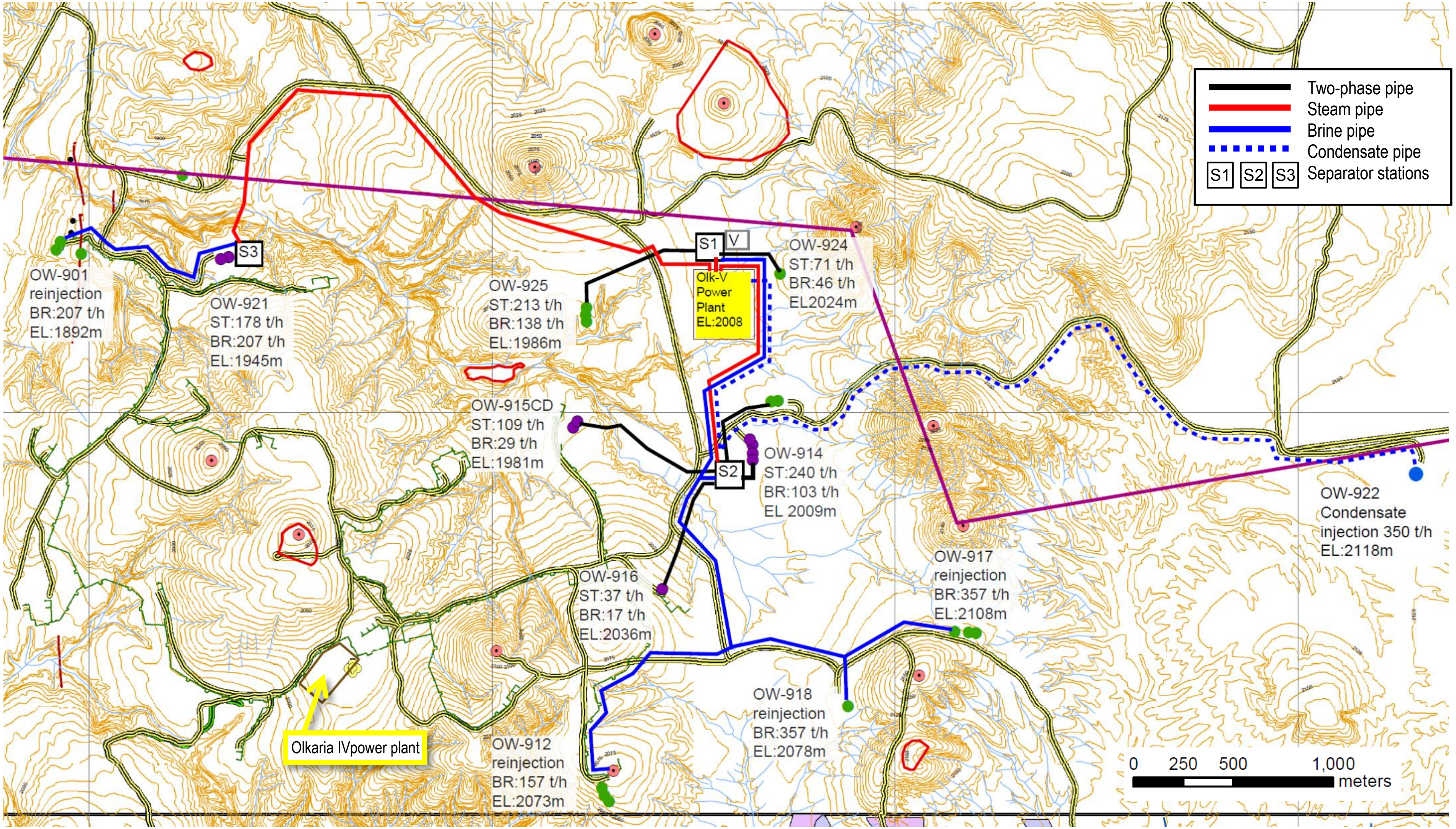


Fig. 3.3.1-1 Proposed location of Olkaria V power plant and steamfield layout

An explanation of "Soil Description" for each soil stratum is mentioned in each boring log sketch. Each explanation for every soil stratum is picked-up and enumerated above the boring log sketch. When the explanation is compared with the panoramic photographs of encroachment wall located beside the small river, one of which is attached to the central part of Geological Cross Section A-A, (Fig. 3.3.1-2), a logical coincidence of strata colors and the stack order of strata can be seen. Therefore, even though there is a long distance between OLK-IV and V, the stack order and conditions of soil strata at these two locations are quite similar. An alternate method of compensating for the lack of geological information for OLK-V, would be to refer the result of the investigation for OLK-IV in the planning and study of OLK-V.

In each soil stratum geologically classified as "Fine Silty Sand (Volcanic ash)"; volcanic ash which was generated broadly by eruption is a major component due to the volcanic zone in the area. It is completely different from marlite or muddy soil which is made by erosive action in the large delta area; those soil strata are simply stacked in order. Considering the above mentioned information and also the similar elevation at the two locations (OLK-IV and V), and the fact that the condition of the foundation ground at OLK-IV is similar to the encroachment cliff wall beside the small river; a strong similarity is confirmed between the geological conditions of both OLK-IV and V.

Design calculation for bored cast in-situ pile at the Olkaria IV geothermal plant was also obtained at this time and the design of the foundation was reviewed. The important plant structure foundation was designed by basically applying D600mm cast in-situ RC pile. The length of pile is from 15m to 25m (4 types); the design pile capacity is 800KN for 15m & 18m piles (80ton per pile), 1,000KN for 20m pile and 1,200KN for 25m pile (vertical load). By adoption of combination for these several types of piles, the extent of freedom for pile design by pile Nos. and layout arrangement would be enlarged against each plant structure. By this way, the foundation of important structure design for OLK-IV plant was ensured. If the same design concept of OLK-IV is utilized in the OLK-V plant design, the design of the foundation will be unstrained and reasonable.

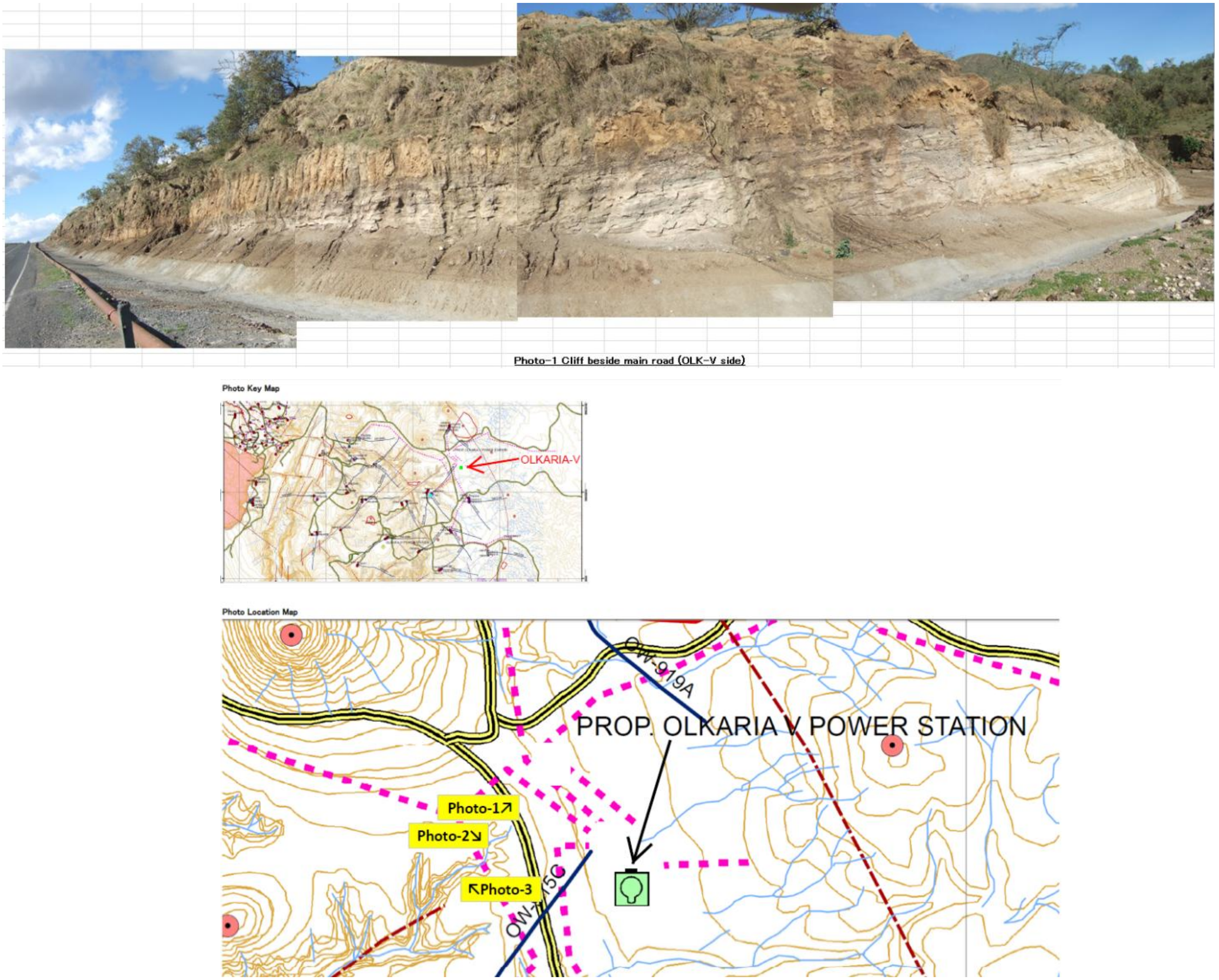


Photo-3.3.1-1 Cliff beside main road

Photo-3.3.1-2 Cliff beside a river (beyond main road)

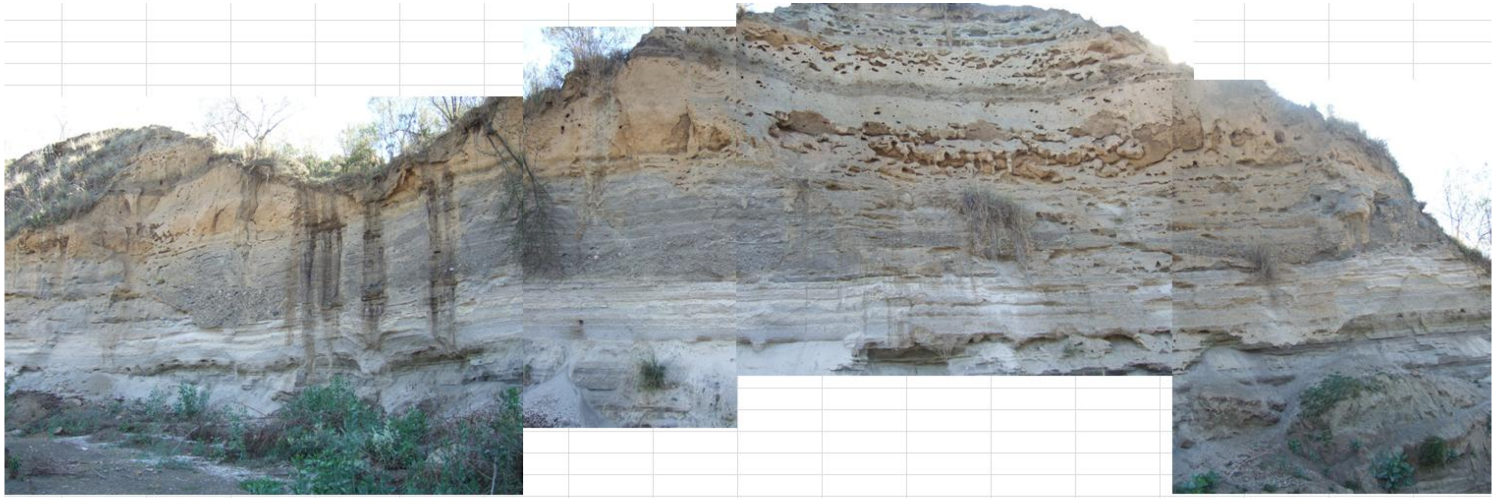


Photo-2b Cliff beside a river (beyond main road) zoom-in

Photo-3 Cliff beside a river (opposite side of Photo-2)

Photo-3.3.1-3 Cliff beside a river (beyond main road and the opposite side)

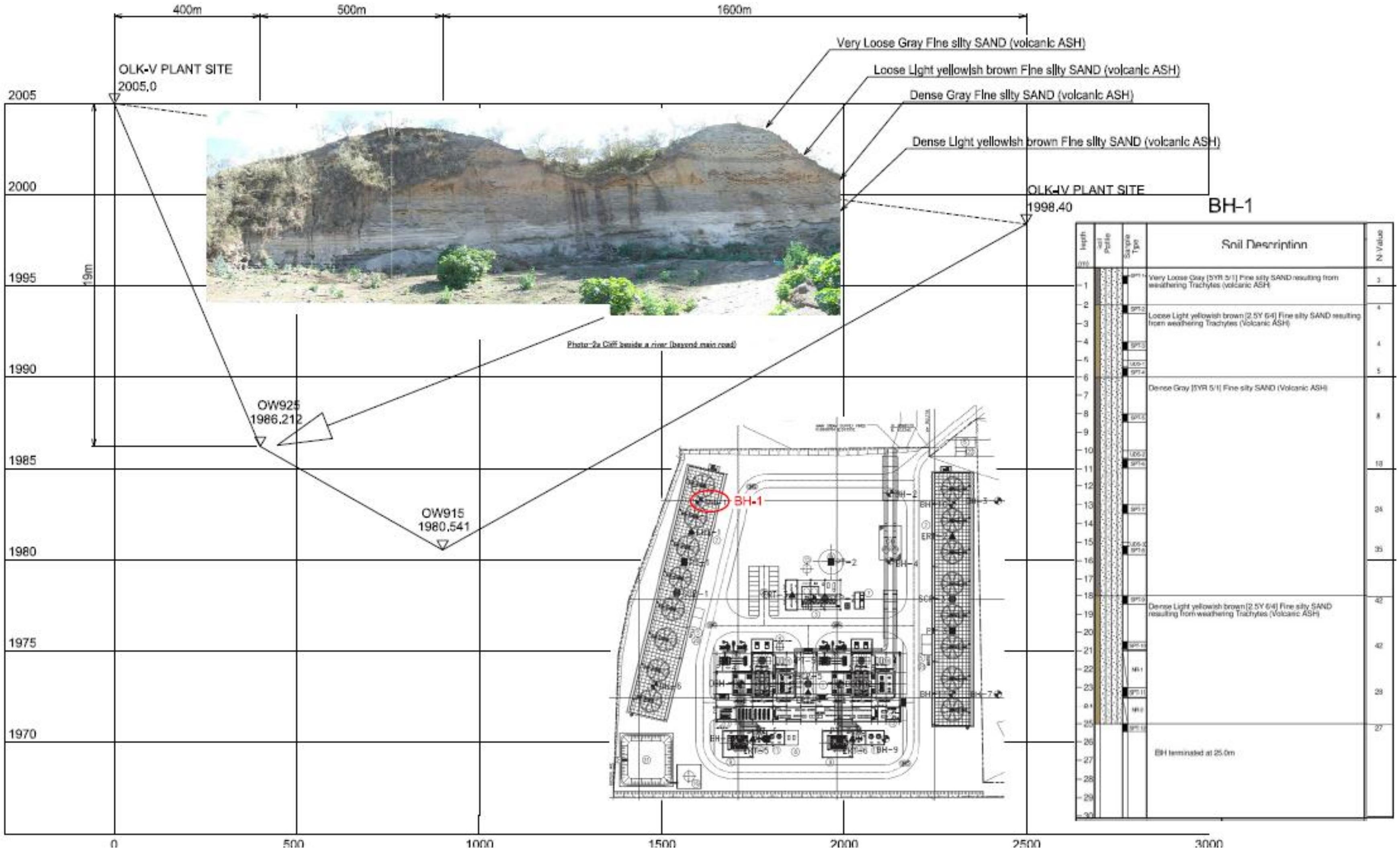


Fig.3.3.1-2a Geological cross section A-A

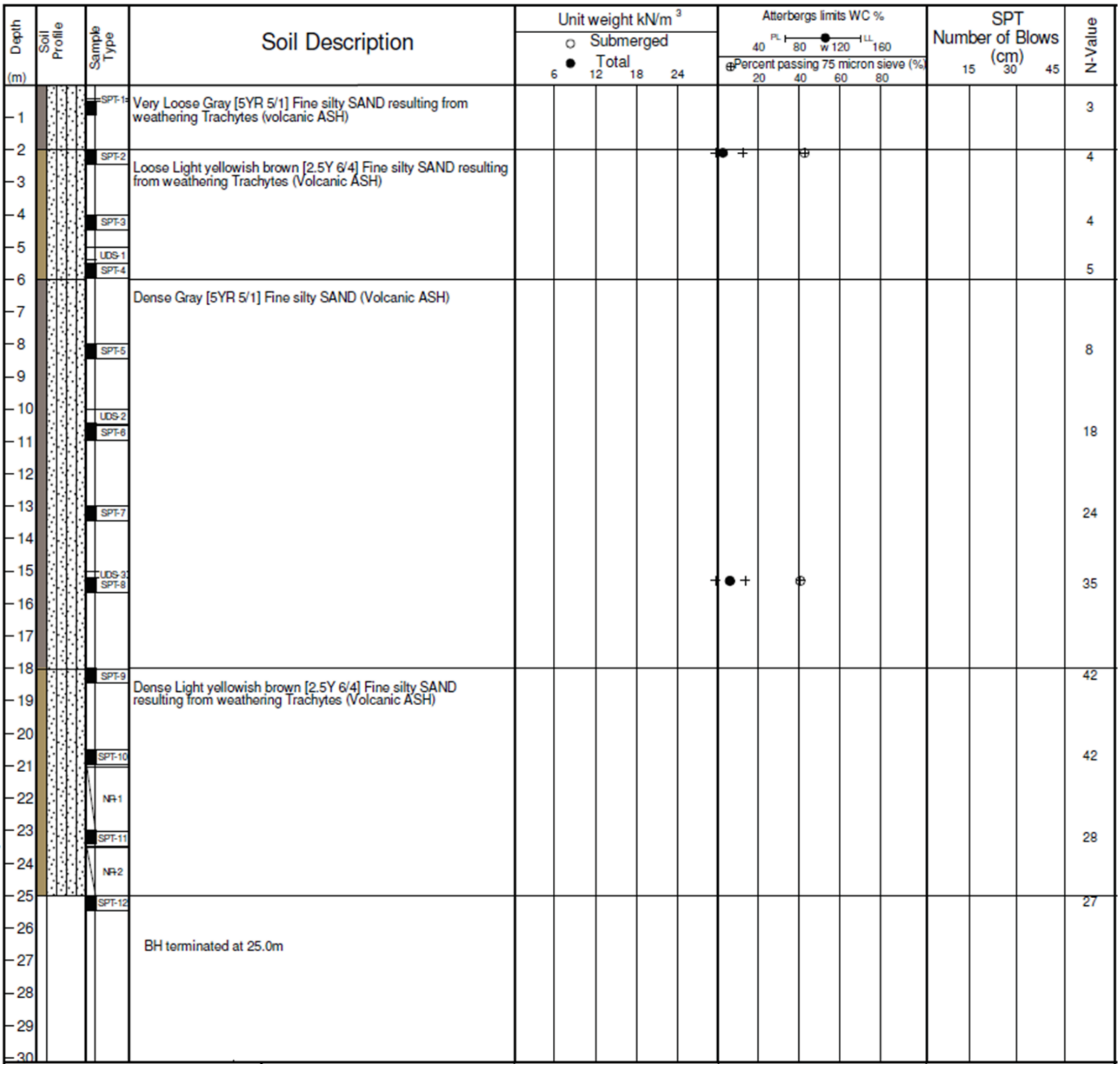


Fig.3.3.1-2b Geological cross section A-A (BH-01borelog)

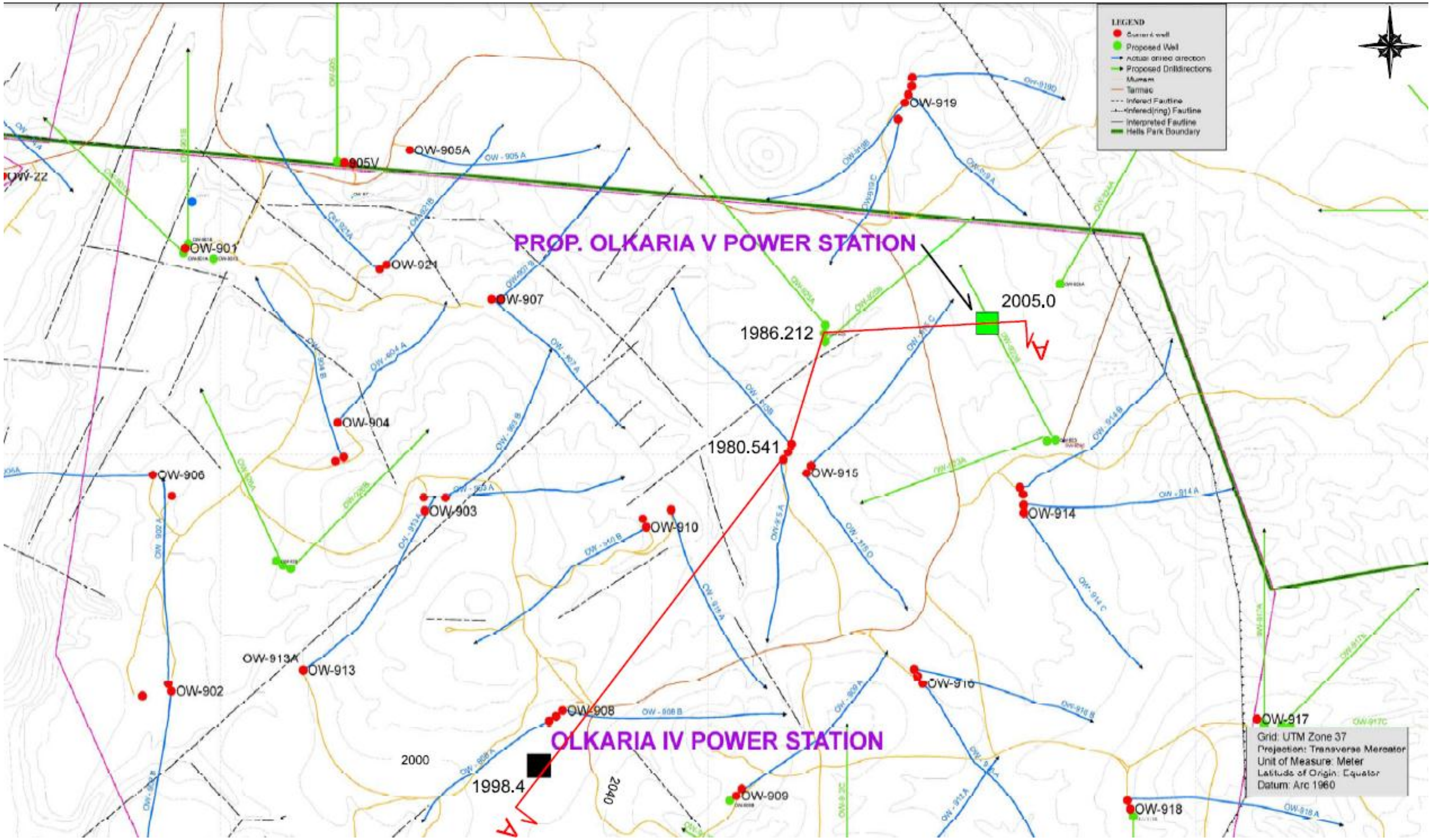


Fig. 3.3.1-3 Geological Plan

(2) Conceptual Design of Power Plant

(a) Layout of the Power Plant

Figure 3.3.1-4 shows a conceptual layout for the Olkaria V geothermal power plant. The power plant consists of steam piping, steam turbines, generators, cooling water systems including condensers and cooling towers, a control room, electrical equipment, a switchyard, auxiliary equipment, and ancillary facilities such as a firefighting system. The area required for installation of the power plant will be approximately 250 m x 200 m excluding the switchyard.

To minimize adverse effects of the fan stacks plume, the cooling tower is located so that the switchyard and the powerhouse will not be downwind when the prevailing wind is blowing. According to KenGen's report "Feasibility Study for Development of KenGen’s Geothermal Concession Area in Olkaria Beyond 430 MWe (Revised September 2012)", the prevailing wind is south-east. Thus, the cooling towers and the vent station should be located on the north of the power plant. The main transformer and switchyard will be located on the opposite side (south of the turbine building).

A steam turbine of single-casing double-flow type is recommended for a 70MW class (gross output 77MW) geothermal power plant. It will be top- or down-exhaust type since the axial-exhaust type is not applicable to a double-flow turbine. For a turbine of this size, top-exhaust type is not recommendable because the very large exhaust duct would result in higher equipment cost and maintenance effort, and lower efficiency due to pressure loss in the duct. Thus, for this project, a down exhaust type turbine similar to that of Olkaria II, IAU, and IV is recommended.

The turbine, generator, hotwell pumps, control equipment and electrical equipment will be installed inside the powerhouse. The condenser and the gas extraction system will be located inside or outside of the powerhouse on the cooling tower side. An overhead travelling crane will be installed in the powerhouse for installation and maintenance of turbines, generators, etc. Adjoining the powerhouse, a control and electrical building will be constructed.

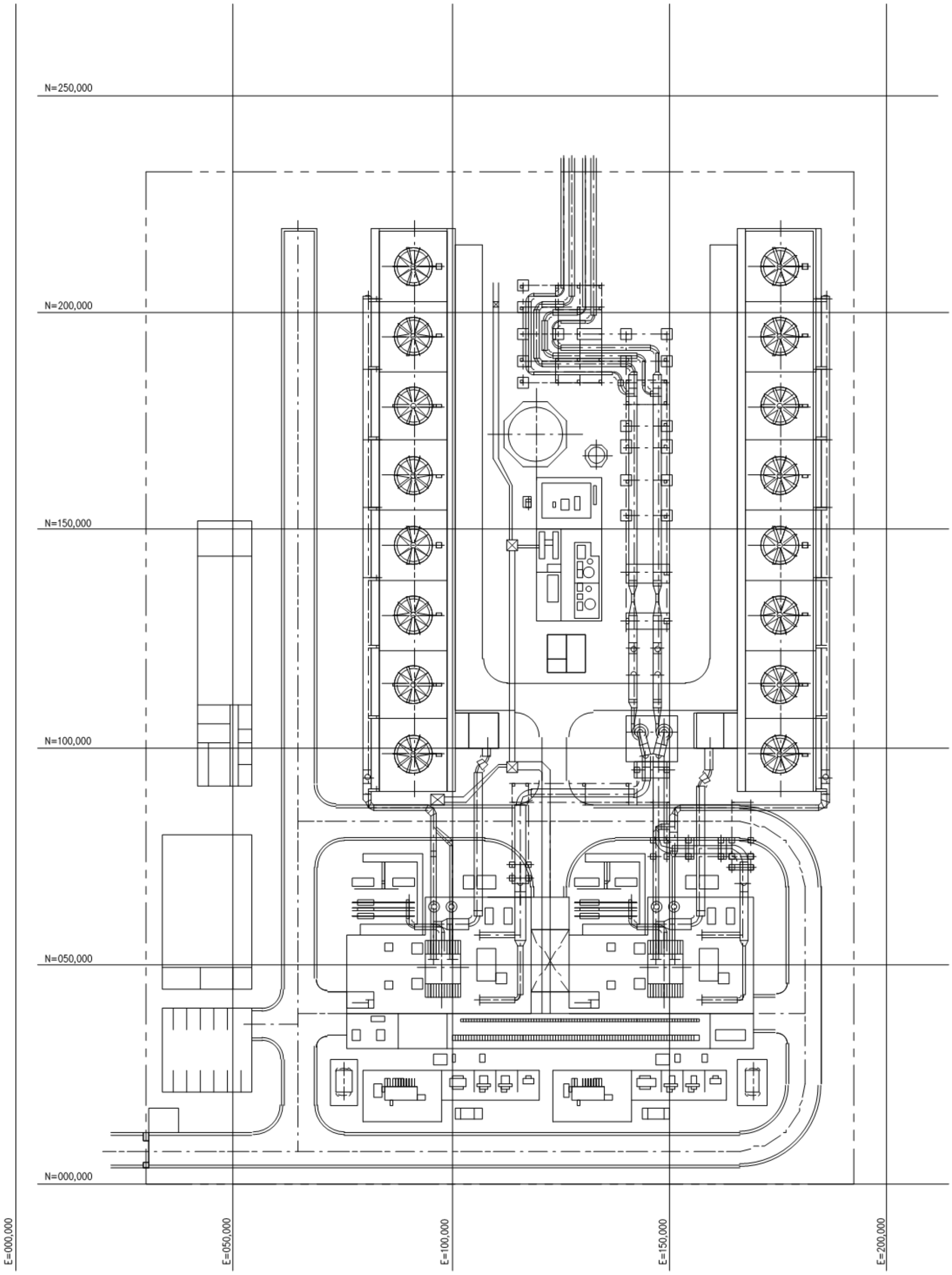


Fig. 3.3.1-4 Layout of Power Plant

(b) Outline of Plant Process

The preliminary process flow of Olkaria Vgeothermal power plant is shown in Figure 3.3.1-5. Steam flows to the steam turbine through a scrubber, strainers, main stop valves, and control valves. Exhaust steam from the turbine flows into a main condenser. In the condenser, exhaust steam is condensed by contacting with cold tubes in which cold water from the cooling tower basin flows. The condensate is sent to the cooling tower top by pump, and is cooled down and recycled as cooling water.

The non-condensable gases (NCG) that are contained in the steam will be removed from the main condenser through the gas extraction system, which consists of ejectors and vacuum pumps. The NCG then will be sent to the cooling tower fan stacks and will be diffused by the warm air discharged upward from the cooling tower fan stacks for dispersion in the atmosphere. The motive steam for the ejectors is supplied from the main steam line.

Cold water from the cooling tower basin is used not only for condenser cooling but also for turbine oil cooling, generator air cooling, air compressor cooling, and for the gas extraction system. Excess condensate is sent to reinjection well(s).

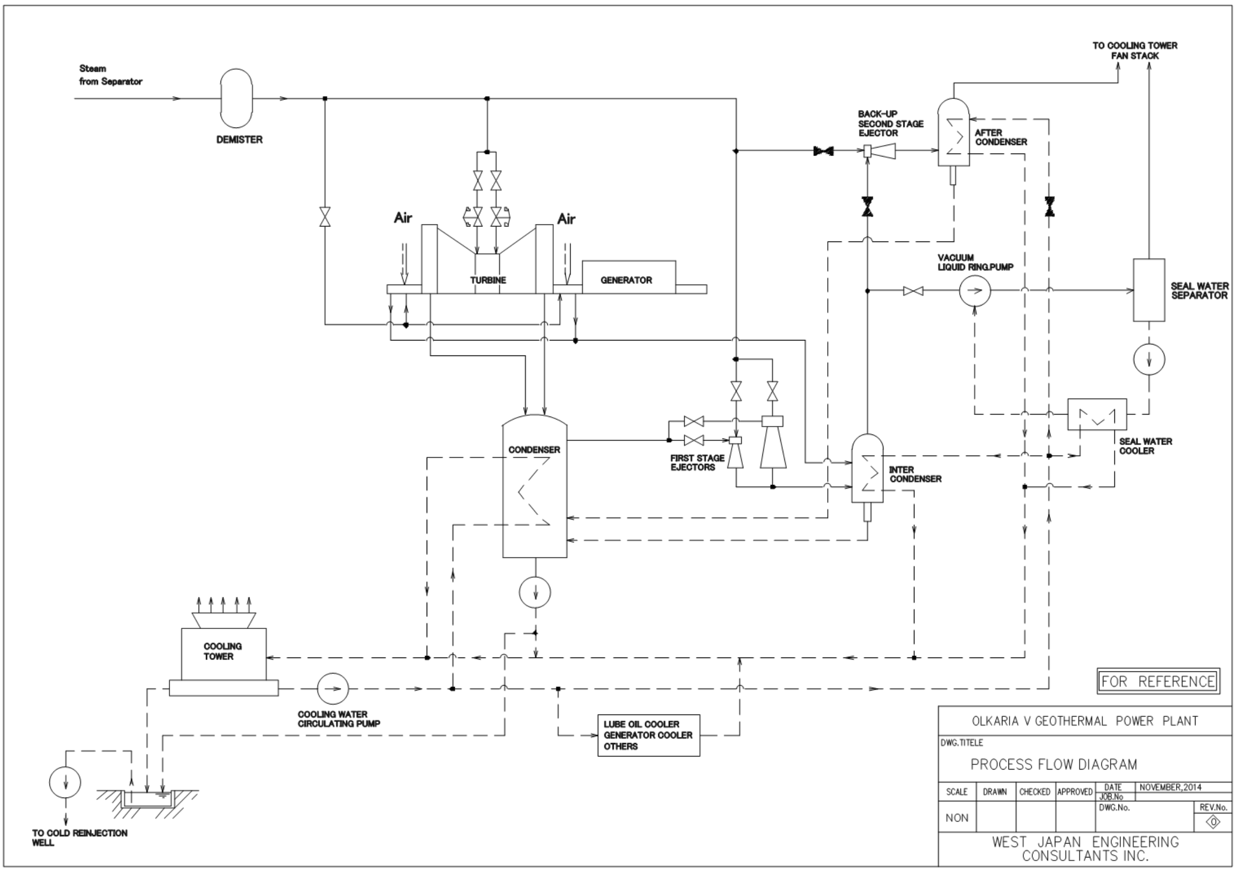


Fig. 3.3.1-5 Plant Process Flow Diagram (Preliminary)

(c) Power Plant Equipment

(i) Power Plant Design Parameters

A plant inlet steam pressure of 12.5 bar(abs) is assumed in the KenGen report "Feasibility Study for Development of KenGen’s Geothermal Concession Area in Olkaria Beyond 430 MWe (Revised September 2012)". This report, however, assumes 11 bar(abs) taking into account the working pressure (11.7 bar(abs)) on the upstream side of steam pressure the let-down station of the Olkaria IV steamfield, considering similarity with the reservoir properties at Olkaria IV and availability of steam transportation between Olkaria IV and V. NCG content is based on the results of the resource review evaluation of this report. Other design conditions are based on those of the Olkaria V power plant.

a. Steam conditions at plant inlet

Pressure:	11 bar (abs)
Temperature:	184 ˚C
NCG content:	2.0 % wt

b. Altitude and meteorological conditions

Design wet bulb temperature:	17 ˚C
Altitude:	2005 masl
Barometric pressure:	0.8 bar(abs)

(ii) Preliminary plant performance

Based on the aforementioned process flow and design parameters, a preliminary heat and mass balance is assessed as shown in Figure 3.3.1-6.

In order to attain a net output of 70 MW per unit, tentative plant performance will be as follows:

Required steam flow	:	518 t/h
Generator output	:	77 MW
Parasitic load (house load + main transformer loss)	:	7 MW
Net output		70 MW

Point	Pressure [kPa]	Temp. [C]	Water/Steam [t/h]	NCG [t/h]	Air [t/h]
0	1,100	184	503.9	10.28	
1	1,100	184	481.2	9.82	
2	1,100	184	22.1	0.45	
3	1,100	184	0.6	0.01	
4					0.10
5	40		0.3	0.01	0.10
7	10	45	481.5	9.83	0.00
8	40	46	24.1		
9	10	42	502.4		
10	352	24	14,864.4		0.26
11	307	40	14,864.4		
12	64	39	16,683.3		
13	35	38	16,683.3		
14			363.4		
15	80	24	16,319.8		
16	101	24	524.2		
17	101	40	905.4		
18	101	40	25.8		
19	10	30	3.2	9.83	0.00
20	40		25.2	10.28	0.00
21	40	46	1.5	10.28	0.10
22	90	46	0.6	10.28	0.10
23		42	17.9		
24		40	121.1		
25			0.9		

Generator output = 76,743 kW
Parasitic load = 6,292 kW
Main transformer loss = 423 kW
Net output = 70,028 kW

Plant steam consumption = 514.1 t/h
Total of excess condensate and blowdown = 139.9 t/h

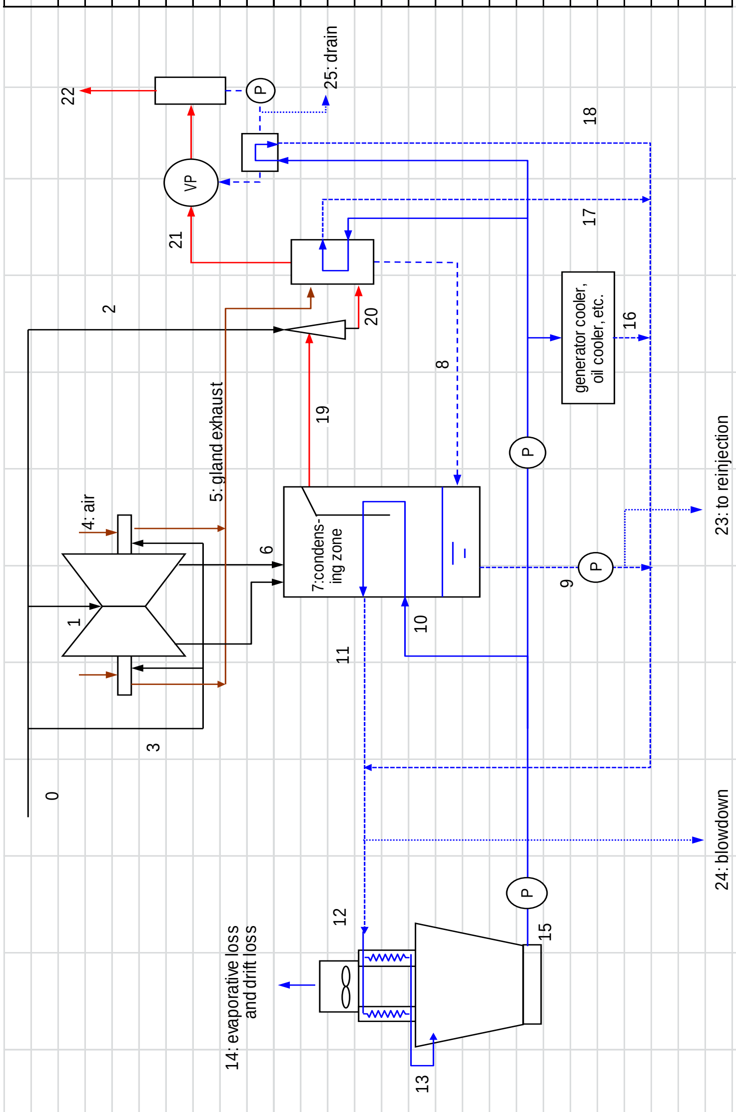


Fig. 3.3.1-6 Heat and Mass Balance Diagram (for reference)

(iii) Mechanical Equipment

a. Steam Turbine

The steam turbine used for this project shall be designed and proven for geothermal applications. The assumed turbine type for Olkaria V is the same as those of Olkaria II, IAU and IV.

Main specifications of the turbine:

• Type	Double flow, condensing, down-exhausting
• Rated output	77 MW (gross) per unit
• No. of units	2
• Steam conditions	11 bar(abs), 184 °C
• Speed	3,000 rpm

Ancillary equipment

• Turbine control system	1 set/unit
• Turbine protection system	1 set/unit
• Lube oil unit	1 set/unit
• Gland seal system	1 set/unit

b. Main Steam System

1) Scrubber

In order to prevent the inflow of mist or drain water into the turbine, a cyclone type scrubber will be installed in the main steam piping for each unit.

2) Steam Flow Meter

For control and monitoring of plant operation, a steam flow meter will be installed downstream of the mist eliminator or scrubber so that the effect of scale buildup on its accuracy will be minimal.

3) Main Stop Valve and Control Valve

The turbine inlet steam pipe splits into two branches, and both will be connected to the turbine through main stop valves (MSVs) and control valves (CVs). This arrangement will allow daily steam-free testing during turbine operation, and prevent the sticking of these valves due to scale deposition.

4) Main Condenser

After it drives the turbine, the steam flows into the main condenser. In the condenser, the steam will be cooled by the cooling water and condense into warm water. The same type of condenser (i.e. surface contact type) is assumed as that which is assumed in KenGen's report "Feasibility Study for Development of KenGen’s Geothermal Concession Area in Olkaria Beyond 430 MWe (Revised September 2012)"

c. Gas Extraction System

The gas extraction system will be a hybrid system similar to that of Olkaria II, IAU and IV. The hybrid system consists of steam jet ejectors, inter-condensers, liquid ring vacuum pumps and seal water separators, back-up ejectors and after-condensers for the vacuum pump. The gas extraction system is recommended to have a capacity to handle 2 % in weight of NCG contents in steam, taking into account the expected NCG contents (1.24 % in weight) and the possibility of significant fluctuations. The number of the ejectors (one or two) will depend on the detailed design of the EPC contractor.

d. Condensate pump

The condensate pump will send the condensate to the cooling tower and the condensate reinjection system.

e. Cooling water pump

The main cooling water pumps will send cooling water from the cooling tower basing to the main condenser. After passing the condenser tubes, the water will return to the cooling tower. An auxiliary cooling water pump supplies cooling water for the turbine lube oil cooler, generator cooler, gas extraction system, air compressors, etc.

f. Cooling tower

The same type of cooling tower is assumed (i.e. mechanical-draft, counter-flow, wet/dry hybrid cooling tower with a FRP structure) as that which is assumed in KenGen's report "Feasibility Study for Development of KenGen's Geothermal Concession Area in Olkaria Beyond 430 MWe (Revised September 2012)" It will be equipped with maintenance stairs and a lifting facility. At the outlet of the cooling tower basin, a mesh screen will be installed to prevent foreign particles from entering the system. Low-noise type fans will be used for noise mitigation.

(iv) Electrical Equipment

a. General

A Single Line Diagram of the power plant is shown in Figure 3.3.1-7. The voltage of the generator output is stepped up to 220 kV by the Main transformer and transmitted to the Olkaria IV switchyard. At the same time, 3.3 kV and 415 V power for the auxiliary equipment in the power plant is supplied through Unit and auxiliary transformers.

Circuit breakers (CB) in the main circuit are located as follows.

1) Generator CB : at the Outlet of the generator

2) Main Transformer CB : on the High-voltage side of the Main transformer

3) Unit transformer CB : on the Low-voltage side of the Unit transformer

b. Generator

An air-cooled, three-phase synchronous generator will be installed for each unit. This is easy to operate, requires less maintenance and is well-proven in geothermal environments. Corrosive gas like H_2S will be removed from the cooling air for the generator by utilizing oxidized catalytic filters etc., since the atmosphere around the geothermal field contains highly corrosive H_2S gas. A brushless exciter system will be adopted.

Specifications of the generator are as follows.

- Type : Cylindrical revolving-field rotor type, totally enclosed, air-cooled, three-phase synchronous generator

- Rated Output : 90.6 MVA
- Rated Voltage : 11 kV
- Frequency : 50 Hz
- Speed : 3,000 rpm
- Power Factor : 0.85 (lag) to 0.95 (lead)
- Neutral Grounding : Transformer grounding
- Excitation System : Brushless

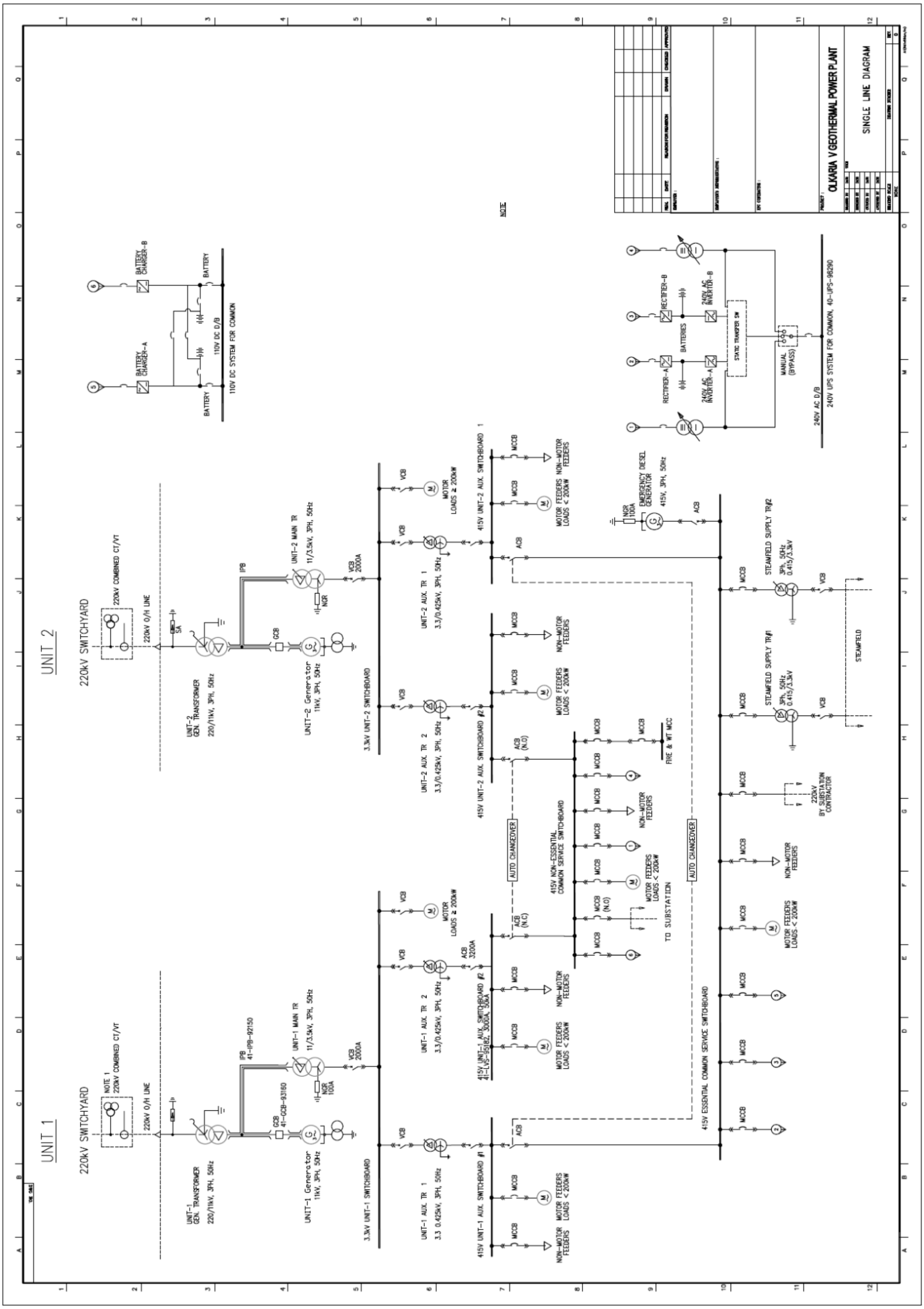


Fig. 3.3.1-7 Olkaria V Single Line Diagram (for reference)

(v) Instrumentation and Control system

The automatic acquisition and archiving of various data of the facility is important for effective management of the power plant. To accomplish this goal, a microprocessor-based Distributed Control System (DCS) will be installed. This DCS system contributes to guarantee the fail-safe operation of the plant with high reliability and productivity.

The DCS consists of a computer and LCD to interface with the operator. The operation of the plant can be controlled from LCD/keyboard terminals in the Control Room, which are the interface between the DCS and operators. A plant interlock system will be provided in addition to the control system. The interlock system for equipment operation will be included in the DCS, while hard-wired relays will be responsible for protection of the generator and the steam turbine.

The major systems and devices which employ automatic control functions in the geothermal power plant are as follows.

a. Automatic Turbine and Generator Controller

This controller can control the following:

- Automatic start-up and shut-down of the turbine (from turbine start-up at cold condition to 100 % load and vice versa)
- Automatic start-up of the turbine and load regulation in conjunction with a digital electro-hydraulic governor

b. Condenser Level

Condensate in the condenser is fed to the cooling tower by the hotwell pumps. The water level transmitters mounted in the condenser feed the level signals to the DCS. The DCS is where specific control logic is programmed, and the condensate level in the condenser is controlled by the DCS to protect the hotwell pumps. As a backup protection, level switches are installed to activate a warning when the condenser level becomes high or low, and to shutdown the unit in case the condenser level becomes very high or very low. This protection will also be included in the DCS.

c. Cooling Tower Level

In order to regulate the cooling water supply to the condenser and the cooling tower basin level, the cooling water flow and the condensate flow to the cooling tower are controlled by control valves.

d. Emergency Generator

An emergency diesel generator will be used to supply emergency power for safe shutdown of the unit.

e. Communication System

An optical fiber communication system and a Power Line Carrier system will be used for communication between KPLC, major substations, and the power plant. A Supervisory Control and Data Acquisition (SCADA) system collects various data about the power plant system, and periodically sends designated data to KPLC and the Remote Control Centre Room in Olkaria I Units 4 and 5

(vi) Measures Against Corrosion

The geothermal steam and ambient air in the geothermal field contain a small amount of corrosive gases such as hydrogen sulfide. Thus corrosion control measures should be taken, for example:

- For selection of steam turbine materials, appropriate materials suitable for each part should be selected, taking into account corrosive performance. The turbine should be designed and manufactured to resist corrosion and erosion resulting from the nature of geothermal steam.
- Oxidation catalyst filters should be installed at the air intake of the generator in order to remove hydrogen sulfide from the air.
- The air conditioning system for the control room and the electrical rooms should be equipped with hydrogen sulfide gas removal filters.
- The cold water basin (and the super structure if applicable) should be constructed with sulfate resistant cement and anti-corrosive coating,
- Pipe thickness should include sufficient corrosion allowance.
- Material and finish should be resistant to corrosive atmosphere. Apply corrosion control design as necessary such as use of stainless steel, FRP, anti-corrosive coating, tight sealing, etc.
- For equipment installed outdoors, sufficient number of spare parts should be stored.

3.3.2 Review of well drilling plan

(1) Production and reinjection well drilling schedule

KenGen's well drilling schedule is shown in Fig.3.3.2-1. Although well allocation connecting to the power plant has not yet been completed, the drilling schedule shows that 8 additional production wells will be drilled by April 2015. Regarding reinjection wells, 11 reinjection wells are planned to be drilled by May 2016. Therefore, the production wells required will be completed by April 2015, and the reinjection wells will be completed by May 2015.

(2) Well operation plan review and proposed plan

Based on the measured flow rates of the existing wells which succeeded in discharge in the Olkaria V development area, the averaged production mass flow rate at the wellhead pressure of 15 bar absolute is about 115 t/h, consisting of steam flow rate 70 t/h and brine (water) flow rate 45 t/h. Assuming this flow rate as the productivity for the additional production wells of those drilled from this point forward, it is expected that 8 additional production wells will be required to provide steam enough for generating 140 MW, as shown in Table 3.3.2-1. Reinjection capacity required is estimated to be about 1,165 t/h, a totaled from both steam condensate from the power plant (in the case of adopting a hybrid cooling tower, around 40% of the total steam flows for the steam turbine) and brine produced from production wells, as shown in Table 3.3.2-2. On the other hand, assuming an injection capacity for each reinjection well as about 150 to 200 t/h, the number of reinjection wells required for disposing of 1,165 t/h is estimated to be 8 wells, as shown in Table 3.3.2-3. As KenGen is willing to distinguish production and reinjection wells depending on the results of well-drilling, 19 wells is the total number of wells currently planned to be drilled for Olkaria V and these wells are practically available to secure required steam production and injection capacity. Therefore, the KenGen's current well drilling plan (8 production wells and 11 reinjection wells) is considered to be appropriate. KenGen is planning to use the well OW-922 that is located in the East of the field as a cold injection well to dispose of steam condensate from the power plant in order to avoid cooling the production zone of the reservoir.

Table 3.3.2-1 Estimation of production rate of additional production wells

No.	Well pad	Well No.	Wellhead pressure (bara)	Steam (t/h)	Water (t/h)	Total (t/h)	Enthalpy (kJ/kg)	Completion depth (m)	Production casing depth (m)	Output (MWe)
1	OW-923	OW-923A	15	70	45	115	2030	3000		9.5
2		OW-923B	15	70	45	115	2030	3000		9.5
3		OW-923C	15	70	45	115	2030	3000		9.5
4	OW-924	OW-924	15	70	45	115	2030	3000		9.5
5	OW-925	OW-925A	15	70	45	115	2030	3000		9.5
6		OW-925B	15	70	45	115	2030	3000		9.5
7		OW-925C	15	70	45	115	2030	3000		9.5
8		OW-925C	15	70	45	115	2030	3000		9.5
				560	360	920			sub-total	75.7
				1123.6	715.6	1839.2			Total	161.9

Table 3.3.2-2 Reinjection capacity required

Reinjection water		
Steam condensate (40%) (t/h)	Produced brine(t/h)	Total (t/h)
449.44	715.6	1165.04

Table 3.3.2-3 Estimation of injection capacity of additional reinjection wells

No.	Well pad	Well No.	reinjection rate (t/h)
1	OW-901	OW-901	150-200
2	OW-907	OW-907B	150-200
3	OW-912	OW-912B	150-200
4	OW-917	OW-917	150-200
5		OW-917A	150-200
6	OW-918	OW-918	150-200
7		OW-918A	150-200
8	OW-921	OW-921B	150-200
		total	1200-1600

ID	Task Name	期間	開始日	終了日
1	Olkaria V 140 MW Drilling Project	3103 days	07/11/17	16/05/16
2	Olkaria V Unit 1&2 (140MWe)	3103 days	07/11/17	16/05/16
3	Production Welll (34 Wells+11 Re-injection)	2746 days	07/11/17	15/05/25
4	OW 905 A	58 days	07/11/17	08/01/14
6	OW-914	54.38 days	09/12/21	10/02/13
9	OW-914A	52 days	10/06/20	10/08/11
12	OW-912B	59.71 days	10/12/14	11/02/11
15	OW 914B (SE)	54.29 days	11/02/12	11/04/08
18	OW 905B (N)	142.67 days	13/12/16	14/05/08
21	OW 905 (Top Holing)	50.38 days	13/04/25	13/06/14
24	OW 905 (Completion)	73 days	14/05/24	14/08/05
27	OW 907B	50.38 days	12/10/25	12/12/14
30	OW 914C	45.38 days	12/12/11	13/01/25
33	OW 916B	51.38 days	12/10/16	12/12/06
36	OW 915C	45 days	12/12/06	13/01/20
39	OW 915D	61 days	13/01/20	13/03/22
42	OW-918	62 days	12/03/19	12/05/20
45	OW-918A	50.38 days	12/09/05	12/10/25
48	OW 917	51 days	12/10/25	12/12/15
51	OW 919	66 days	12/12/15	13/02/19
54	OW 919A	67 days	13/02/19	13/04/27
57	OW 919B	67.38 days	13/04/26	13/07/02
60	OW 921	55 days	13/07/02	13/08/26
63	OW-921A	60.38 days	13/08/27	13/10/26
66	OW-921B	58.33 days	13/10/22	13/12/19
69	OW-919C	54.38 days	13/12/19	14/02/11
72	OW-919D	61 days	14/02/12	14/04/14
75	OW-923A (SW)	73 days	14/08/05	14/10/17
78	OW-923B (NW)	73 days	14/10/17	14/12/29
81	OW-923C (NE)	73 days	14/12/29	15/03/12
84	OW-922	73 days	14/04/16	14/06/28
87	OW-922A (N)	73 days	14/09/09	14/11/21
90	OW-922B (E)	73 days	14/11/21	15/02/02
93	OW-922C (S)	73 days	15/02/02	15/04/16
96	OW-917A (NW)	73 days	14/06/28	14/09/09
99	OW-917B (E)	73 days	14/12/30	15/03/13
102	OW-913 (V)	73 days	15/03/13	15/05/25
105	OW-912C (N)	73 days	14/08/27	14/11/08
108	OW-912D	73 days	14/11/08	15/01/20
111	OW-924	73 days	15/01/20	15/04/03
114	OW-901A	73 days	14/08/06	14/10/18
117	OW-901B	73 days	14/10/18	14/12/30
120	Re-injection Wells (11-Wells)	503 days	14/12/30	16/05/16
121	OW-X1	73 days	14/12/30	15/03/13
124	OW-X2	73 days	15/03/13	15/05/25
127	OW-X3	73 days	15/05/25	15/08/06
130	OW-X4	73 days	15/08/06	15/10/18
133	OW-X5	73 days	15/10/18	15/12/30
136	OW-X6	73 days	15/03/05	15/05/17
139	OW-X7	73 days	15/05/17	15/07/29
142	OW-X8	73 days	15/07/29	15/10/10
145	OW-X9	73 days	15/10/10	15/12/22
148	OW-X10	73 days	15/12/22	16/03/04
151	OW-X11	73 days	16/03/04	16/05/16

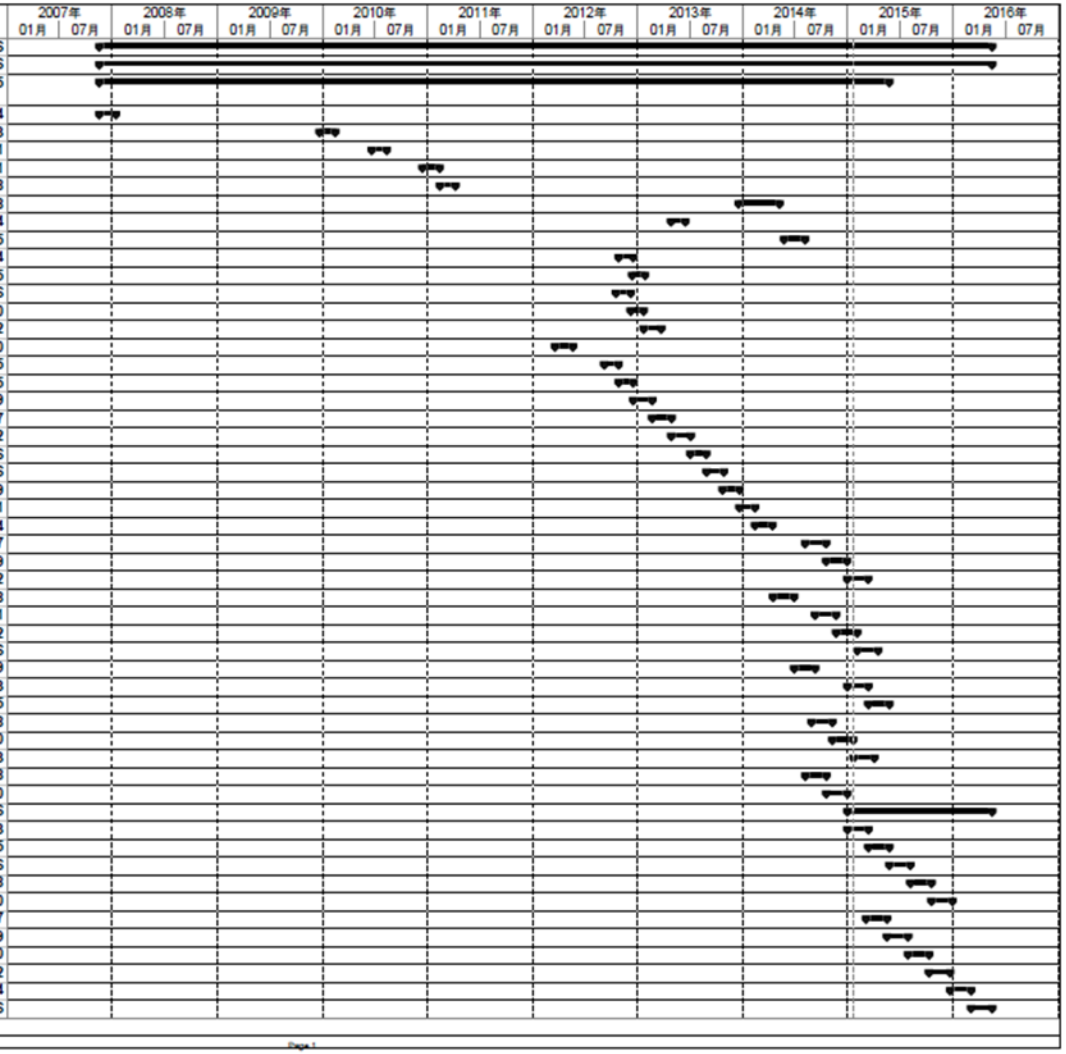


Fig. 3.3.2-1 Well-drilling schedule

3.3.3 Review of Steamfield Facilities

(1) Configuration of the Steamfield

The plant site for Olkaria V proposed by KenGen is different from the place shown in Fig.J6 of the KenGen report ”Feasibility Study for Development of KenGen’s Geothermal Concession Area in Olkaria Beyond 430 MWe (Revised September 2012)”. Thus, a conceptual design of the steamfield was made from scratch.

It is envisioned that drilling of wells and construction of the power plant and the steamfield will be done in parallel in order to shorten the project schedule. This means, depending on the results of production tests of new wells, locations of production wells and reinjection wells may be altered and the design of the steamfield will need to be revised during its construction stage. In this report, it is assumed that the main production well pads will be the well pads OW-914, 915 and OW-916, which are located close to the proposed power plant site and are expected to produce high temperature fluids. It is assumed that the reinjection well pads will be located in the surrounding area such as OW-917, 918 and OW-901. A conceptual design was made based upon these assumptions. Figure 3.3.3-1 shows topology of the steamfield. Pipeline routes are shown in Fig 3.3.1-1.

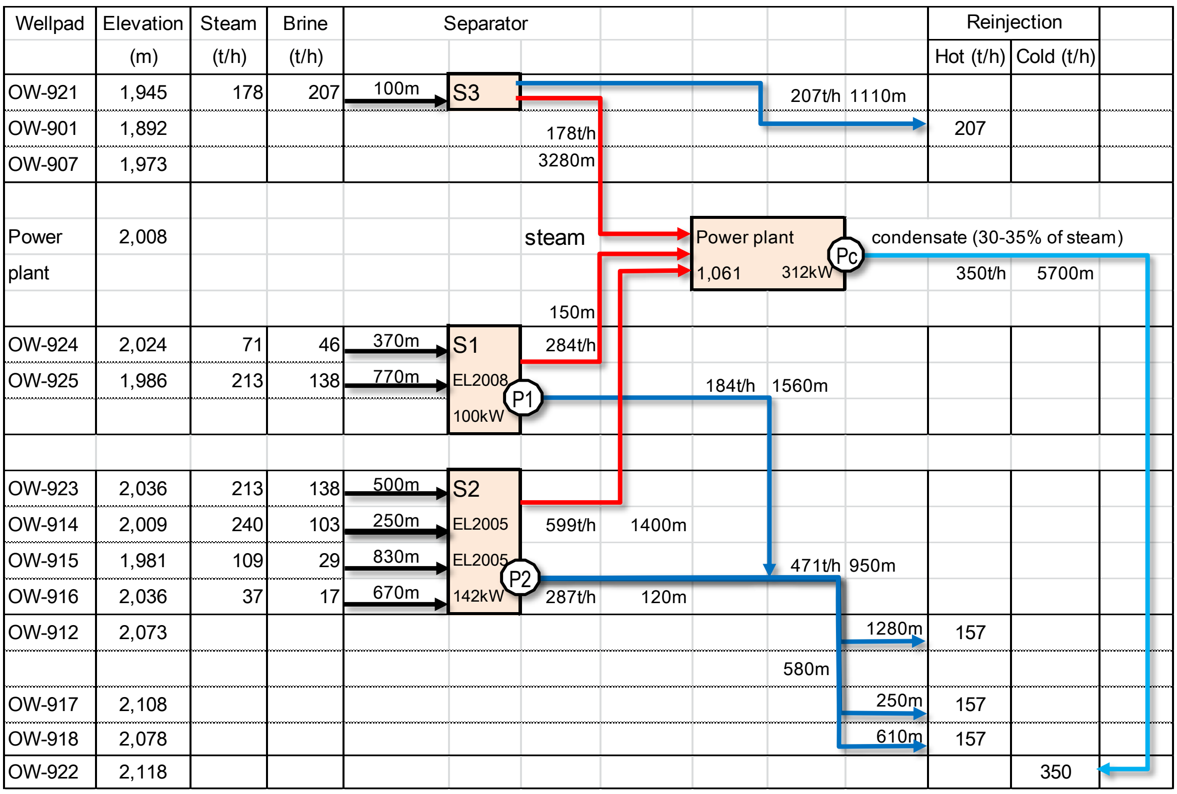


Fig. 3.3.3-1 Configuration of Steamfield

(2) Main Components of the Steamfield

(i) Separators

The production wellpads are divided into three groups by the gulliesin the project area.

- OW-924, OW-925 near the power plant

- OW-923, OW-914, OW-915, OW-916 to the south of the power plant
- OW-921 at north-west end of the project area

Each group will have a separator station (S1, S2, and S3) in order to avoid excessive pressure loss in very long two-phase pipelines. The same type of separator as those in Olkaria I, II, IAU, and IV (vertical cyclone separator) is assumed.

(ii) Steam pipelines

The steam pipe from the separator station (S3) near OW-921 passes the gulley on the north side of OW-921, and goes along the existing road to the power plant. The steam pipe from the separator station S2 goes through the east side of the power plant to avoid the deep gulley between the power plant and S2.

(iii) Brine pipeline

The brine pipe from the separator station S3 is connected to the reinjection wells at OW-901, which is both close to S3 and at a lower elevation than S3. Brine will flow from S3 to OW-901 by gravity. Brine from the two separator stations in the east (S1 and S2) will be sent to the reinjection wells in the south of the project area at OW-912, OW-918, and OW-917.

(iv) Condensate pipeline

The condensate recovered at the power plant (30% to 35% of steam) will be sent to the reinjection wells to the south-of the project area at OW-922. The condensate pipeline will be an underground HDPE (high density polyethylene) pipe along the existing road.

(v) Reinjection pumps

The reinjection wellpads (OW-912, OW-918, OW-917, and OW-922) are at higher elevations than the separator stations and the power plant. To avoid instability of flow due to flashing of brine in the pipe, reinjection pumps (brine booster pumps) will be installed at the separator stations S1 and S2. A condensate reinjection pump will be installed at the power plant. Capacity and required power are estimated as follows:

Separator statin S1 :	Head 110m, Flow 322 t/h, Power 175 kW
Separator statin S2 :	Head 100m, Flow 149 t/h, Power 75 kW
Condensate :	Head 180m, Flow 350 t/h, Power 312 kW

(vi) Silencer drain

Drain of the silencers (or rock mufflers) at wellpads and the vent stations will be stored in the ponds at each of the pads and stations, and pumped to the reinjection wells.

(3) Pipe Size

The steam pipes and brine pipes were sized taking into account the commonly recommended velocities (30 to 40 m/s for steam and 1 to 2 m/s for brine) and the increase of flow caused by connecting make-up wells in the future. Pressure drop and flashing of brine in pipe, and flow pattern in two-phase pipes (to be mist or annular flow) were checked. Table 3.3.3-1 shows the results of pipe sizing.

Table 3.3.3.-1 Pipe size

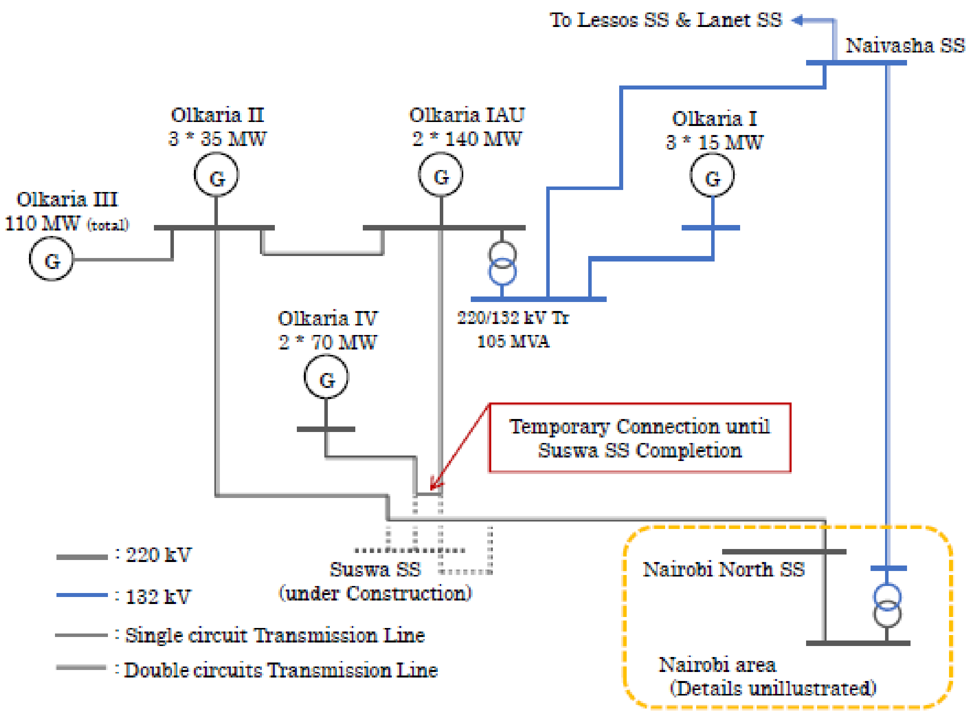
From	To	Flow [t/h]	Distance [m]	Pipe size [mm]
Two-phase pipe				
OW-921	Separator station S3	Steam 178, Brine 207	100	600
OW-924	Separator station S1	Steam 71, Brine 46	370	450
OW-925	Separator station S1	Steam 213, Brine 138	770	700
OW-923	Separator station S1	Steam 213, Brine 138	500	700
OW-914	Separator station S2	Steam 240, Brine 103	250	750
OW-915	Separator station S2	Steam 109, Brine 29	830	500
OW-916	Separator station S2	Steam 37, Brine 17	670	400
Steam pipeline				
Separator station S1	Power plant	284	150	750
Separator station S2	Power plant	599	1400	1100
Separator station S3	Power plant	178	3280	700
Brine pipeline				
Separator station S1	Confluence 1	184	1560	300
Separator station S2	Confluence 1	287	120	350
Confluence 1	Junction 1	471	950	500
Junction 1	OW-912	157	1280	300
Junction 1	Junction 2	314	580	400
Junction 2	OW-918	157	250	300
Junction 2	OW-917	157	610	300
Separator station S3	OW-901	207	1110	350
Condensate pipeline				
Power plant	OW-922	350	5700	315

3.3.4 Review of Transmission Line and Switchyard Plan

(1) Transmission Line System in the Olkaria Area

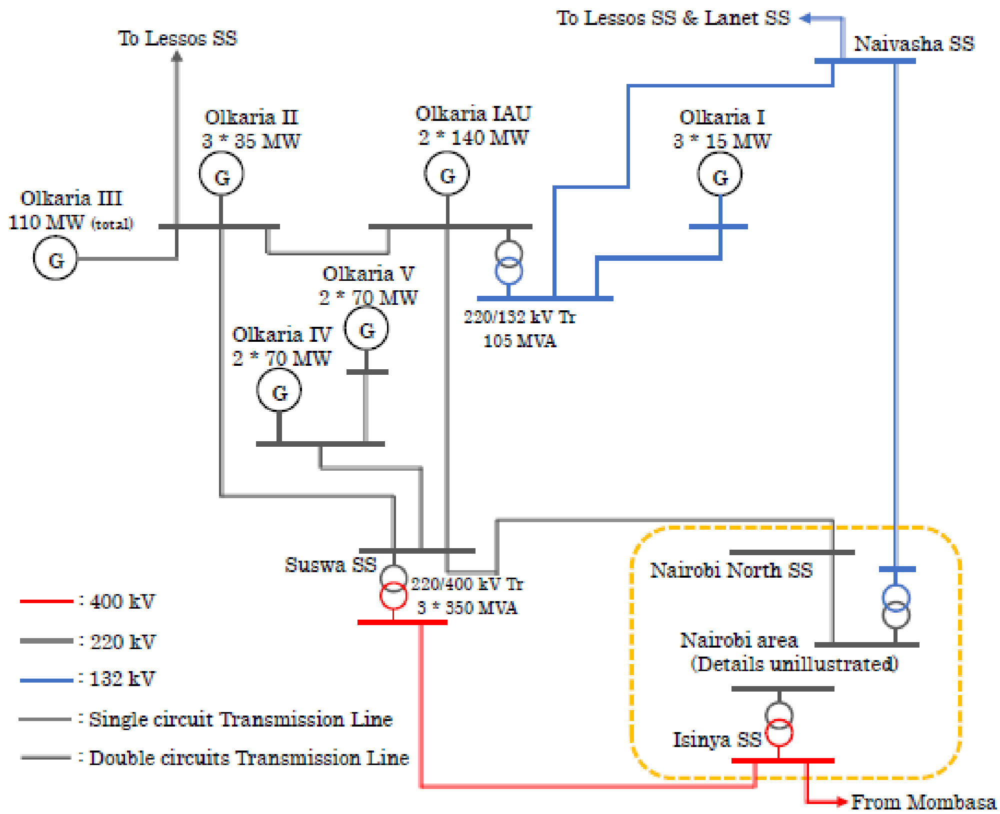
Olkaria I, II, III & IV power plants are under operation and they play an important role in supplying electricity to the largest consuming area in Kenya, the Nairobi region. The transmission network in the Olkaria area at the time of the preparation of this report is shown in Fig. 3.3.4-1.

Several kinds of power developments in the power sector are in progress so that the transmission network developed for when the Olkaria V power plant is planned to commence its operation in 2018, is assumed as Figure 3.3.4-2.



(Source) Study Team

Fig. 3.3.4-1 Present Condition of Transmission Line Network around Olkaria



(Source) Study Team

Fig. 3.3.4-2 Transmission Line Network around Olkaria (Olkaria V in service)

(2) Transmission Line Plan

Since the existing "Feasibility Study for Development of KenGen's Geothermal Concession Area in Olkaria beyond 430 MWe (Revised September 2012)" mentioned that Olkaria V generated power should be interconnected to the switchyard of Olkaria IV and no transmission line route was recommended, the route between Olkaria IV and V has been studied in this report after confirmation of existing facilities and circumstances around the area.

The generation facilities for the Olkaria V plant consists of two, 70 MW (net) 2 sets, so that continuous transportation of generated power to the grid will be required after commencement of commercial operation for the two units. Thus, the transmission line between Olkaria V and IV is designed to be double circuit in order to secure high reliability.

The conductor to be used for the line will be a single Aluminum Conductor Steel Reinforced (ACSR) code name Canary (900 MCM) which is used in Kenya as a standard conductor for 220 kV transmission lines. This conductor can accommodate 961 A (conditions: 75 degree Celsius conductor temperature, 25 degree Celsius ambient, 0.61 m/s wind, 1033 W/(sq. meter) sun, 0.5 coefficients of emissivity and absorption)[1] which is equivalent to 366 MVA at 220 kV.

It is recommended to apply approximately 80 % of the maximum current rating of the conductor, for continuous maximum rating during normal operation, in consideration of leaving margin for various conditions which affect the capacity rating, so that the current rating of Canary should be 290 MVA. KPLC and KETRACO have been operating the rated capacity of the Canary conductor as 250 MVA, it is a number that has more than 30 % of the margin for the maximum allowable value.

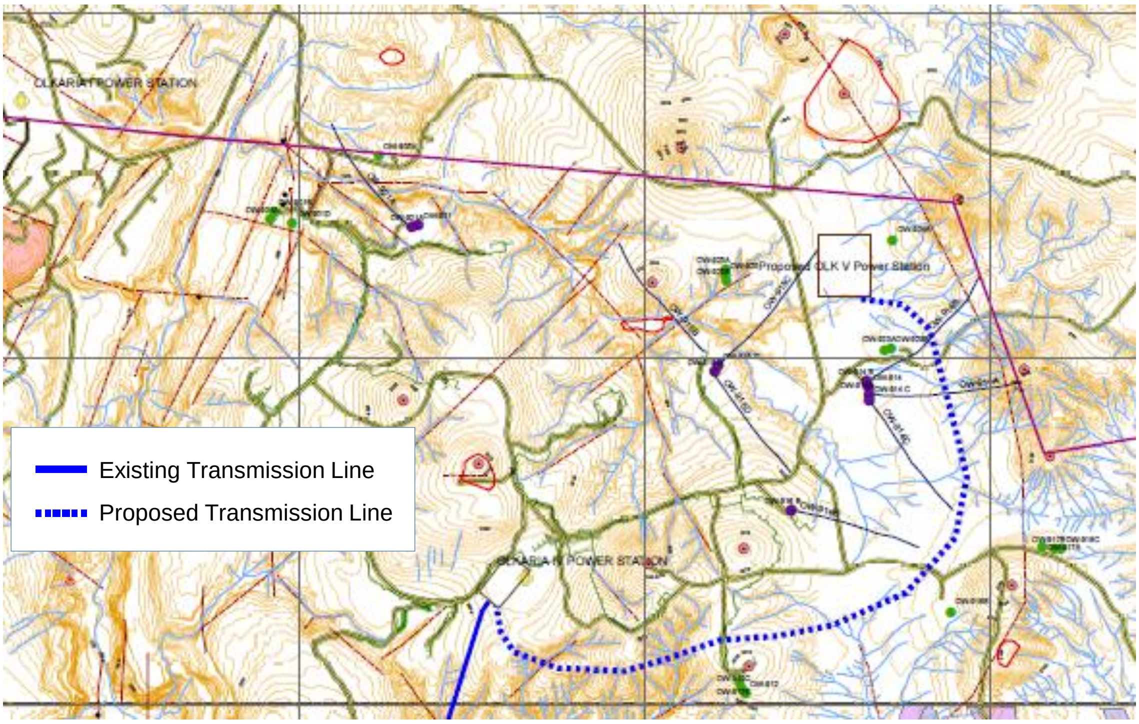
OPGW (Optical fiber composite overhead Ground Wire) will be used for the ground wire of the transmission line to communicate between stations for operation and protection purposes.

Towers for the transmission line will be primarily selected as same types as the ones used for the Olkaria II, I additional Units and IV connections. Thus, the basic span length between adjacent towers will be the same as that for the existing towers, 370 m, .

Since the Olkaria IV switchyard, to which the transmission line will be connected from Olkaria V, is located on the other side of the main building of Olkaria IV when viewed from Olkaria V, the transmission line route is planned to circumvent the east side of topographically gentle slope in the hilly terrain because the switchyard of Olkaria IV has a wider expansion space for line bays on the east side.

The transmission line route studied is approximately 5 km in length and is shown in Figure 3.3.4-3 and approximately 15 towers will be constructed. It is predicted that a larger amount of tension-type towers will be required for this curve type of planned route. The planned transmission line route area is mostly bush and plain. The objects along the way of the line are geothermal steam piping, roads for maintenance and shrubs. And since there are neither deep valleys, cliffs, other transmission lines to traverse, nor residences to avoid, it is not necessary to prepare special towers on the route.

[1] Cable manufacturer document (SURAL)

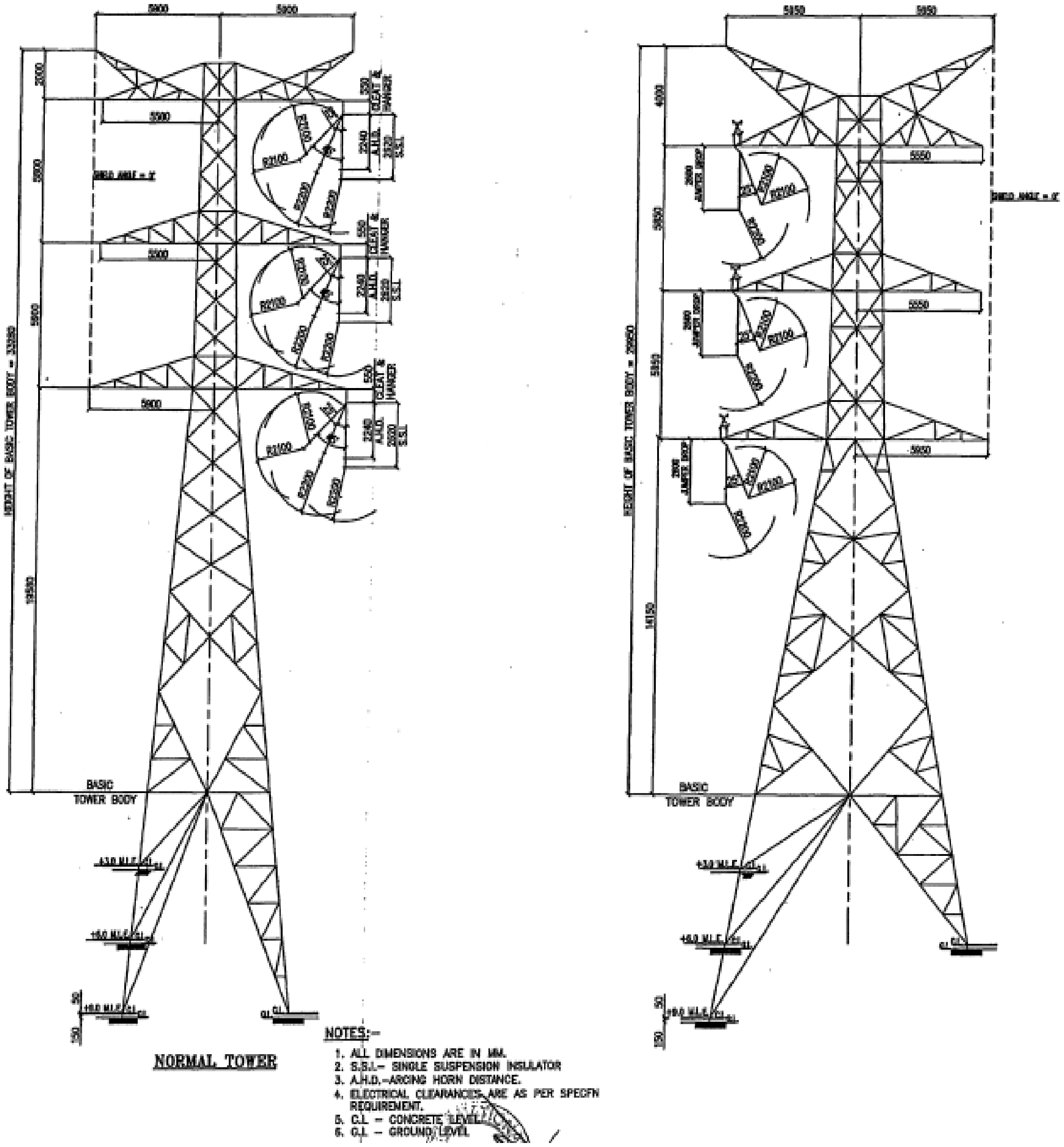


(Source) Prepared by the study team on a map received from KenGen

Fig. 3.3.4-3 Transmission Line Route Plan

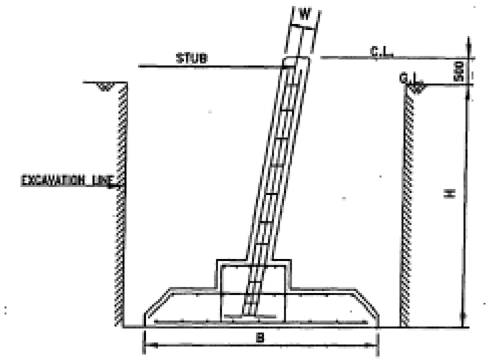
The Olkaria area is located on the floor of the Great Rift Valley. The geology of the project area is dominated by the formation of the Great Rift Valley when the volcanic material of Pleistocene Age was extruded forming the base material. The soil of project area of Olkaira IV is described as sandy-based deposition strata of volcanic ash so called "Fine Silty Sand (Volcanic ash)". As explained in Figure 3.3.1-2 about the ground condition, both the soil layer structure and the overall condition of the soil at Olkaria V are extremely similar to that of Olkaria IV. The soil layer structure is described as "Fine Silty Sand (Volcanic ash)". It is considered appropriate for the initial stage of planning that the type of foundation for the towers to be constructed between Olkaria V and IV utilize a chimney and pad footing foundation, which was used for whole transmission line towers in the Olkaria IV project. The field bore log at the generator transformer of Olkaria IV where the closest to the switchyard is attached as Fig. 3.3.4-6 for reference.

The typical drawings of transmission line towers and the sketch of the tower foundation are described below.



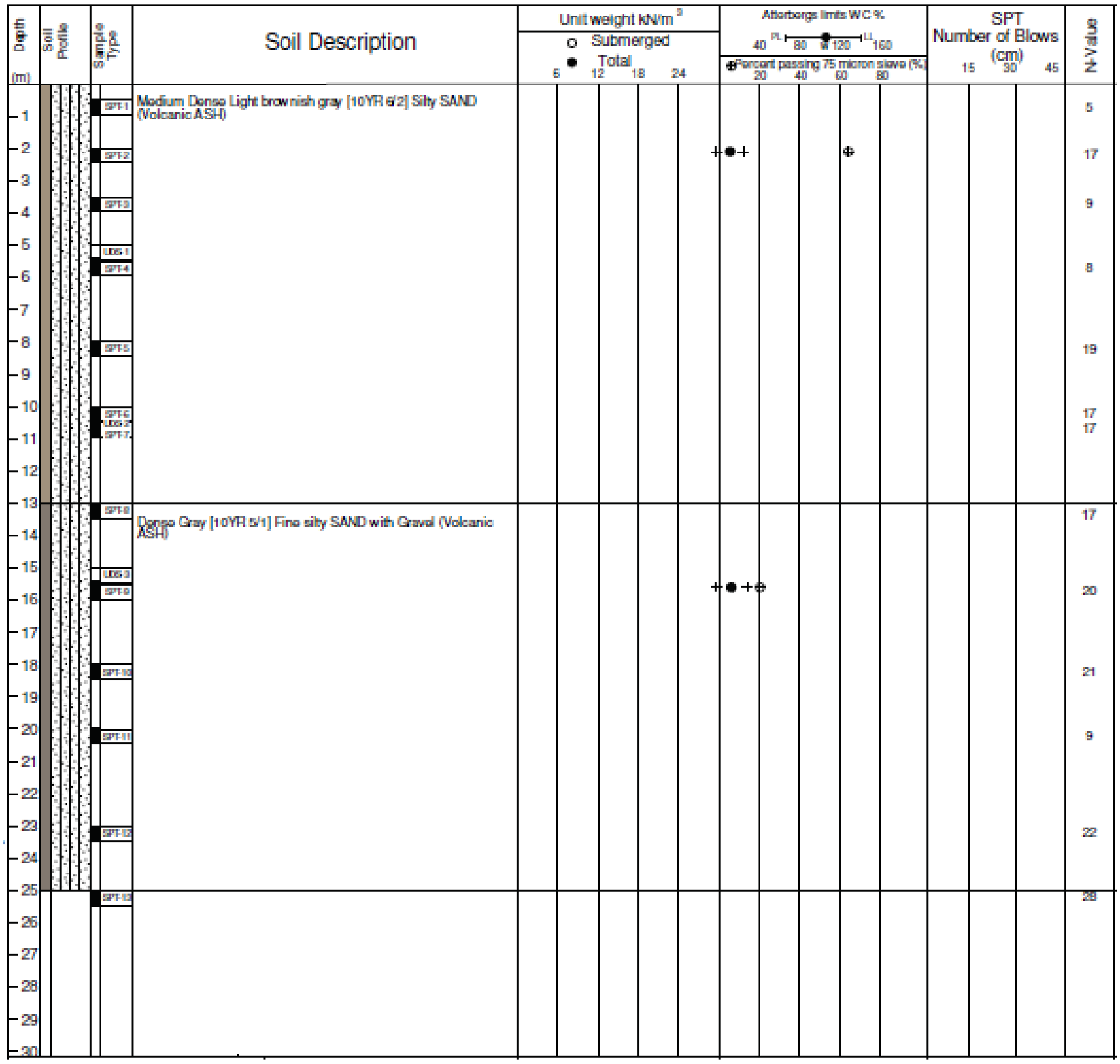
(Source) Olkaria IAU & IV Transmission Line Project Contract Document

Fig. 3.3.4-4 Transmission Line Tower
(left: Suspention type, right: Tension angle type (10 degree or less))



(Source) Olkaria IAU & IV Transmission Line Project Contract Document

Fig. 3.3.4-5 Chimney and Pad Type Tower Foundation



(Source) Olkaria IV Project Geotechnical Report

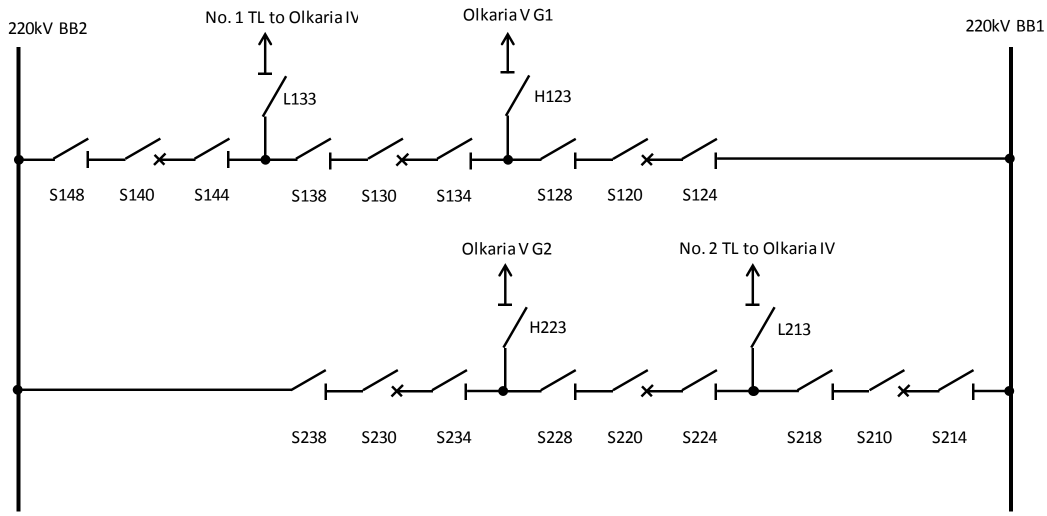
Fig. 3.3.4-6 Bore Log at Generator Transformer in Olkaria IV

(3) Outdoor Switchyard Plan

1) Olkaria V Switchyard

The configuration of the Olkaria V outdoor switchyard will be basically the same as Olkaria IV, because the switchyard has to accommodate two bays for 70MW generators and two bays for 220 kV transmission line, which is exactly same combination as Olkaria IV. Olkaria V will also utilize the same equipment specifications and a ring bus system in consideration of the operation and from a maintenance point of view. The configuration of the primary equipment of the switchyard and the general layout of Olkaria V are shown in Figures 3.3.4-4 and 3.3.4-5 respectively.

The size of the switchyard is approximately 110 m by 110 m.



(Source) Study team

Fig. 3.3.4-7 Configuration of Switchyard Primary Equipment in Olkaria V

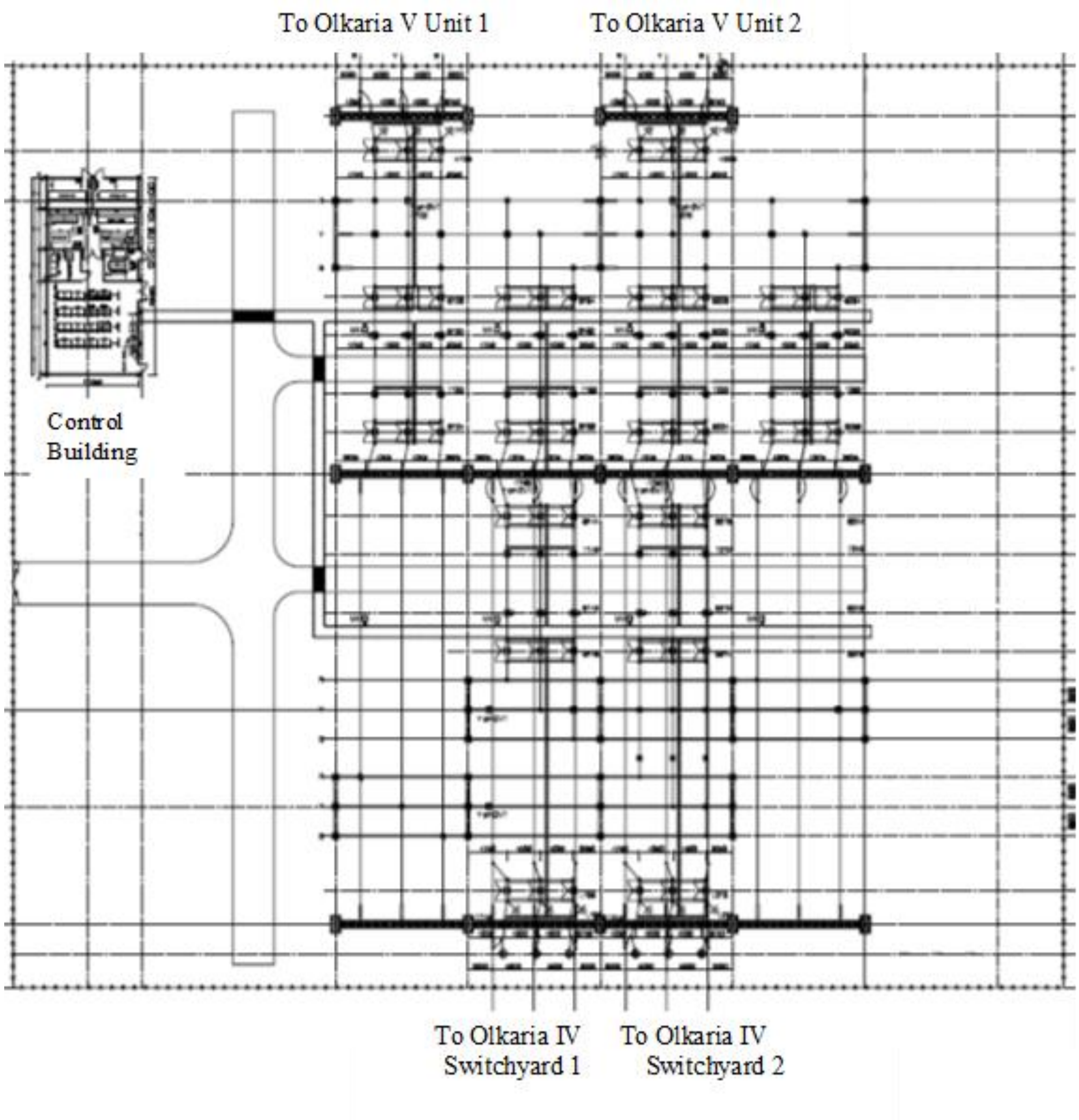
The major specifications of the primary equipment in the switchyard are the same as Olkaria IV and those are as follows:

i. Common specification for primary equipment
- Rated voltage: 220 kV
- Maximum operating voltage: 245 kV
- Lightning impulse withstand voltage: 1,050 kV

ii. Circuit Breaker: 6 sets
- Rated current: 1,600 A
- Rated short-circuit breaking current: 40 kA

iii. Disconnecting Switch: 12 sets (manual operation) and 4 sets (motorized operation and integral earth switch)
- Rated current: 1,600 A
- Rated short-time withstand current: 40 kA

iv. Main Bus
- Material: Aluminum pipe
- Rated current: 2,500 A
- Rated short-time withstand current: 40 kA

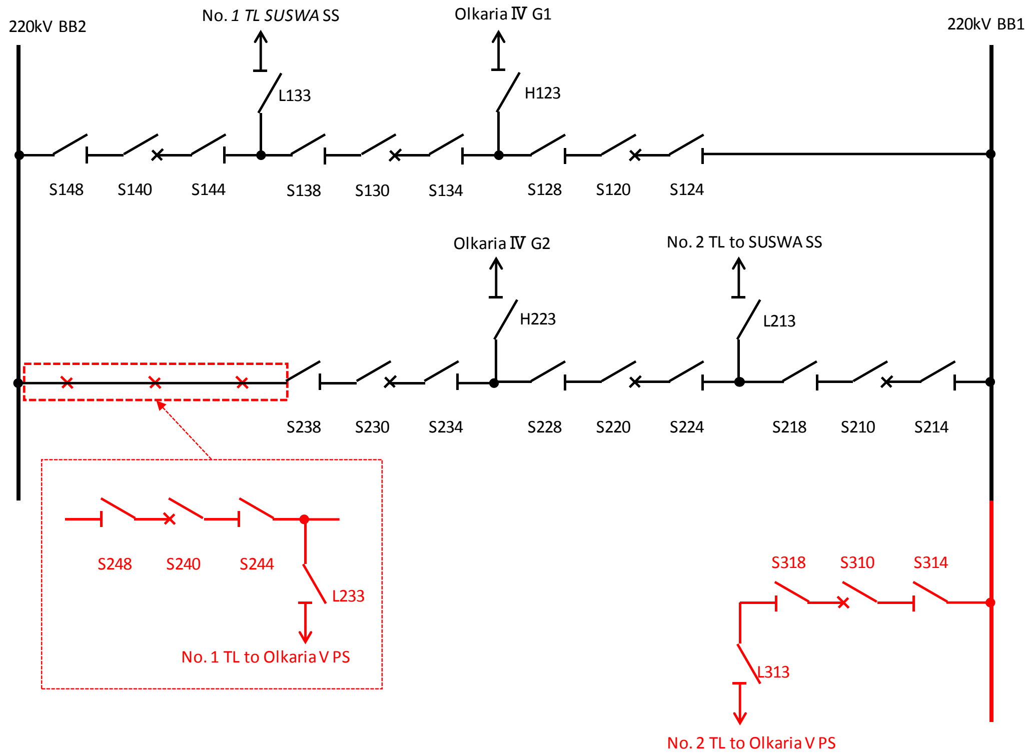


(Source) Modified by Study team based on Olkaria IV layout prepared by the Contractor

Fig. 3.3.4-8 General Layout Plan of Switchyard in Olkaria V

2) Modification of Olkaria IV Switchyard

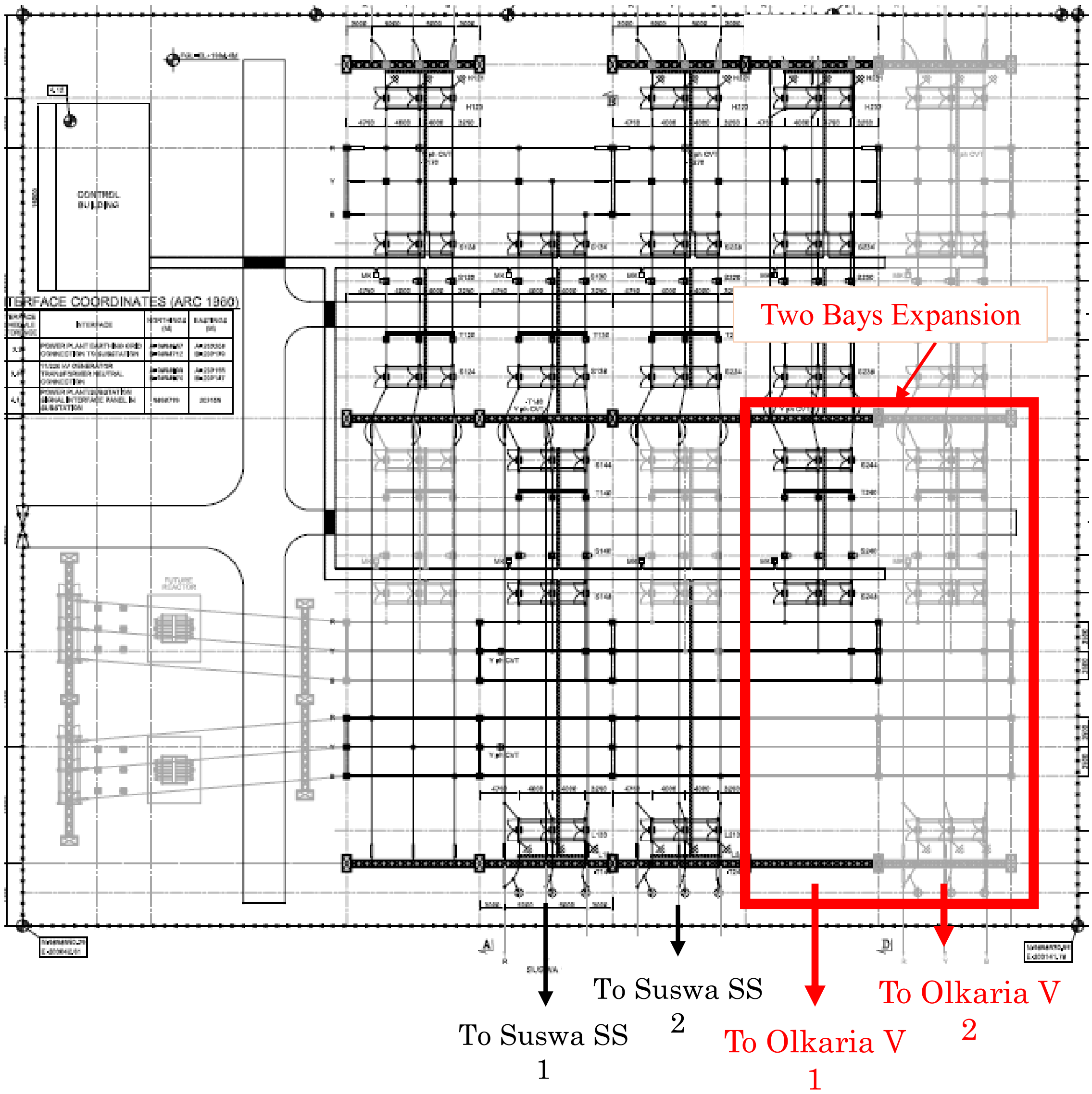
The current switchyard of Olkaria IV, which the double circuit transmission line from Olkaria V will be connected to, has two branch ring buses each of which have one spare space for an additional bay. Those spaces are separately located on the eastern and western side of the switchyard. Therefore, because the spare bar spaces are located on the other side of the switchyard from each other, it is difficult to connect the double circuit lines which are hanging from the same tower to these separated bay gantries. Therefore, the eastern side area, where future expansion space of the yard is available, will be utilized to install a new bay for one line connection with the main bus bar extension modification. The configuration of the switchyard's primary equipment and the general layout of Olkaria IV are shown in Figures 3.3.4-6 and 3.3.4-7 respectively.



(Source) Study team (Red marked indicates modification for Olkaria V)

Fig. 3.3.4-9 Configuration of Switchyard Primary Equipment in Olkaria IV

The first line of the double circuit lines from Olkaria V will utilize the spare bay space and the second line will be connected to the expanded main bus through switchgear without preparation of an additional ring bus. There are some bays available under operation at the 220 kV substations in Kenya which have the same configuration for only one line application from the main bus.



(Source) Modified by Study team based on Olkaria IV layout prepared by the Contractor
(Red marks indicate modification for Olkaria V)

Fig. 3.3.4-10 General Layout Plan of Switchyard in Olkaria IV

(4) Technical Confirmation on the System

1) Capacity of Lines and Switchyard Facilities in View of Power Flow

The capacity of transmission lines and facilities for the switchyard related to the Olkaria V project has been confirmed as follows:

It is normal practice that the overload capability of the facilities should be carefully designed in consideration of N – 1, which means one facility is out of service because of some reason, such as an accident. Because the N – 1 condition is a kind of emergency operation, when considering overload operation for the facilities, over-investment in expensive redundant capacity should be avoided.

i. Olkaria V Switchyard
- 220kV Main bus: 2,500 A
  Adequate capacity to accommodate the net capacity of two generators, 165 MVA (433 A) (= 2 * 70 MW/0.85） is secured.
- Rated current of circuit breaker and disconnecting switch: 1,600 A
  Adequate capacity to accommodate the ring bus current when only one line in service, 433 A is secured.

ii. Transmission Line from Olkaria V to Olkaria IV
- Conductor capacity: 290 MVA/line, 2 lines
  Adequate capacity to accommodate the net capacity of two generators when only one line is in service, 165 MVA is secured.

iii. Olkaria IV Switchyard
- 220kV Main bus: 2,500 A
  Adequate capacity to accommodate the net capacity of four generators Olkaria IV & V, 330 MVA (866 A) (= 4 * 70 MW/0.85） is secured.
- Rated current of circuit breaker and disconnecting switch: 1,600 A
  Adequate capacity to accommodate the ring bus current when only one line is in service, 866 A is secured.

iv. Transmission Line from Olkaria IV to Suswa Substation
- Conductor capacity: 290 MVA/line, 2 lines
  14 % overload operation is required of the net capacity of four generators when only one line is in service, 330 MVA, however, the conductor can accommodate 366 MVA at the maximum conductor temperature of 75 degree Celsius[2] so that continuous line operation is adaptable with careful observation of the necessary conditions.

v. Suswa Substation and Transmission Lines to Nairobi Area
Power transportation facilities (transmission lines and transformers) from Suswa Substation to the Nairobi region will be as described below when Olkaria V starts commercial operation.

- Transmission line to Nairobi North Substation: 290 MVA/line, 2 lines
- Transmission line to Isinya Substation: approx. 1,000 MVA/line[3], 2 lines
- 220/400 kV Transformer: 350 MVA/set, 3 sets

One line transmission line at 400 kV can accommodate a capacity of almost three sets of 350 MVA transformers, so that the N – 1 condition at one 350 MVA transformer (one transformer out of service) is the most severe case and the situation would result in 1,280 MVA （2*350 MVA＋2*290 MVA） Therefore, 1,280 MVA will be the maximum capacity to transport electricity to the Nairobi region.
If all the power generated in the Olkaria geothermal area (meaning from Olkaria I to V), a total of 680 MW (756 MVA at power factor 0.9) flows to Suswa substation, the power transportation facilities in and around the Suswa substation can sufficiently accommodate the entirety of power generated from the Olkaria geothermal power plants.
However, the Suswa substation will be a hub substation receiving power from stations other than the Olkaria power stations, including power imported from

2 Refer to 3.1.5 (2) Transmission Line Plan
3 Predicted as two Condor (795 MCM) conductors because detailed information is unavailable

Ethiopia through a HVDC line. Therefore, it is recommended to that additional study be completed in terms of reliable grid operation for the whole power system nationwide.

2) Short Circuit Fault Current Study

When a short circuit fault occurs in the Olkaria IV or V area, the current supplied from the Kenya grid only flows from Suswa substation, so that the three phase short circuit current was calculated assuming a 220 kV bus as an infinite bus at Suswa substation. This makes it possible to select equipment specifications without affecting future power grid development.

For the calculation, the reactance values of the power system were obtained from PSS/E input data received from KPLC, the values of generators and generator transformers were obtained during site surveys (design values and name plate indicated values) and the facilities of Olkaria V were assumed to be the same as the facilities of Olkaria IV.

Table 3.3.4-1 Reactance Values for Short Circuit Fault Calculation

	Data obtained	%X @100MVA	Remarks
Transmission Line (Suswa substation – Olkaria IV)	0.024767 p.u./line @100MVA	2.48 %	Input data of PSS/E received from KPLC
Transmission Line (Olkaria IV - Olkaria V)	0.002972 p.u./line @100MVA	0.30 %	Input data of PSS/E received from KPLC
Generator (Olkaria IV)	Xd”=15 % @88.55 MVA	16.9 %	Design value of manufacture
Generator (Olkaria V)	Xd”=15 % @90.6 MVA	16.6%	Assumed to be the same as Olkaria IV, Capacity adjusted for this study report
Generator Transformer (Olkaria IV)	%Z=11.6% @90MVA	11.7%	Assumed as X/R=10
Generator Transformer (Olkaria V)	%Z=11.6% @90MVA	11.7%	Assumed as same as Olkaria IV

(Source) Prepared by study team utilizing data received from KenGen & KPLC

Table 3.3.4-2 Results of Fault Current Calculation for Olkaria IV

Three phase short circuit current at 220 kV Olkaria IV Switchyard		Fault Current
Flow from Suswa Substation (2 lines)	21.2 kA	**24.9 kA**
Flow from Olkaria IV Generators (2 sets)	1.84 kA	
Flow from Olkaria V Generators (2 sets)	1.84 kA	

(Source) Prepared by study team

Table 3.3.4-3 Results of Fault Current Calculation for Olkaria V

Three phase short circuit current at 220 kV Olkaria V Switchyard		Fault Current
Flow from Suswa Substation (2 lines)	18.9 kA	**22.5 kA**
Flow from Olkaria IV Generators (2 sets)	1.72 kA	
Flow from Olkaria V Generators (2 sets)	1.85 kA	

(Source) Prepared by study team

Since the calculation was made utilizing reactance value only, actual fault current will be less than the calculated value. The rated short-time withstand current of the primary equipment and the rated short-circuit breaking current of the circuit breakers for Olkaria IV & V are planned to adopt 40 kA, which is a much higher value than the calculated values and are therefore adequate.

Kenya implemented the short-circuit fault current calculations in the LCPDP which includes future plans of power facilities, and it calculated 9.96 kA three-phase short-current at 220 kV bus at Olkaria IV in 2030.

3) Stability Study

The steady-state stability of the Olkaria V generator was studied as one machine connected to an infinite bus system.

The rated specification of a generator for Olkaria V is defined as follows:

- Rated output: 77 MW（70 MW net）
- Power factor: $\cos\theta = 0.85$(lag) - 0.95(lead)
- Rated capacity: 90.6 MVA
- Short circuit ratio: studied at 2 cases of 0.58 and 0.64

The Suswa substation 220 kV bus was assumed as an infinite bus and reactance value of the power system was calculated primarily with input data of PSS/E for the year 2017, received from KPLC.

i. Generator reactance: Xd @1.000 MVA base
   Xd = 19.6 p.u. (SCR: 0.58) & 17.8p.u. (SCR: 0.64)

ii. Outside reactance from Generator: Xe
   Generator transformer + Transmission line (Olkaria V – Olkaira IV – Suswa substation) + Reactance of power grid

   The Olkaria IV generators were considered to be out of service condition in the calculation in order to make outside reactance value higher for severe study. Two cases of operation for the transmission line between Olkaria IV and the Suswa substation were studied, one is only one line in service and the other is both of the two lines in service.

   Xe = 2.05 p.u. (only one line in service), 1.93 p.u. (both lines in service)

iii. Generator voltage: E
   Lowest operation voltage of 95 % applied in order to study at severe condition

iv. Steady-state stability limit curve @1,000MVA base
   - Circle of radius = $E^2/2\ (1/Xe + 1/Xd)$

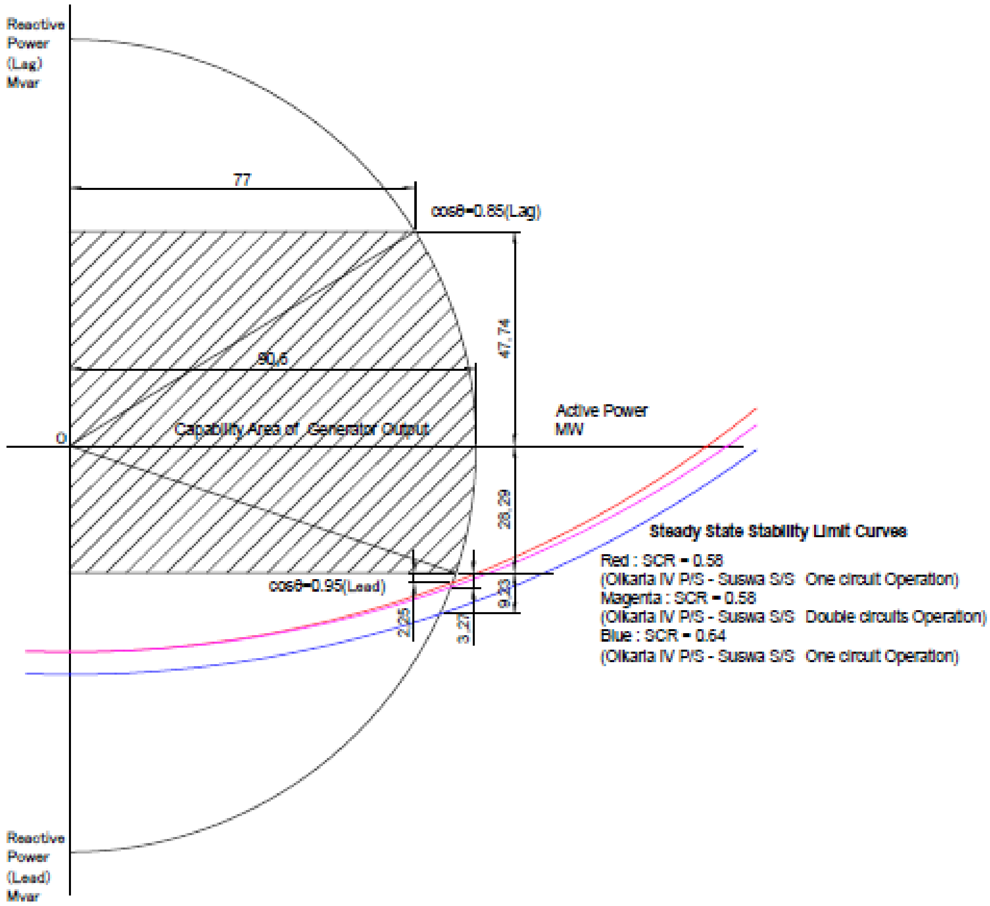
= 0.243 (0.58, only one line in service)
0.257 (0.58, both lines in service)
0.259 (0.64, only one line in service)

- Center of the circle (on Y axis) = $E^2/2$ (1/Xe − 1/Xd)

= 0.197 (0.58, only one line in service)
0.211 (0.58, both lines in service)
0.208 (0.64, only one line in service)

The relationship of the assumed generator output capability area and the steady-state stability limit curves, which were calculated using the results above, are shown in Figure 3.3.4-8.

The generator can be operated anywhere in the output capability area (power factor 0.85lag to 0.95 lead) which is inside the limit curve, even at the most severe case when the condition of generator SCR = 0.58 and transmission line between Olkaria IV and Suswa substation has only one line in service. However, it is recommendable that a higher short circuit ratio (0.64) machine should be selected to secure the margin for power factor lead operation.



(Source) Study team

Fig. 3.3.4-11 Steady-state Stability Study (Olkaria V 90.6 MVA Generator)

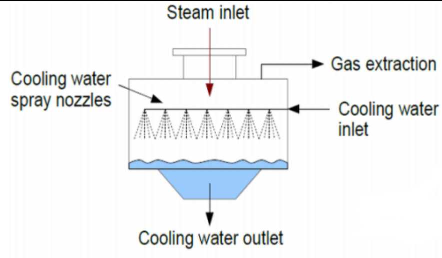
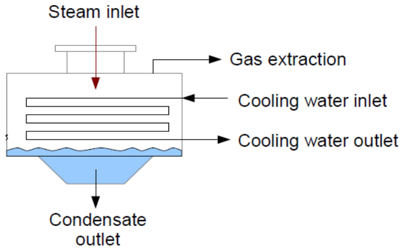
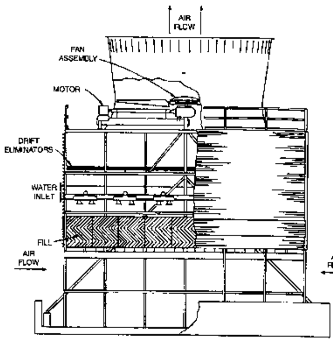
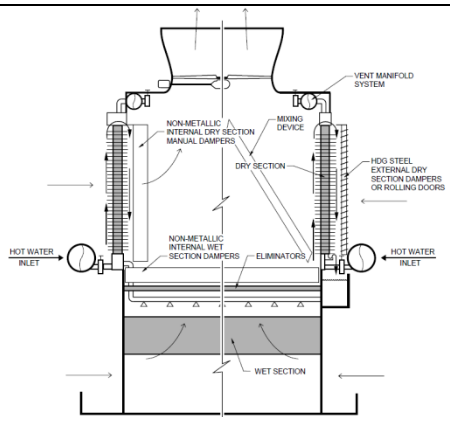
Although it is also important to verify the transient stability as well as the steady-state stability when connecting the generator to the grid, KPLC is performing the power flow analysis and the fault current calculation only and has not performed transient stability analysis to date. KPLC has recognized the importance of the analysis and has started collecting the required data, however, the prospect of completion of the study is unknown. A review of the dynamic stability of the power system is stipulated in Kenya Electricity Grid Code (2008) and should be made by the system operator in consultation with network service providers. Unfortunately this review has not yet been realized. It is recommended that the transient stability analysis be made prior to the preparation of bidding documents of the power plant EPC of Olkaria V and the results be reflected in the specifications of the generating facilities.

3.3.5 Review of construction method

The cooling option of the power plant assumed in KenGen's report "Feasibility Study for Development of KenGen’s Geothermal Concession Area in Olkaria Beyond 430 MWe (Revised September 2012)", is a surface condenser with wet/dry hybrid cooling tower for water conservation (i.e. aimed at increasing reinjection by reducing evaporation loss of water at the cooling tower)(Table 3.3.5-1).

Its drawbacks compared with a conventional direct contact condenser with wet cooling tower are higher capital costs, lower efficiency, more maintenance efforts, higher steam consumption, and a larger footprint of the cooling tower. This report assumes the same cooling option. However, the final decision on the cooling option should be made during preparation of the bid documents of the power plant EPC on the basis of the results of the reservoir simulation and chemical data of the geothermal fluid, and detailed study on the power plant's heat-mass balance and cooling tower design.

Table 3.3.5-1 Comparison of Cooling Options

	Direct contact condenser with Wet cooling tower (Olkaria I, II, IAU, IV)	**Surface condenser with Hybrid cooling tower** (assumed for Olkaria V)
Condenser		
Cooling tower	 (Source: Black & Veatch, "Power Plant Engineering", Chaplan & Hall, 1996)	 (Source: Paul A. Lindahl, et.al., "Plume Abatement and Water Conservation with the Set/Dry Cooling Tower", Cooling Tower Institute Technical Paper No.TP93-01, 1993)
Evaporation loss	75% of steam	66% of steam
Blowdown	23% of steam	22% of steam
Condensate recovery	none	10% of steam
Total of blowdown and condensate	23% of steam	32% of steam
Parasitic load	6 - 7 %	8 - 9%

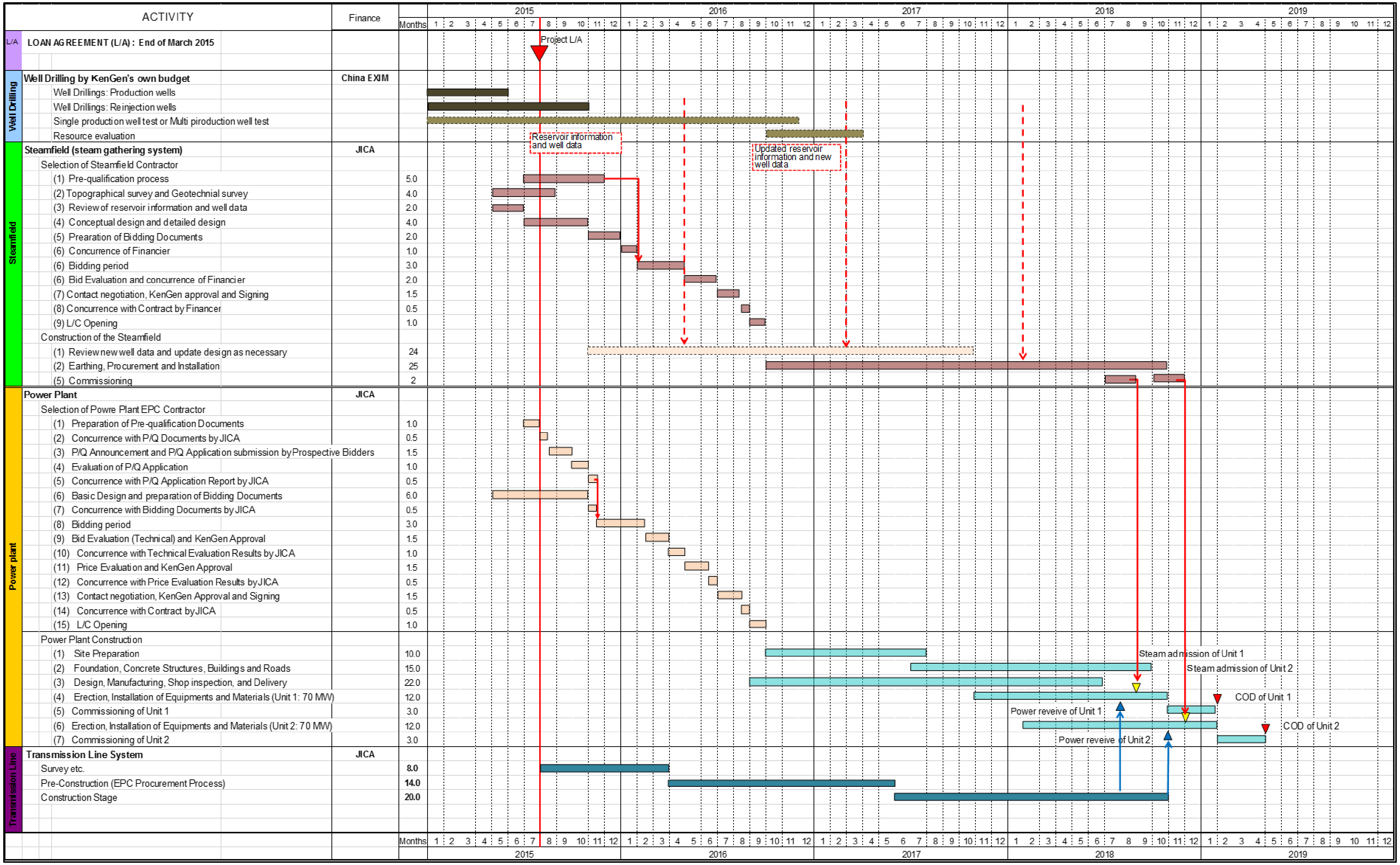
(Source) Study team, and Feasibility Study for Development of KenGen's Geothermal Concession Area in Olkaria Beyond 430 MWe (Revised September 2012), Figure 21 and Table 6 modified)

3.4 PROJECT IMPLEMENTATION SCHEDULE

Figure 3.4-1 shows the overall project implementation schedule for the surface facilities. It includes typical periods of time for JICA concurrence requirements concerning several procurement procedures. The actual construction period of Olkaria IV and other geothermal projects, and the resource development plant by KenGen are also taken into account.

KenGen is planning to procure consulting services under finance other than Japanese ODA Loan. The bidding was closed in September 2014 and re-bidding was announced on December 9, 2014. Therefore, it is assumed that the consultant will start preparation of pre-qualification (P/Q) documents and basic design of the steamfield and the power plant at the end of April 2015.

According to the tentative project implementation schedule below that was devised assuming the period of the Loan Agreement (L/A) to be late July 2015, it was revealed that the completion date of Olkaria V Unit-1 (70 MW) would be at the end of January 2019, and the completion of Unit-2 would be at the end of April 2019.



(Source) Study team

Fig. 3.4-1 Project implementation schedule

3.5 ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

To review the exiting ESIA report and RAP report, the required information was collected and additional interviews were carried out during the first work in Kenya. The main information collected in the first work is shown in Table 3.5-1.

During the second work in Kenya, as in the first work, the required information was collected and additional interviews were conducted. Furthermore, follow up information was collected based on the advice of the environmental and social consideration advisory committee. Moreover, a follow-up study was carried out on the implementation status of the existing involuntary relocation program. The main information collected in the second work is shown in Table 3.5-2.

The detailed information about the environmental and social considerations is described separately in the Progress Report.

Table 3.5-1 List of the main information collected in the first work in Kenya

No.	Report
1	The Proposed 140MW Olkaria V Geothermal Power Plant, Environmental and Social Impact Assessment (ESIA) Study Report, 2014
2	Memorandum of Understanding (MoU) between Kenya Electricity Generating Company ltd (KenGen) and the Olkaria 280 MW Geothermal Development Project Affected Persons – PAPs, 2013
3	Memorandum of Understanding (MoU) between Kenya Wildlife Service and Kenya Electricity Generating Company, 2008
4	Hell's Gate-Mt. Longonot Ecosystem Management Plan, 2010-2015
5	Lake Naivasha Basin Integrated Management Plan 2012-2022
6	Environmental & Social Impact Assessment Study Report for the Proposed Drilling of Eighty (80) Geothermal Steam Production Wells for Expansion of Electricity Power Generation at Greater Olkaria Geothermal Field in Naivasha District,2012

Table 3.5-2 List of the main information collected in the second work in Kenya

No.	Report
1	Information about the impact on animals and plants caused by existing power plants (carried out by interviews)
2	The Environmental Management and Coordination Act Environmental Impact Assessment License (NEMA)
3	Amendment No.1 to the Memorandum of Understanding (MoU) Between Kenya Electricity Generating Company Ltd. (KenGen) and the Olkaria 280 MW Geothermal Development Project Affected Persons (PAPs) (October, 2014)
4	Meeting minutes of the public consultations after resettlement

3.6 ESTIMATION OF THE PROJECT COST

The base cost of this project is estimated using 2014 prices. The price contingency is calculated using JICA's suggested inflation rate for Kenya. Seven (7) percent of physical contingencies for construction costs and five (5) percent of physical contingencies for consultancy services cost were also considered. The project cost is estimated with the compositions below.

- ✓ Land Acquisition
- ✓ Lot1. Steam Gathering
- ✓ Lot2. Power Plant
- ✓ Lot3. Switch Yard and Transmission Line
- ✓ Lot4. Other Relevant Infrastructure (well drilling, steamfield roads and environmental rehabilitation)
- ✓ Administration Cost
- ✓ Consulting Fee
- ✓ Contingencies
- ✓ Interest During Construction and Front End Fee

The project cost consists of Lot 1(steam gathering system), Lot 2 (power plant) and Lot 3(switch yard and transmission line), that are the targets of Yen loan, and Lot 4 (infrastructure). The cost of Lot 4, except for the cost for steamfield roads and environmental rehabilitation, and consultant fee, are prepared by KenGen's own budget.

The cost of well drilling is calculated from unit price and the number of wells utilized for Olkaria V. The exchange rates used for the calculation are as follows.

Table 3.6.-1 Exchange Rates and Escalation Rates

Exchange Rate	1US$	120.48	Yen
	1 KES	1.33	Yen

(Source) JICA

3.7 FINANCIAL SITUATION OF KENGEN

The financial data of KENGEN is summarized below.

Table 3.7.-1 The KENGEN's profit and loss statement trend (Unit KShs in million)

	2010	2011	2012	2013	2014
Sales of Power	10,998	14,389	15,999	16,451	17,424
Interest	398	549	953	676	416
Others	114	284	484	595	651
Revenue Total	11,510	15,222	17,436	17,722	18,491
Operating Cost	8,558	10,014	10,266	10,641	11,812
Other gains and lossess	-274	-440	153	53	-67
Financial Cost	741	1997	2972	3001	2588
Total Cost	9,025	11,571	13,391	13,695	14,333
Profit Before Tax	2,485	3,651	4,045	4,027	4,158
Tax (- is credit) *	-802	1,571	1,223	-1,198	1,332
Profit after Tax	3,287	2,080	2,822	5,225	2,826
Other adjustment	1363	-633	-962	-17	1,244
Net INCOME after Tax	4,650	1,447	1,860	5,208	4,070

Remarks: The negative figure of tax is tax credit which is due to Kenya's investment enhancement system

Source: Annual report 2014, KENGEN

The revenue from the sales of power is increasing steadily, and consequently the total revenue is also increasing. The ratio of change in total revenue has large figure in 2011 but has decreased in 2012 and 2013. However, the ratio has increased from 1.6% in 2013 to 4.3% in 2014. The change in profit before tax shows also the same trend, and the figure has changed from – 0.4% in 2013 to 3.3% in 2014. These are because the hydropower plants could not operate satisfactorily due to water scarcity arouse from unfavorable weather, cost increase due to high investment to new power plants, purchase of spare parts, etc. The amount of net income before tax is also generated without problem, but has changed drastically from year to year. In 2014 it has decreased 20% from previous year. But this is because it has jumped to 180% in 2013 due to the tax credit system as an incentive to investment activities in places other than Nairobi, Mombasa, and Kisumu, which led to large amount of profit after tax.

The trend of balance sheet is shown in the following table.

Table 3.7.-2 The trend of KENGEN's Balance Sheet (Unit: KShs in million)

	2010	2011	2012	2013	2014
Assets					
Current Assets	32,849	19,539	22,288	25,128	27,631
Non current Assets	117,718	141,454	140,857	163,545	222,575
Total Assets	150,567	160,993	163,145	188,673	250,206
Equity and Liabilities					
Current Liabilities	6,970	11,256	15,001	17,672	25,196
Non Current Liabilities	73,066	80,318	78,074	97,042	148,300
Capital and reserves	70,531	69,419	70,070	73,959	76,710
Total Equity and Liability	150,567	160,993	163,145	188,673	250,206
Increase in Assets		6.9%	1.3%	15.6%	32.6%

Source: Annual report 2014, KENGEN

The volume of assets is also increasing without problem. Compared with previous year, it has decreased in 2012 to 1.3% but increased to 15.6 and further 32.6% respectively in 2013 and 2014. The increase was mainly due to increase of Non Current Liabilities, and the trend is also shown in Non Current Assets. This is because of capital investment of power generation in 2013 and 2014.

The trend of cash flow is shown in the followings.

Table 3.7.-3The Trend of KENGEN's Cash Flow (Unit: KSh in million)

	2010	2011	2012	2013	2014
Operating Activities Cash	2,125	4,512	3,050	22,962	12,107
Investing Activities	-16,356	-22,397	-8,635	-34,495	-59,959
Financing Activities	31,340	-330	2,905	15,093	48,484
Total (Net Increase)	17,109	-18,215	-2,680	3,560	632
Cash/Equivalent at the beginning	4,222	21,331	3,116	436	3,996
Cash/Equivalent at the end of the year	21,331	3,116	436	3,996	4,628

Source: Annual report 2014, KENGEN

Looking the outstanding balance at the end of year, large fluctuation can be seen. The outstanding balance was KSh 21,331 million in year 2010. It has decreased to 436 in 2012 but increased to KSh 3,996 million and further to KSh 4,628 million in 2013 and 2014 respectively. The breakdown shows that the cashflow in operating activities increased in 2013 and this supports the investment activities together with financing cash flow. It has similar tendency operation in 2014 resulting into the same trend. Although the sales revenue has not increased in 2013 and 2014 as compared with 2012, the increase of cash flow was realized with the external borrowings in 2013 and 2014 as well.

Major financial indicators are shown in the following table

Table 3.7.-4 Major Financial Indicators

	2010	2011	2012	2013	2014
Sales Profit Ratio (Net Income/Profit)	23%	25%	25%	24%	24%
Capital/Asset Ratio	46.8%	43.1%	42.9%	39.2%	30.7%
Current Ratio	471.3%	173.6%	148.6%	142.2%	109.7%
Return on Equity	3.5%	5.3%	5.8%	5.4%	5.4%
Return on Assets	1.7%	2.3%	2.5%	2.1%	1.7%

Source: JICA Survey Team

The sales profit ratio is stable. The capital/asset ratio has been decreasing but still it has more than 30% when the borrowings has increased in 2013 and 2014, hence it is sustainable. The current ratio has also been decreasing. It has more than 140% until 2013 but has decreased to 110% which has slightly concerned. The return on equity was increased from 3.5% to 5% and remains steadily.

3.8 KENGEN'S ORGANIZATION STRUCTURE FOR THE PROJECT IMPLEMENTATION AND MAINTENANCE

3.8.1 Organization structure for the project implementation

The existing reports to be reviewed have no description about KenGen's organization structures for the construction stage. Organization structures for implementing the projects were provided by KenGen in this mission and are shown in Fig.3.7.1-1 to Fig.3.7.1-3.

3.8.2 Organization structure for maintenance

Although the existing report indicates the number of people required for maintenance in Table 12, there are no descriptions about the entire organizational structures of KenGen's headquarters and Olkaria office, and also organizations for the social and environmental portions (monitoring and countermeasure works). Organization structures for maintenance were provided by KenGen in this mission and are shown in Fig.3.8.2-1 and Fig.3.8.2-2.

According to KenGen, they are just now partially revising their organization structures. Therefore, KenGen will inform us about the revised organizational structure after it is finalized. KenGen's organizational structure is basically organized so that the Business Development Division should primarily resolve the issues in the stage of project formation, and then the Geothermal Division should implement the project, including the construction and operation/maintenance, once the project is formulated.

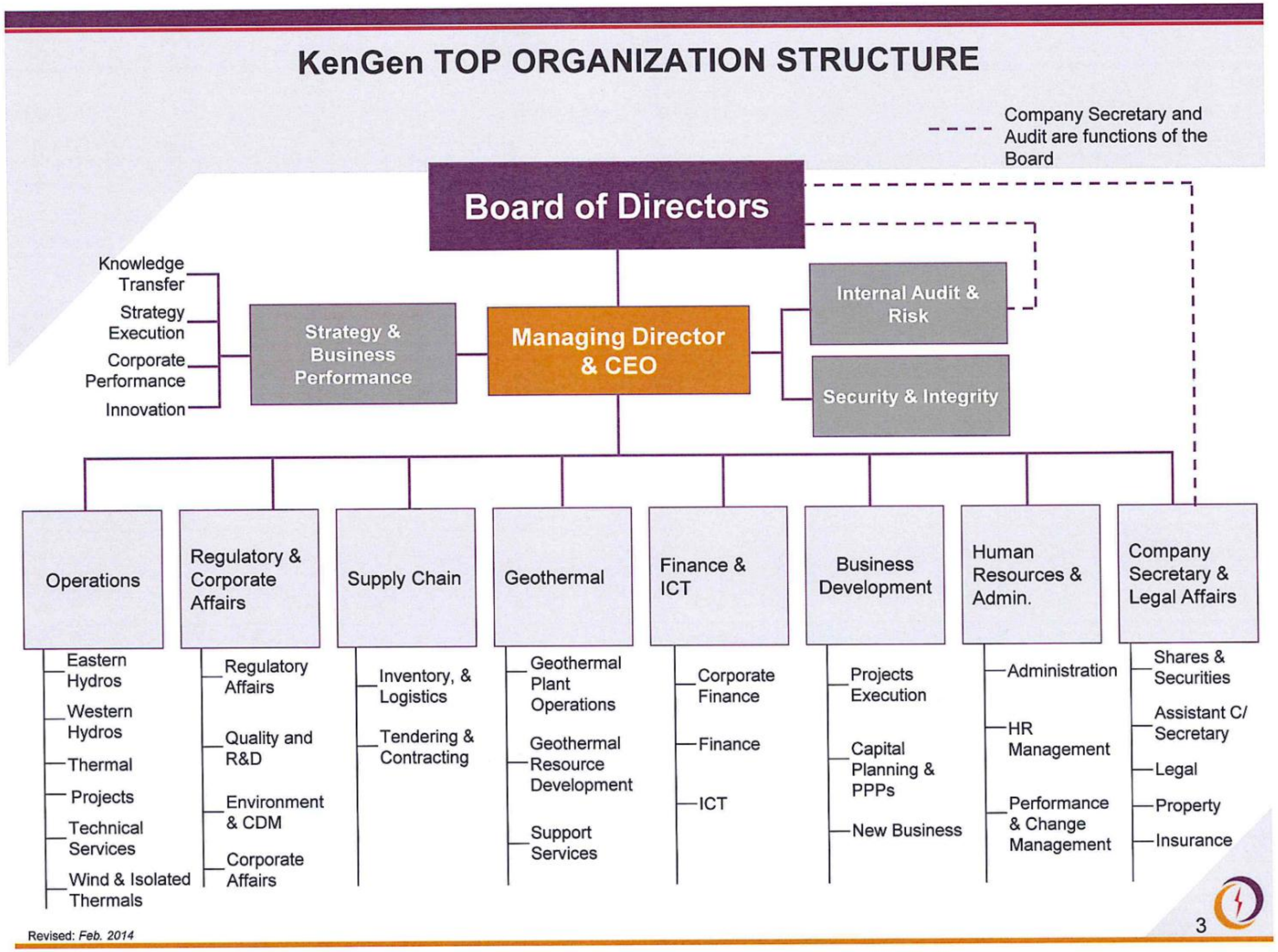


Fig. 3.8.1-1 KenGen top organization structure

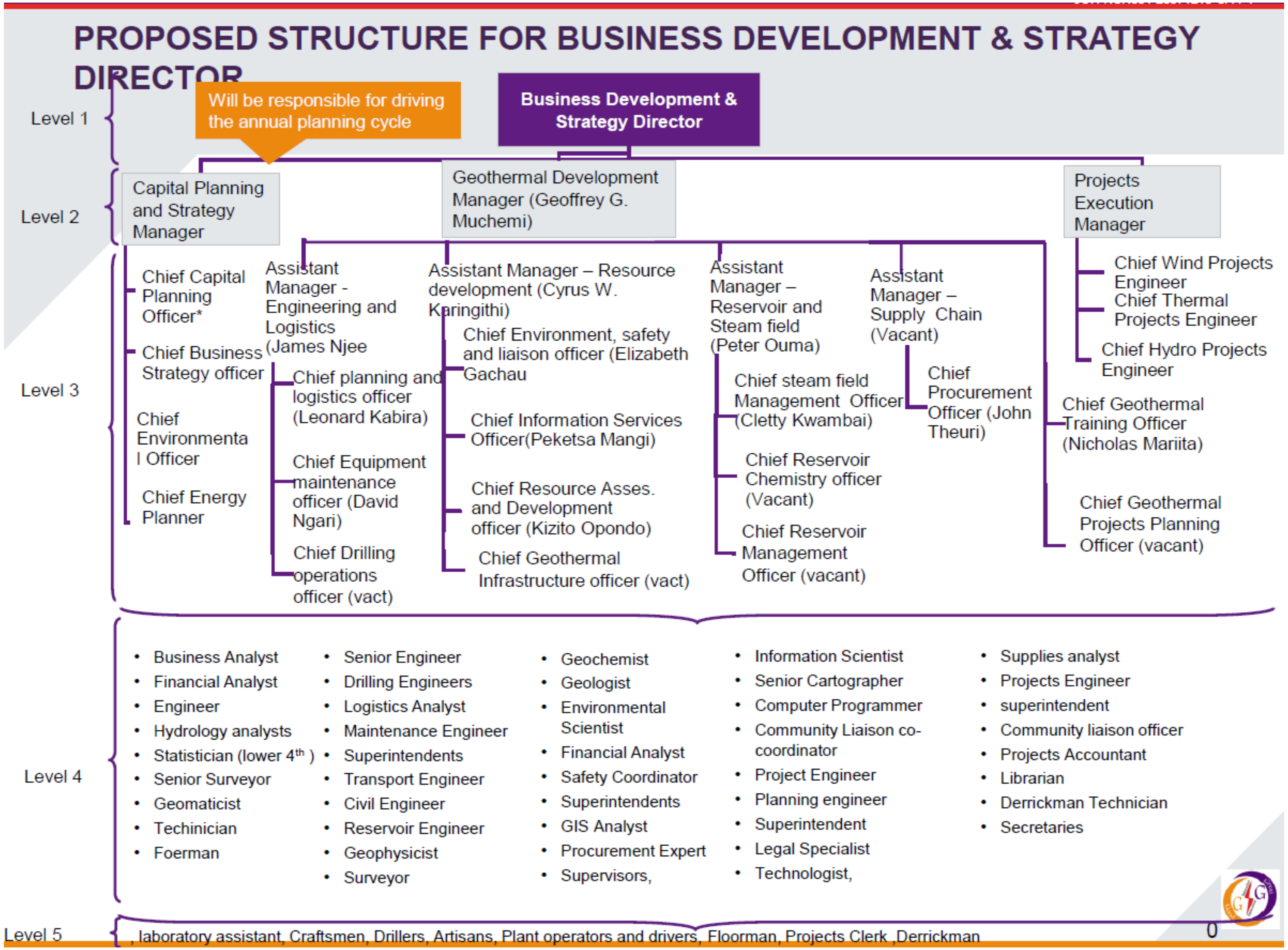


Fig. 3.8.1-2 Proposed structure for Business Development and Strategy Director

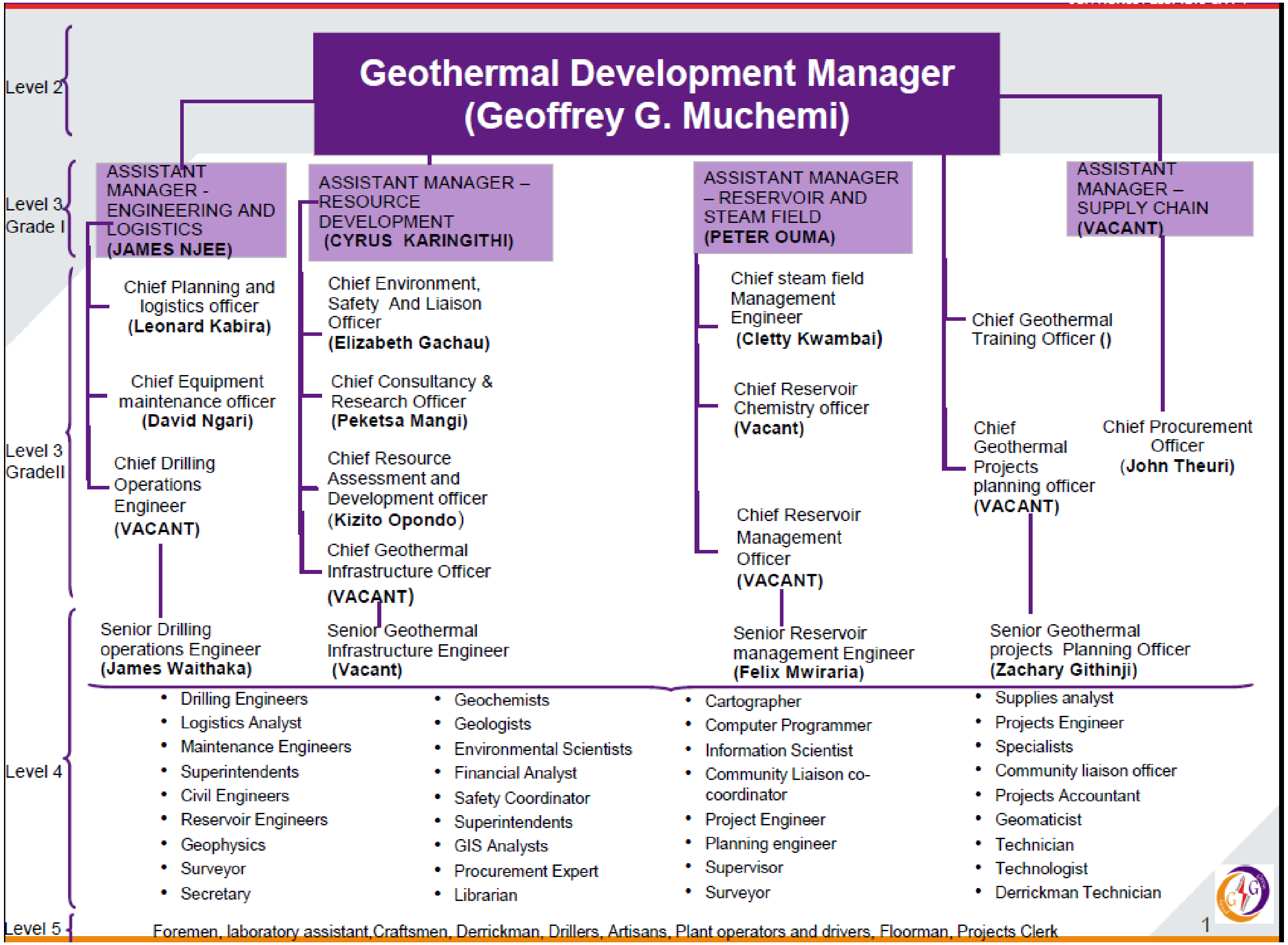


Fig. 3.8.1-3 Geothermal Development structure

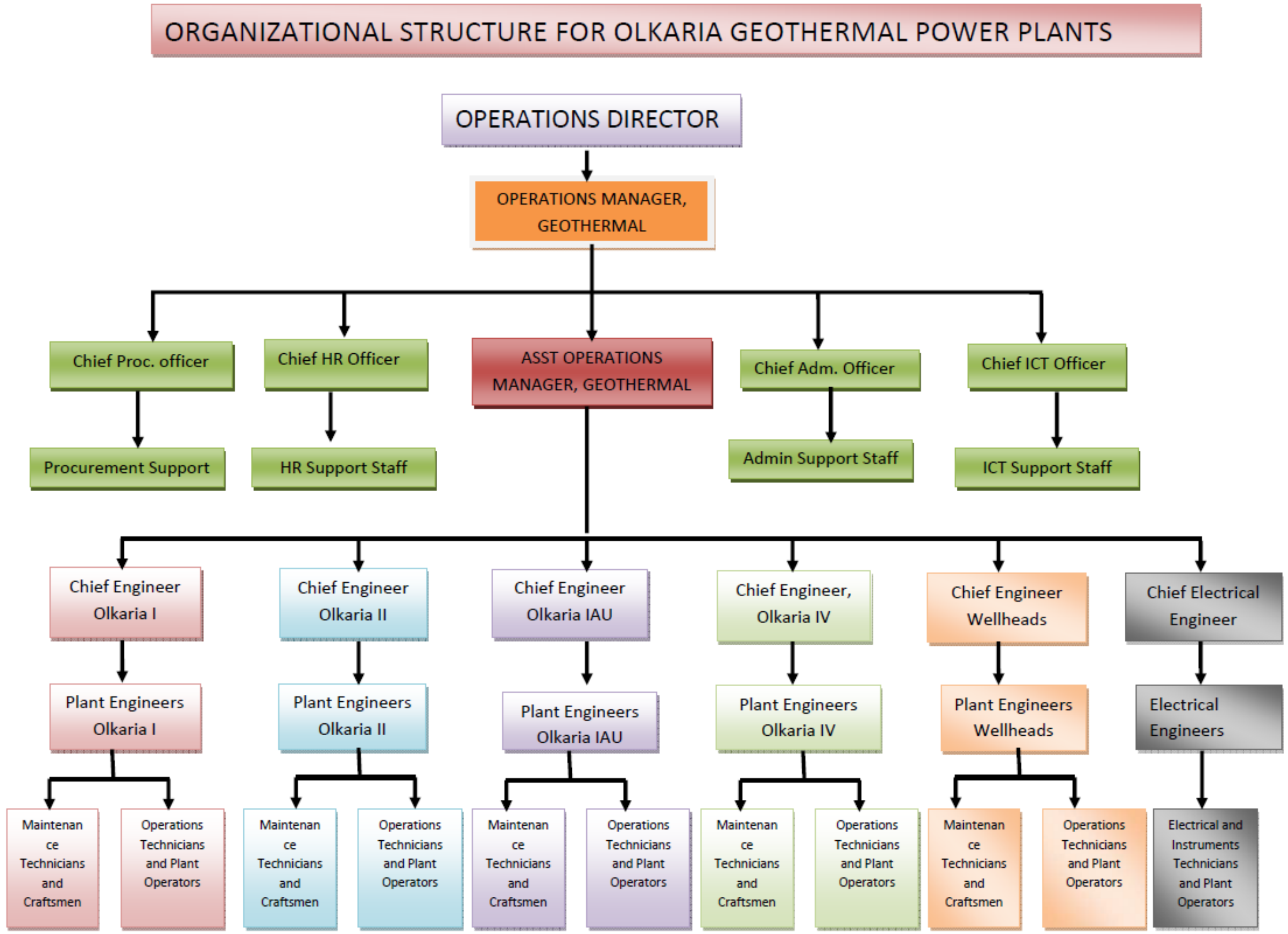


Fig. 3.8.2-1 Organization structure for Olkaria geothermal power plants

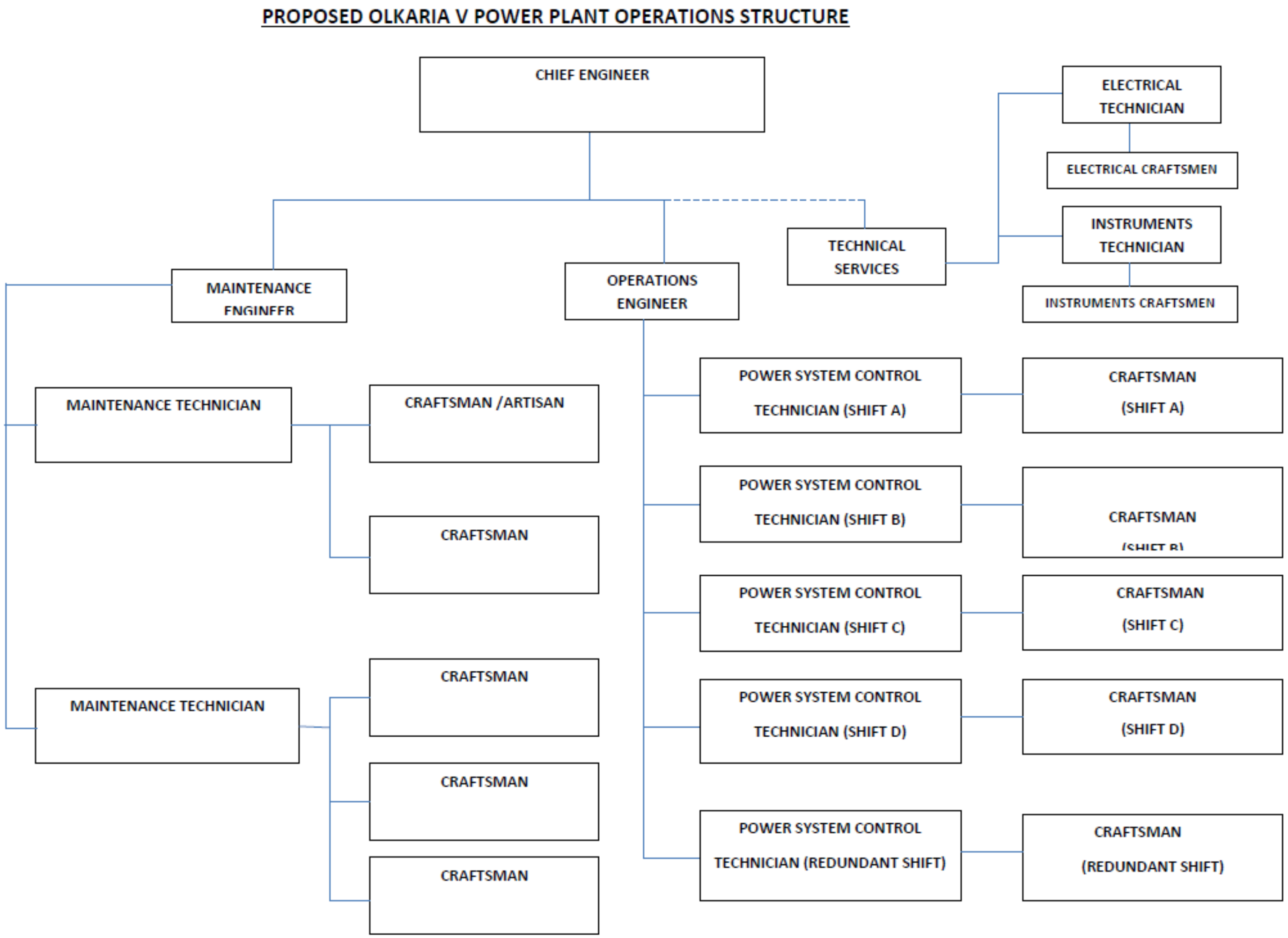


Fig. 3.8.2-2 Proposed Olkaria V power plant operations structure

3.9 FINANCIAL AND ECONOMIC EVALUATION

3.9.1 Project cost estimation

KenGen plans to develop the Olkaria V geothermal power plant with a capacity of 140 MW, 70 MW x 2 Net with the financial assistance of JICA. The base costs of the project were estimated using 2014 prices and the price contingencies were estimated using escalation rates for Kenya specified by JICA. The physical contingencies, seven (7) percent of construction cost and five (5) percent of consultancy services cost were also considered.

(1) Cost composition

The project cost is estimated using the following compositions;

- ✓ Land Acquisition
- ✓ Lot1. Steam Gathering
- ✓ Lot2. Power Plant
- ✓ Lot3. Switch Yard and Transmission Line
- ✓ Lot4. Other Relevant Infrastructure (Well Drilling, Steamfield Road and Environmental Rehabilitation)
- ✓ Administration Cost
- ✓ Consulting Fee
- ✓ Contingencies
- ✓ Interest During Construction and Front End Fee

(2) Currency and exchange rate

The cost estimated is divided into foreign and local currencies but all expressed in US dollars. The escalation rates used for the calculation of the price contingencies are those specified by JICA for 2014 goods and services for Kenya.

Table 3.9.1-1 Exchange rates and escalation rates

Exchange Rate	1US$	120.48	Yen
	1 KES	1.33	Yen
Escalation Rate	DC	5.4 %	
	FC	2.0%	

(Source) JICA

(3) Operating indicator of the project

The operating indicator of the project is shown in Table 3.9.1-2. The costs for construction of pipeline (Lot 1), power generation facilities (Lot 2), transmission line (Lot 3) and steamfield road and environmental rehabilitation (parts of Lot4) were assumed to be the subject of Yen loans.

Table 3.9.1-2 Operating indicator

Indicator	Target
Maximum Net Output	140 MW
Capacity Factor	81.83%
Availability Factor	90%
Transmission Loss	0.05%
Outage Hours for Every Cause	Scheduled shutdown 312 hours/year Forced shutdown 564 hours/year
Outage Times for Every Cause	Maintenance Stop 1 time/year

(4) Finance Procurement Plan

KenGen will implement the project using a Japanese Government ODA Loan from JICA for 55% of the total project cost. KenGen will make use of its equity for the remaining 45% of the project cost. KenGen's desired rate of return for its equity is 17.86% before tax and 12.50% after tax. The consulting cost is included in KenGen equity. A consultant for this project has been employed by KenGen.

Since the financial internal rate of return (FIRR) is calculated after tax, the after tax rate of return is used for KenGen equity. The weighted average cost of capital (WACC) for the project, the hurdle value as compared with the obtained FIRR, becomes 5.86% accordingly.

Other terms and conditions of the Yen loan are as follows;

- ✓ General untied
- ✓ A Front End Fee of 0.2% of the commitment amount at the beginning of the project will be imposed.

3.9.2 Result of preliminary analysis of finance and economy

(1) Financial Analysis

The geothermal electricity selling price has been regulated by the Ministry of Energy, "Feed-in-Tariffs (FIT) Policy on Wind, Biomass, Small Hydro, Geothermal, Biogas and Solar Resource Generated Electricity, 2nd Revision, December 2012". According to this regulation, the electricity generated under the project will be sold to the off-taker at the nearest substation and the FIT value for a geothermal project above 10 MW installed capacity is 8.8 cent/kWh. But KenGen suggested that the JICA study team calculate the Levelized Energy Cost of Electricity for this project. Additionally, the JICA study team calculated the levelized unit electricity price per kWh discounted at 10%. This discount rate is used for power projects in Kenya (Updated Least Cost Power Development Plan Study Period 2013-2033, March 2013). Using this unit electricity cost, the free cash flow for 25 years will be calculated to obtain the project financial internal rate of return.

The obtained FIRR value will be compared with the project's WACC of capital in order to examine the project's financial feasibility. In addition, the repayment schedule of the loan and cash flow statement with debt service ratio will be prepared. Further, sensitivity of the FIRR to the project cost, power selling rate and capacity factor will be tested.

The land acquisition, well drilling works, consulting service fee and KenGen administration costs were appropriated for the KenGen Equity portion, and the ratio of the total project cost is 44.9%. The project finance from the JICA is 55.1%.

Although JICA specified that the repayment period will be 40 years including a grace period of 10 years, the study adopts a repayment period of 15 years including a grace period of 10 years in consideration of the project life of 25 years.

In accordance with the financing report of KenGen's annual report, the corporate tax of the geothermal power undertaking is 30%. The depreciation method is a straight line without residual value. The economic life of the geothermal well and geothermal power facilities including steam gathering system is 25 years and that of transmission line and substation is 40 years, respectively based on the information from KenGen. The depreciations of the geothermal well, power facilities and transmission line do not affect the FIRR calculation.

The project operating conditions are assumed as follows;

Installed Capacity:	70 MW x 2 (Net)
Station Power Ratio:	9.09 %
Capacity Factor:	90%
Production Wells:	33 wells at commissioning
Reinjection Wells:	8 wells at commissioning
Transmission Losses:	0.05 %
Annual Generation:	1214.1 GWh
Energy at Transmission End:	1103.1 GWh

The levelized energy cost (LEC) was calculated with variable discount rates. The reference discount rate used was 10% as in the Updated Least Cost Power Development Plan Study Period 2013-2033. The LEC considers not only the initial investment but also O&M cost in the course of 25 years of operation. The calculated FIRR value of the project is much higher than the WACC. However, the equity IRR values do not exceed the respective RORs. So, the project is concluded to be financially feasible but does not satisfy the expected return of equity of KenGen.

(2) Economic Analysis

The economic viability of the project was evaluated using an economic internal rate of return method. Selecting an alternative power project which may be able to supply an equal benefit (electric power) to the society, the study team calculated the EIRR which equalizes the cost and benefit for a period of economic life. The cost here is the sum of the costs of steam supply and power generation facilities as well as the O&M costs and the benefit is the costs of the alternative. The evaluation is made by comparison between the obtained EIRR and the discount rate of 10% which is applied for power projects in Kenya.

As an alternative to the project which could supply an equal amount of generated power to the society, coal-fired thermal power with capacity factor ranges from 85% to 90% as a base load power source was selected and compared with their operating conditions:

In order to compare the costs of the project and the alternative project, the project EIRR (with and without transmission line (T/L)) was calculated. The project, both with and without transmission line, exceeded the hurdle rate of 10% and should the project avert the operation of the alternative project, the country could save imported coal fuel expenses amounting to US$56.9 Million annually. The project's economic viability over the alternative is justified, and the project is economically the correct selection to pursue from the stand point of the national economy.

(3) Evaluation

This project is one of the national projects listed in the LCPDP of the Ministry of Energy. It is considered a very significant power expansion project, because there is a forecast that Kenya will suffer a severe power shortage owing to increased economic activities. In addition, the project will generate power making use of an indigenous energy source as well as avoiding the use of coal or other fossil fuel energy. The project is an environmentally friendly project. As a summary, the project demonstrates that it is financially and economically feasible and is worthy to pursue.

3.10 CONSIDERATIONS FOR PROJECT IMPLEMENTATION

3.10.1 Project package

The project will be packaged into four contract lots, namely

(i) Lot I (Steam-field Development Contract),
(ii) LOT II (Power Plant - Civil, Electrical and Mechanical EPC Contract)
(iii) Lot III (Sub-station, transmission line and interconnection into the grid) and
(iv) Lot IV Local infrastructure works (access roads, Water Supply, offices for the Engineer, Training School and Hostel). The scope of the contract packages are detailed hereunder.

A consultant for the project will be appointed for design and supervision works. KenGen will form a Project Implementation Team (PIT) to oversee and coordinate the project implementation, to provide employer supplied items and manage the internal and external stakeholders. The PIT will identify operations and maintenance (O&M) requirement and facilitate training and staffing for O&M. The relationships between KenGen, Consultant and Constracors is shown in Fig.3.10.1-1.

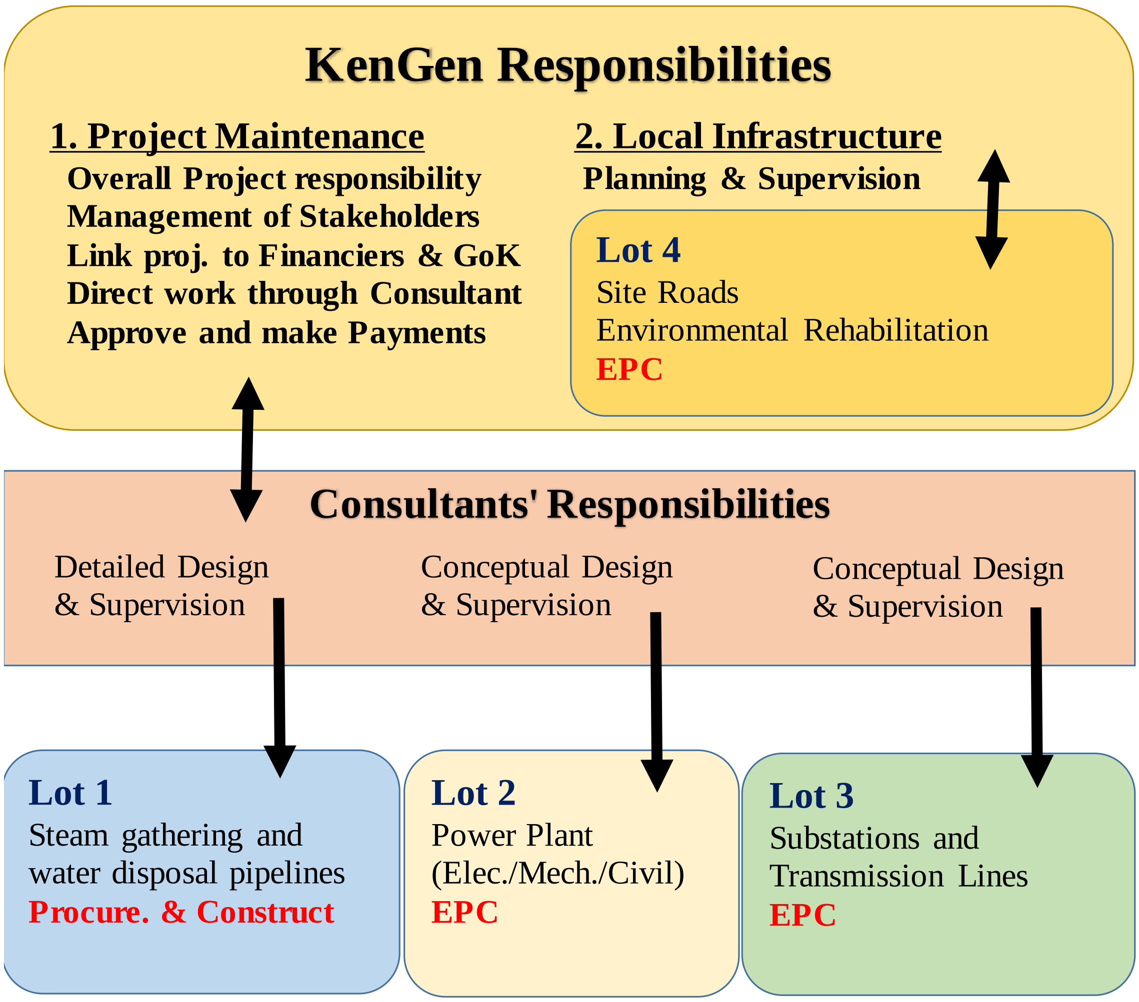


Fig.3.10.1-1 Relationships between KenGen, Consultant and Constractors

3.10.2 Procurement and contracts of Consultant

A consultant will be appointed to carry out design and supervision of construction and commissioning. The procedure of consultant procurement is as follows.
1) Request Letter of Interest (LOI)
2) Pre-qualification of the consultant who submitted LOI
3) Request for proposal including both technical and financial portions
4) Evaluation of technical proposal
5) Public opening and evaluation of financial proposal
6) Calculate the combined and financial score of proposal
7) Negotiations
8) Award of contract

The Scope of consultant shall include the following:

i) Prepare concept designs for the entire project for concurrence with the employer.
ii) Prepare detailed design including Bill of Quantities for the steam field portion (Lot I).
iii) Prepare final concept design for the EPC contract for power plant (Lot II)
iv) Prepare final concept design for the EPC contract for High Voltage sub-station and Transmission lines (Lot III).
v) Preparation of pre-qualification documents
vi) Preparation of technical specification, schedules and complete tender documents
vii) Assist the Employer in tender evaluation
viii) Preparation of tender evaluation reports
ix) Assist in the tendering process upto award
x) Preparation of revised drawings & designs as required
xi) Preparation of construction drawings
xii) Project management;
xiii) Construction works supervision;
xiv) Coordinate Training of KenGen's staff.
xv) Management of Defects during Defects Liability Period

3.10.3 Project implementation structures

It is proposed that the project be implemented consisting the follow:

i) The Project Steering Committee consisting of the following:
- Chairman of the committee being the KenGen MD & CEO.
- All Executive committee members.
- The Geothermal Operations Manager.

ii) Project Implementation Team (PIT) is to be appointed including the following
- PIT leader proposed as the Project Execution Manager
- Assistant PIT leader proposed as the Asst. Projects Execution Manager
- Resident Manager proposed as the Chief Projects Engineer
- Resident Project Monitoring and Risk Assessment Engineer
- Local Infrastructure Manager
- Stake holder coordinator – *full time*
- Site Office Administration staff
- Resident Civil Engineer - *counterpart*
- Resident Mechanical Engineer – *counterpart*
- Steam field Engineer - *Counterpart*

- Resident Electrical Engineer - *Counterpart*
- Environmental & Social Officer – registered with NEMA - *Counterpart*
- Health & Safety Engineer –Registered with DOSH - *Counterpart*
- Finance officer – *part time*
- Legal officer – *part time*
- Procurement officer – *part time*
- Human Resources Officer – *Part time*
- Chief Operations Engineer Olkaria V. – *part time*
- Senior Technical Services Officer Olkaria V. – *part time*
- Representative of KETRACO – *part time*
- Representative of KPLC – *part time*

iii) Consultant

- A support office at their head office
- Local office at site
- Project manager
- Steam field manager
- Steam field Design Engineer
- Steam field Supervision Engineer
- Power plant mechanical supervisor
- Power plant civil supervisor
- Power plant electrical and control supervisor
- HV. Substation supervisor
- HV Transmission Line supervisor
- EHS Officer
- QS officer
- Project Administrator / data clerk

3.10.4 Project management

(1) Interfaces and coordination of works

All interfaces will be determined with the help of consultant and the works allocated suitably. In this project the main interfaces include

- Handing over of production and Reinjection wells to the Contractor by KenGen
- steam supply by Lot I to Lot II boundary
- High voltage (220kV) power connection to Power Plant and to Exiting Substations

Other interfaces will include coordination between KenGen, KETRACO, KPLC, relevant Government Departments/Ministries, Financiers and local authorities.

(2) Meetings

The following meetings will be necessary for managing the project.

- Monthly progress meetings with each contractor and consultant
- Site coordination meetings e.g. EHS, interface meetings, technical meetings

(3) Reporting

The following reports will be required

- Monthly project monitoring report from PIT
- Monthly progress report from the Contractor
- Monthly progress evaluation report by the consultant

(4) Communication

The communication channel is as follows:

- The PIT leader shall report to the steering committee chairman. The PIT leader shall prepare their internal communication structure and advice the other parties.
- The Consultant shall report to the PIT. The consultant shall prepare their internal communication structure and advice the Employer
- The Contractor shall be reporting to the Employer through the Consultant. Each contractor shall prepare their internal communication structure and advice the Employer.

3.10.5 Quality assurance and control

To ensure quality control and standards are established and maintained, the following processes must be detailed in the consultancy and construction contracts.

(1) Design Review mechanism.
(2) Site Inspections and reporting
(3) Construction Materials Approvals Laboratory Tests and interpretation of results
(4) Factory Acceptance Tests for major equipment will be mandatory
(5) Environmental Management Plan implementation procedures
(6) Health and Safety procedures
(7) Payment procedures
(8) Claims and Variation procedures

3.10.6 Management of Defect

(1) Defects During Construction shall be managed as per the QAC above. Further, Kengen and consultants staff are required to ensure non-conformances are addressed at site through (i) joint site inspections and discussions, (ii) site meeting (iii) site instructions and (iv) site notices and letters etc

(2) Defects after hand over (During Defects Liability Period)
This shall be managed in accordance with Kengen QMS procedures including

- Filling defects forms by any KenGen or Consultant officers who notices the defects and submit for corrective action to the contractor.
- Invite the consultant Employer and contractor for joint inspection in the middle of defects period and invite the consultant, Employer and contractor for joint inspection one month before hand over. Overhaul inspection of the main generation equipment to be done during this event.

The KenGen Operations and Maintenance Division shall determine and arrange for the O&M requirements including staffing and transport. These should be similar to the existing geothermal power plants.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

The objective of the study is to evaluate the appropriateness of the geothermal development plan for Olkaria V as a project financed by Yen loan, by examining the existing exploration reports and relevant materials.

The review of existing exploration reports revealed that the target of the exploration activities was the greater Olkaria region and these reports were not specifically intended for the development of Olkaria V in either the upstream (reservoir) or downstream (power generation facilities) side. Thus the study concentrated on collecting materials and data possessed by KenGen, KPLC and KETRACO which could be utilized for the evaluation of the Olkaria V development plan. Also, additional information collection was attempted by inquiry, site reconnaissance and additional data analysis. The appropriateness of the Olkaria V development plan was examined by integrating all the information collected together with exploration reports of the greater Olkaria region.

The result of examination revealed that, from a viewpoint of geothermal resources assessment, the development of 140 MW in the Olkaria V area would be feasible, since

- Olkaria V is located in the up-flow zone of high temperature fluid (> 300 ^{o}C) and a promising geothermal resource is reserved in the area.
- 60% of the necessary amount of steam has been already been confirmed by the discharge tests of existing wells.
- There is a plan to drill an additional eight (8) production wells and eleven (11) reinjection wells. 140 MW of power generation is found to be feasible by using the existing wells and the additional wells.
- An existing forecasting simulation study shows the sustainability of 140 MW of power generation for 30 years.

At present KenGen has not decided the detailed well operation plan, and the plan will be finalized considering the results of drilling that is currently under way. Thus, as a part of the examination in the current study, a tentative well operation plan was assumed, and a suitable piping plan for steam and brine was devised based on the tentative well operation plan. The construction cost was estimated based on the well operation plan and the piping plan. The plan of plant construction and a plan of transmission connecting Olkaria V and the existing Olkaria IV were devised accordingly. The total project cost and project implementation schedule were worked out. The development plan was then examined for its economic and financial efficiency.

The proposed site for the Olkaria V power plant is the flatland (approximately 250m x 200m) to the west of the proposed wellpad OW-924. Although a long pipeline is needed to bring steam from the production wells, this location has several advantages such as requiring less civil work, no tree felling, and being beside the existing road. The capacity and steam consumption of the power plant are as follows:

Power generation system: single-flash cycle

Steam consumption:	518 t/h x 2 units
Gross output:	77 MW x 2 units
Parasitic load:	7 MW x 2 units
Net output:	70 MW x 2 units

The location of production wells and reinjection wells may be altered and the design of the steamfield will need to be revised during its construction stage depending on the results of production tests of the new wells. In this report, a conceptual design was made based on the development scenario tentatively assumed in the review of the geothermal resource. A 220 kV double circuit transmission line of 5km length will connect the switch yards of Olkaria V and Olkaria IV.

According to the tentative project implementation schedule that was devised assuming the period of the Loan Agreement (L/A) to be late July 2015, it was revealed that the completion date of Olkaria V Unit-1 (70 MW) would be at the end of January 2019, and the completion of Unit-2 would be at the end of April 2019. The costs for construction of pipeline (Lot 1), power generation facilities (Lot 2), transmission line (Lot 3) and steamfield road and environmental rehabilitation (parts of Lot4) were assumed to be the subject of Yen loans.

4.2 RECOMMENDATIONS

As the water from drilled and tested production wells in the Olkaria V area is relatively high in silica, it is imperative to avoid silica scaling from the water separated from steam. The weighted average silica concentration is calculated to be 1,000ppm in the water with the maximum steam separation at the atmospheric pressure. To keep the undersaturation condition in terms amorphous silica (silica scale) for such water, the steam separation temperature shall be set at 180°C or higher (pressure: around 10 bara or higher) and the separated water shall be directly reinjected without cooling. However, the silica concentration in the water is significantly different from well to well. For the utilization of wells discharging water high in silica (wells in the pad OW-915), special care must be taken to avoid scaling. No silica scaling problems have been reported in the production tests of wells in the pad OW-915 (personal communication from a KenGen engineer). This is possibly because of the slow reaction rate of silica polymerization (kinetic effect) and/or the high brine pH (~10) of the wells. In the power plant operation stage, in regards to steam production from the wells on pad OW-915, it is recommendable to use high wellhead pressures, as much as possible, in order to lower the degree of silica oversaturation in the brine from the OW-915 wells with a higher pressure and temperature at the two-phase line up to the separator station in where the brine is diluted by mixing with brines from other wells. In regards to setting the separator temperature (pressure) and designing the reinjection water line, it is desirable to review them for optimization at the stage when the production test data of all the wells required for the project has been obtained

After commissioning plant operation, in order to maintain stable power generation in the future, it is recommended to optimize the development plan by conducting reservoir simulation along the scenario of generation capacity of the power plant, steam mass requirement and well allocations for Olkaria V.

The same cooling option of the power plant is assumed (i.e. surface condenser with wet/dry hybrid cooling tower) as that which is assumed in KenGen's report "Feasibility Study for Development of KenGen’s Geothermal Concession Area in Olkaria Beyond 430 MWe (Revised September 2012)". It aims to increase reinjection by reducing the loss of water through evaporation at the cooling tower. The drawbacks of this cooling option when compared with a conventional direct contact condenser with wet cooling tower are higher capital costs, more maintenance efforts, higher steam consumption, and a larger footprint of the cooling tower. Therefore, the final decision on the cooling option should be made during preparation of the bid documents of the power plant EPC on the basis of the results of the reservoir simulation and detailed study on power plant's heat-mass balance and cooling tower design.

Although it is also important to verify the transient stability as well as the steady-state stability when connecting the generator to the grid, KPLC is performing the power flow analysis and the fault current calculation only and has not practiced transient stability analysis to date. KPLC has recognized the importance of the analysis and has started collecting the required data, however, the prospect of completion of the study is unknown. It is recommended that the transient stability analysis be made prior to the preparation of bidding documents of the power plant EPC of Olkaria V and the results be reflected in the specifications of the generating facilities.