Pre-feasibility report for additional exploratory drilling of 15 wells in NELP-I offshore block KG-DWN-98/2, KG Basin, Andhra Pradesh

Introduction

India's demand for petroleum products is growing at a very rapid rate. Substantial efforts are therefore, necessary to boost the level of exploration activity in the country, so that, new discoveries can be made and the quantum of crude oil and gas production increases significantly in the years to come. Thrust is being given to frontier areas like deep and ultra-deep water offshore areas. NELP-I offshore block **KG-DWN-98/2** located in the east coast of Godavari Delta assumes importance with a string of significant oil & gas discoveries made by ONGC during last 10 years.

The offshore block KG-DWN-98/2 with an area of 7294.6 sq.km. was initially awarded to Cairn Energy India Limited (CEIL) with 100 % PI in the 1st round of NELP bidding in April, 2000. Subsequently, south-eastern part of the block with an area of 2462 sq.km was relinquished in 2004. In March' 2005, ONGC has acquired 90 % of PI and operatorship. From 28.08.2014 onwards ONGC has become 100% PI holder of the block.

Efforts carried out by CEIL & ONGC during last 15 years of exploration/appraisal (Phase-I & Phase-II) drilling, has resulted in a significant oil & gas discoveries in the northern and southern parts of the block. The northern part of the block, covering 3800 sq.km. was declared as '**Northern Discovery Area' (NDA)** with prominent finds/discoveries such as Annapurna, Kanakadurga, Padmavati, **DWN-N-1, A-1, D-1/KT-1, E-1, U-1, W-1, A-2, M-3, M-4 and F-1** with their extensions. The southern part of the block, covering an area of 3494 sq.km was declared as "**Southern Discovery Area" (SDA)** with significant gas discoveries in **UD-1, UD-4 and UD-5.**

To harness the hydrocarbon discoveries made so far in the block, FDP has been finalized and submitted to DGH in Sept'2015 as per the article 2.5.6 of PSC and is under review of MC. A cluster development scenario is envisaged for the monetization of the discoveries so far made in the block.

Further, integrated G & G studies are in progress to add more value to the block. The necessary inputs are in place to execute the development plan after ML grant before exploitation activities begin in the block, in accordance with the time lines given in PSC.

After acquisition of additional 3D seismic data, Controlled Source Electro Magnetic Survey (CSEM) followed by G&G studies. It is proposed to drill additional exploratory/appraisal wells for gaining more leads to the accretion of the hydrocarbon reserves. Additional exploratory / appraisal drilling will further enhance the commerciality of the block and will help in cost effective implementation of the development project with upward revision of hydrocarbon production figures.

So far, CEIL & ONGC had obtained Environmental Clearances for exploratory drilling of 39 wells in the block. The details of the ECs obtained and their status are as given below:

<table>
<tr><th>Sl. no.</th><th>EC No.</th><th>No of locations</th><th>Obtained by</th><th>Remarks</th></tr>
<tr><td>1</td><td>J-11012/2/2001-IA II
dated 15th June’ 2001</td><td>9</td><td>CEIL</td><td rowspan="4">Drilling completed at all the locations</td></tr>
<tr><td>2</td><td>J-11011/18/2004-IA II (I)
dated 8th December’ 2004</td><td>11</td><td>CEIL</td></tr>
<tr><td>3</td><td>J-11011/474/2010-IA II (I)
dated 11th May’ 2011</td><td>2</td><td>ONGC</td></tr>
<tr><td>4</td><td>J-11011/70/2011-IA II (I)
dated 4th September’ 2012</td><td>7</td><td>ONGC</td></tr>
<tr><td>5</td><td>J-11011/189/2013-IA II (I)
dated 24th January’ 2014</td><td>10</td><td>ONGC</td><td>Drilling completed at 3 locations</td></tr>
</table>

Ou of the 39 locations, exploratory drilling at 32 locations have been completed and at remaining seven locations drilling will be taken up during the course of the year.

Geological setting & Stratigraphy

Krishna-Godavari (KG) Basin, a peri-cratonic rift basin along the East Coast of India, is located between 15 to 17.50 N and 80 to 89.50 E. It covers an area of 41,000 sq.km both onshore and offshore and includes the deltas of Krishna and Godavari rivers. The basin comprises of the sediments ranging in age from Lower Permian to Recent. The Krishna-Godavari Basin is characterized by a series of NE-SW trending en-echelon horsts and grabens formed during the Jurassic - Cretaceous break-up between India and Antarctica.

These NE-SW structures overprinted the NW-SE trending Permo-Triassic Pranhita-Godavari Graben. The morpho-tectonic elements of the basin are defined by deep-seated basement controlled fault systems with a series of asymmetric half-grabens and horsts.

The grabens were filled with thick Middle Jurassic to Early Cretaceous clastics. Rifting ceased and widespread Late Cretaceous clastics buried the 'horst and graben' topography. The onset of passive margin progradation towards the south-east commenced during the Late Cretaceous, and paleo-shelf breaks have been recognized in the sub-surface. During the latest Cretaceous to earliest Paleocene, the Indian sub-plate was tilted down towards the south-east. This event was caused by the uplift of north-western India as it drifted northwards over the Deccan "hot spot."

The Krishna-Godavari basin was down-warped so that the gradient from source to basin (toward the east-southeast) was increased. Higher depositional energy of the proto-Krishna-Godavari river system led to an influx of coarse clastics causing vigorous passive margin progradation to the southeast. It has been postulated that this system had coalesced during the Eocene to form a single delta front extending in a SE direction from the current position of the Krishna River.

The two present-day delta promontories became established in their present positions in the late Neogene. With the Tertiary base providing the glide plane, slippages and slides controlled by the instabilities generated by rapid sedimentation at or near shelf edge led to development of growth fault systems in the coastal and offshore areas. The abundance of Tertiary mobile shale enhances the potential for remobilizing sediments later.

The basinal character of the distal offshore is strongly controlled by the lithological and structural attribute of the Tertiary mobile shale formation. Sediment loading caused the subjacent shale mass to squeeze forward and outward on the slope to build the distal delta. Due to plasticity of the over pressured Vadaparru marine shale, the overlying sedimentary sequence, therefore, built up over a relatively unstable substratum. The attendant structural evolution is marked by sequences of major shale diapirism and faulting, resulting in fault bounded mini-basins. Successive mini-basins contain sedimentary fill that is younger down-dip. The shale diapirs started to grow in the offshore area during Miocene and continued up to Pliocene.

Most of the extensional (growth fault system and related roll-over anticlines) and compression (shale diapir and thrust system) structures in KG basin's present day continental slope is related to mobile Vadaparu shale deformation (Sahoo, 2005).

The thick Tertiary passive margin system is the primary focus for the exploration activities in the KG-DWN-98/2 contract area. The overall sequence thickens basin ward, away from the present day coastline. The offshore portion of the Tertiary basin includes depositional systems ranging from shore-face through to deep-water submarine fan sandstones. The primary targets for exploration in the KG-DWN-98/2 permit area are Miocene to Pliocene submarine sands. These sands were sourced from the Krishna and Godavari River system, and deposited on the lower slope in the area of study.

Structuring in the basin is primarily related to the sediment loading and subsequent collapse of the shelf edge, forming genetically linked growth fault and toe thrust pairs. Two main phases of this occurred viz., Late Eocene to Early Miocene; and Late Miocene through to Pliocene, and continue to the present day. The dominant structures in this part of the basin are a major north-east-trending down-to-basin growth fault, the associated large G1, G-2, G-3 and G-4 low-side rollover trend, and the genetically related younger toe thrust complex. These Pliocene listric faults generally have a NNE-SSW trend and typically sole out in the shale below. Stratigraphic trapping is also likely to be important, with traps formed by up dip pinch-out of the linear slope fan channel complexes.

The slope apron system is dominated largely by slump packages composed of deformed hemi pelagic shale and contorted thin bed turbidities, slide blocks and chutes in filled with slope related mudstone, thick and thin bedded, discontinuous turbidities and debris flows. Gullies and constructional channel systems may traverse the disrupted slope apron surface and pass laterally and basin ward into more stable areas where laminated mudstone and sandy mudstones predominate. Local developments of turbidities within these gullied and channeled areas may lead to isolated channel fills of heterogeneous turbidities containing sandstones with interbedded mudstones.

The main depositional elements in this geological setting are incised slope channels, constructional leveed channels, distributary channel complexes and distributary lobes. The intra-slope basin ponding is believed to depended, primarily on the prevalence of following factors:

- Toe-thrusting
- Mud diaparism
- Palaeo-topography of the sea floor
- Sediment supply
- Prevailing eustatic condition

In the KG Basin, two main periods of listric fault toe-thrust detachment occurred during Mid-Late Oligocene and Basal Pliocene to Pleistocene. Both the events led to an increase in sedimentary input and subsequent loading. In both cases, the expected sequence of events starts with an early stage low stand (ponding "fill" episodes) and low stand/high stand ("spill" episodes) at later stages (source – Peter M. Barber, July 2002).

The area where the block KG-DWN-98/2 is located, the startigraphy consists of slope depositions systems and deep water depositional systems. The Pliocene section is generally clay dominated with few deep water channel and fan deposits. Miocene to Eocene consists of deep water clays and sand deposits in the form of basin floor fans and channels. These form exploration targets over basement highs. On the slope Miocene onlaps also form exploration targets. Cretaceous section is available in the rifts as well as around the Basement highs and is expected to contain good quality source rocks and reservoirs as in the nearby nomination acreages.

Project description

In this project it is proposed to drill additional 15 exploratory/appraisal wells based on the leads provided by the latest G&G and CSME studies to further augment hydrocarbon discoveries so far made for cost effective exploitation. Block co-ordinates, co-ordinates of the proposed locations for exploratory drilling and other details of the present project are given in Table Nos: 1-3 respectively. Map showing the proposed locations is given in Fig. No: 1.

Table no.1: Block Co-ordinates

Project Region: Offshore area in KG Basin, Andhra Pradesh						
Block Title: NELP-I Block KG-DWN-98/2						
Block Area (Sq. Km.): 7294.6						
Block Coordinates:						
POOINT	**LATITUDE (N)**			**LONGITUDE (E)**		
J	15	30	00	82	07	00
I	16	10	00	82	07	00
H	16	10	00	82	15	00
G	16	19	50	82	15	13
F1	16	26	03	82	20	20
F	16	26	03	82	24	59
E	16	28	42	82	25	00
D	16	31	42	82	29	58
L	15	30	00	82	30	00
M	15	30	00	82	21	00
N	15	12	00	82	21	00
O	15	12	00	82	26	30
P	14	54	00	82	26	30
Q	14	43	00	82	10	00
R	14	43	00	82	00	00
A	15	29	00	82	00	00

Table no.2: Co-ordinates of the proposed locations

Sl. no	Location Name	X	Y	Bathymetry (m)	Target depth (m)	Nearest distance from the coast (in km)	Well cost estimate
1	**NL-1**	658475.00	1825822.65	530	2000	22	248
2	**NL-2**	653881.00	1823041.00	420	3000	19	368
3	**NL-3**	652512.50	1819697.65	500	2600	20	320
4	**NL-4**	658493.44	1817652.98	848	3500	23	430
5	**NL-5**	654525.00	1812785.15	780	2700	24	332
6	**NL-6**	649450.00	1807522.65	765	2800	28	344
7	**NL-7**	642237.50	1804310.15	675	2800	27	344
8	**NL-8**	655650.00	1803860.15	1070	2300	35	282
9	**NL-9**	641075.00	1799685.15	740	2700	30	332
10	**NL-10**	624700.00	1781747.65	890	2000	39	245
11	**NL-11**	631900.00	1784735.15	948	3200	40	393
12	**NL-12**	657743.23	1793428.23	1240	2400	45	295
13	**NL-13**	626176.00	1763459.00	1380	2500	55	307
14	**NL-14**	620373.00	1741936.00	1900	5300	76	650
15	**NL-15**	639490.00	1742378.00	2260	7000	80	860

Table no.3: Project details

No. of wells to be drilled	**15**
Total project cost (Rs. crores)	**5750**
Duration of drilling	**45-60 days per well**
Water depth (m)	**420 to 2260**
Quantity of drilling fluid (m^3).	**700-900**
Quantity of cuttings (m^3).	**300-500**
Quantity of waste water (m^3/D).	**20**
Flaring during production testing.	**2 to 3 days** (Integral flare boom attached with the rig)

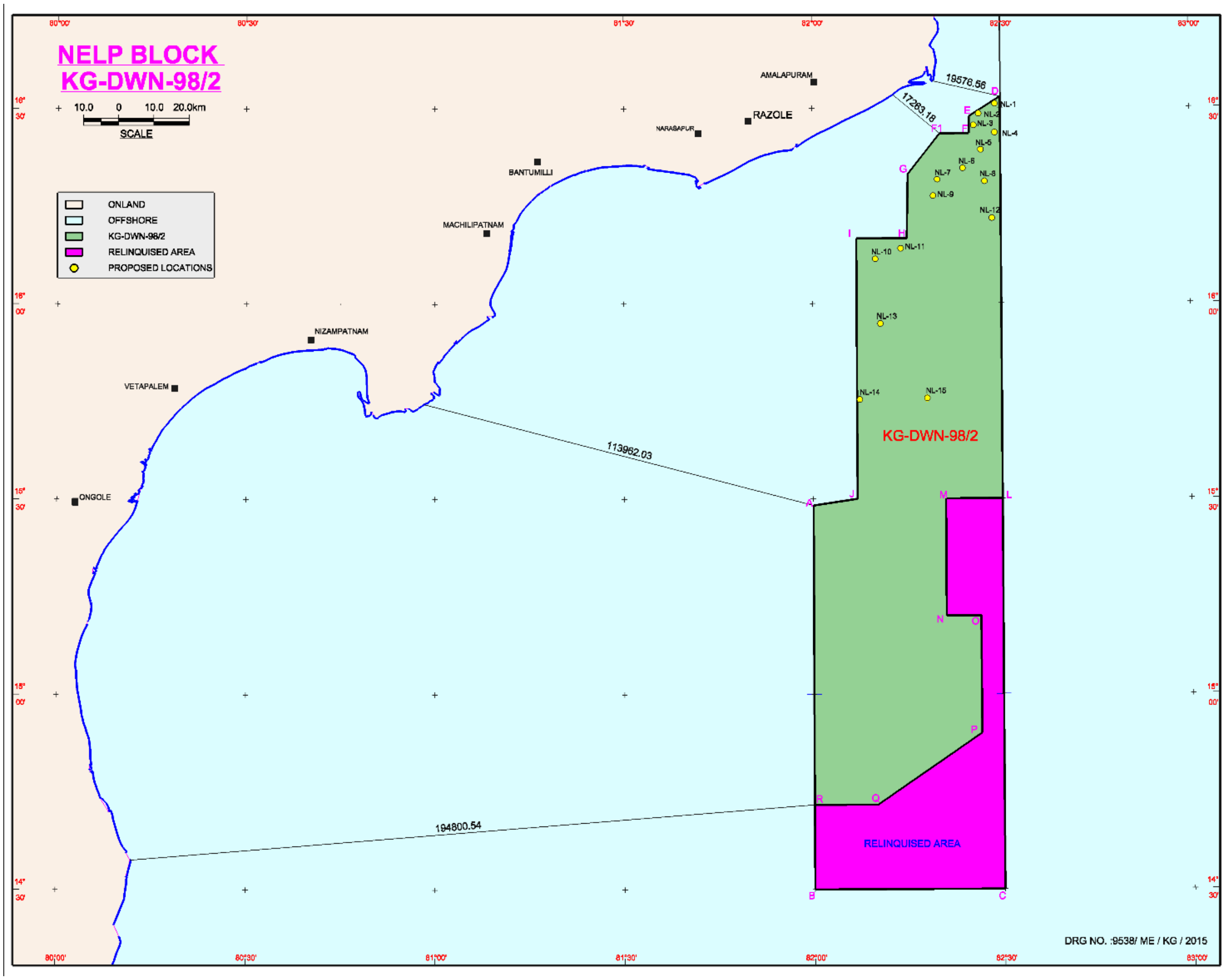

Figure no.1: Location map of block KG-DWN-98/2 showing the proposed locations

Drilling Operations

Drilling in deep waters is done by using drill ship which is a self propelled, dynamically Positioned (DP) vessel (Fig no. 2) with on board integrated drilling facilities. The well is drilled using rotary drilling system that consists of a derrick mounted on the drill floor, at the top of which is mounted a crown block and a hoisting block with a hook. From the swivel Kelly stem is suspended through a square or hexagonal Kelly bush which fits into the rotary table. The rotary table receives the power to drive it from an electric motor. The electric motor rotates the rotary table which passes through the Kelly bush and the rotations are transmitted to the bit. As the drilling progresses, the drill pipe in singles is added to continue the drilling process. At the end of the bit life, the drill pipes are pulled out in stands and stacked on the derrick platform. After changing the bit, the drill string is run back into the hole and further drilling is continued. This process continues till the target depth is reached.

Fig no.2: Typical offshore drillship

Cuttings generated due to the crushing action of the bit, are removed by flushing the well with duplex/triplex mud pumps. The mud from the pump discharge through the rotary hose connected to stationary part of the swivel, the drill string and bit nozzles. The mud coming out of the bit nozzles pushes the cuttings up in the hole and transports them to the surface through the annular space between the drill string and the hole. The mud not only carries away crushed rock from the bottom of the hole, but it also cools the bit as it gets heated due to friction with formation while rotating. The mud not only helps in balancing subsurface formation pressures and also helps in preventing the crumbling or caving of the well bore by forming a mud-cake on the walls.

At the surface, the mud coming out from well along with the cuttings falls in a trough, passes through the solids control equipment i.e. shale shaker, de-sander and de-silter.

These equipment remove the solids of different sizes which get mixed with the mud during the course of drilling. The cleaned mud flows back to the suction tanks to be re-circulated into the well. The drilling mud/fluid circulation is thus a continuous cyclic operation. The properties of the mud such as density, viscosity, yield point, water loss, pH value etc. are continuously tested to ensure that the drilling operations can be sustained without any down hole complications. Sufficient hydrostatic head (mud density) is maintained to prevent any formation fluid contaminating and surfacing.

Drilling is a temporary activity which will continue for about 45-60 days for each well in the block. The rigs are self-contained for all routine jobs. Once the drilling operations are completed, and if sufficient indications of hydrocarbons are noticed while drilling, the well is tested by perforation in the production casing. If the well is found to be a successful hydrocarbon bearing structure, it is sealed off for future development, if any.

Drilling of deep water wells requires specially formulated drilling fluids, to give mud weight (density), fluidity and filter cake characteristics. The drilling muds have several functions like lubrication and cooling of the drill bit, balancing subsurface formation, bringing out the drill cuttings from the well bore, thixotropic property to hold cuttings during non-operations, formation of thin cake to prevent liquid loss along well bore etc. Several additives are mixed into the mud system to give the required properties. Water based mud is initially used. Subsequently Synthetic Oil Base (SOBM) mud is used in the target sections (12-1/4” & 8-1/2”) to avoid hole complications associated with the geological formations, temperature and associated hole stability problems. SOBM provides flat rheology profile in temperature range of 40 to 250^{o} C, which better manages the Effective Circulating Density (ECD) and hydraulics, thereby allowing good hole cleaning. The essential constituents of Synthetic Oil Base Mud are base oil, lime and $CaCl_2$, brine, along with Emulsifier and Wetting agents. Viscosifier used to control fluid loss.

The constituents of WBM & SOBM are given in **Table nos**. **2 & 3**. The special additives and their functions of WBM are shown in **Table no. 4.**

Power generation

The drilling process requires movement of drill bit through the draw works which require power. The power requirement of the drilling rig will be met by using the Diesel Generator sets of 1430 kVA capacity 4 nos. with a diesel consumption of about 8-12 Kl / day. The exhaust stacks of the DG sets are likely to vent off the emissions at the height of approximately 30 m above mean sea level.

Water requirements

The water requirement in a drilling rig is mainly meant for preparation of drilling mud, domestic and wash use. The daily water consumption will be around 30 m^3/d of which 10 m^3/d will be used for mud preparation and 20 m^3/d will be used for domestic purposes including drinking.

Solids removal

The quantity of drill cuttings generated is around 300-500 $m^{3.}$ The rock cuttings and fragments of shale, sand and silt associated with the return drilling fluid during well drilling will be separated using shale shakers and other solids removal equipment like de-sander and de-silter. The recovered mud will be reused while the rejected solids will be collected and discharged into the waste pit.

Drill cuttings and waste residual muds

During drilling operations, approx. 300-500 m^3 per well of wet drill cuttings are expected to be generated from each well depending on the type of formation and depth of drilling. In addition to the cuttings 20 m^3/day of wastewater is likely to be generated during well drilling. The waste residual muds and drill cuttings which contain clay, sand etc. will be diluted and disposed to sea after dilution as per GSR-546 (E) guide lines @ 50 bbls/hr intermittently. .

Testing

Testing facilities will be available at drilling rig for separation of liquid phase and burning of all hydrocarbons during testing. The drill ship will be equipped with integral flare boom for flaring during production testing

Chemical storage

The drilling rig will have normal storage facilities for fuel oil, required chemicals and the necessary tubular and equipment. The storage places will be clearly marked with safe operating facilities and practices.

Manpower

The drilling rig will be operated by approx. 50-60 persons on the rig at any time. The manpower will operate in two shifts with continuous operations on the rig. On board accommodation is available.

Logistics

Crew transfers to and from the drilling rig by helicopter and materials, diesel and chemicals will be transported through offshore supply vessel.

Table no. 4: Ingredients of Water Based Drilling Fluid

Sl. No	Chemicals
1.	Barite
2.	Bentonite
3.	Carboxy Methyl Cellulose
4.	Mud Thinner / Conditioner
5.	Resinated Lignite
6.	Non-Weighted Spotting Fluid
7.	Weighted Spotting Fluid
8.	EP Lube
9.	Drilling Detergent
10.	Caustic Soda
11.	Potassium Chloride
12.	Soda Ash

Table no. 5: Ingredients of Synthetic Oil Base Mud (SOBM).

PRODUCT	Concentration(lb)	Purpose
Asphasol	5.0	Inhibitor
Barite	As required	Weighting Agent
Bentonite	As required	Clay
Calcium carbonate	As required	Loss control Additive
Caustic soda	0.5	pH
Citric acid	As required	pH control
Conquor 303A	As required	Corrosion Inhibitor
Klastop	10.5	Emulsifier
Duovis	1.5	Viscosifier
Glydrill-MC	17.5	Hydrate inhibitor
Guar GUM	As required	viscosifier
KCL	23.5	Inhibitor
MEG	28.0	Hydrate inhibitor
MI-cide	0.3	Biocide
Nacl	56.0	Hydrate inhibitor
PacUL	3.5	Fluid loss control
Polyplus RD	1.5	Encapsulating Polymer

Table no. 6: Special additives and their functions in water-based drilling fluids

S. No.	Chemical Name	Functions
1.	Sodium bicarbonate	Eliminate excess calcium ions due to cement contamination
2.	Sodium chloride	Minimize borehole washout in salt zone
3.	Groundnut shells, mica of cellophane	Minimise loss of drilling mud to formation
4.	Cellulose polymers or starch	Counter thick, sticky filter cake, decrease filter loss to formation
5.	Aluminium stearate	Minimize foaming
6.	Vegetable oil lubricant	Reduce torque and drag on drill string
7.	Pill of oil-based mud spotting fluid	Counter differential pressure sticking of drilling string; Pill is placed down hole opposite contact zone to free pipe