



Multilateral Systems for Deep Water Reservoirs

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Abstract

Norsk Hydro's Troll Olje Field (the oil rim of the giant Troll gas field) has successfully utilized multilateral wells in order to effectively drain the oil reserves from the field using the existing sub-sea template structure. To date, over 20 multilateral wells have been completed. An innovative new multilateral system has been developed that provides mechanical and hydraulic isolation at the multilateral junction without cement, and re-entry capabilities into both the main and lateral well bores. This system also is very mechanically simple to run, utilizing a minimal number of trips to establish the junction and achieve mechanical and hydraulic isolation.

The implementation of multilateral technology has dramatically impacted the ability to produce the oil reserves in the field by decreasing draw down pressures and increasing sweep efficiencies within the reservoir. The enhanced drainage area from additional drainage points also allows a more complete drainage of the reservoir within the constraints of the number of slots available on the sub-sea template. This system also has application in multiple reservoir layers within the same well bore.

This paper will discuss the implementation of the multilateral system, its' operational and financial impact and potential application to other deep-water areas.

Introduction

Multilateral technology has been successfully applied around the world including the deep water environment. One of the best examples of this is the Troll Olje field.

The Troll Olje Field is located approximately 80 km north west of Bergen, in the Norwegian Sector of the North Sea. The water depth is 315 – 340m. The field is divided by two major, curved, north-south trending faults which separate the field into three provinces (**Figure 1**). Troll Olje consists of the two western parts, Troll West Oil Province (TWOP) and Troll West Gas Province (TWGP). The third province is Troll East (gas production)¹.

The Troll Olje oil column is approximately 22 - 26m thick in TWOP and 11 - 13m thick in TWGP. The

combined development is estimated to recover a total of 1.33 billion barrels of oil. Communication between the three areas affects the fluid flow and has an impact on the production strategy of the field

By December 2002, a total of 21 multilateral wells, of which 18 were TAML Level 5 dual lateral ITBS™ junctions, had been drilled and completed on the Troll Olje Field. The field is currently producing ≈ 445,000 bbl/d making it the largest producing oil field in the North Sea. This accounts for more than 13% of Norway's production.

The Success at Troll

The multilateral well concept has been introduced on Troll Olje primarily to increase the total drainage area from the existing sub-sea template structures. New horizontal producers are continuously being drilled to recover reserves from the relatively thin oil legs before gas production induces oil column movements.

Troll was the first deepwater development to successfully utilize Multilateral Technology². These installations were successful although operationally complex. Through the application of lessons learned and improvements to the system, installation times were dramatically improved. However, it was felt that installations still took too long, especially for expensive, hostile operating areas. In addition, there were several system capability issues to resolve. This resulted in the development of the ITBS™.

While exploring operational improvements to the legacy system, Norsk-Hydro and Sperry-Sun decided to jointly develop a new system that would incorporate the features and benefits necessary to properly develop the Troll field. The new system incorporates many of the design features from existing, proven systems as well as lessons learned from previous operations³. The system was developed in response to a need for:

- Reducing installation time in comparison to the early Troll Olje installations.
- Hydraulically isolating the window junction.
- Avoiding the use of the resin treatments as in previous systems

- Mechanically tying-back the lateral liner to the main casing string
- Optimizing the flow area of each producing string
- Minimizing the number of steps/components to complete the junction

Many of these same benefits are applicable to other deepwater developments around the world

System Description

The ITBS™ system (**Fig. 2**) was designed to utilize a modified RMLS™ pre-milled window and drilling whip-stock to facilitate casing exit.³ The permanently installed deflector is retained in place by the standard nipple profile (the Sperry-Sun latch system utilized in many multilateral systems). The deflector contains an internal sealing element to accept the polished stinger of the flexible hanger. The lateral leg of the flexible hanger is designed to bend over the junction allowing the main bore stinger to enter the deflector and seal-off creating a mechanical and hydraulic seal between the lateral and main-bore.

A Y-block assembly above the flexible hanger ensures re-entry tools travel through the main-bore leg of the flexible hanger. Lateral re-entry is accomplished by setting a tubing exit whip-stock in the internal landing profile. This tool is designed to guide the bull nose of the service tool into the lateral. Re-entry tools can be run on either coil tubing or wireline.

The initial system specifications are:

- 9-5/8 -in., 47 lb/ft casing
- 8-1/2 -in. lateral well-bore drill-out
- 7-in. lateral liner
- 1,000 psi pressure rating (burst/collapse)
- 4-3/4-in. bore equivalent flow area through each leg
- Maximum tool size for through tubing intervention: 3-3/8 inches.

Early Operations

This tool was developed and implemented in less than 11 months. As to be expected there were some teething problems in the first several installations, but overall the program has been an operational success. Lessons learned through the early wells have been applied to later installations with the result being an improvement in efficiency and capability. Several improvements to the design and operations sequences have created a very robust system with a very consistent track record. To date there have been 18 dual ITBS™ systems installed.

Installation Successes

The initial objectives for the dual ITBS™ development were achieved:

- Reduction in installation time to less than six days from 14 days.
- Increased production figures.
- Hydraulic and mechanical seals for junction isolation to prevent potential sand production.
- Simple and robust installation process with no steel milling involved.
- Optimisation of flow area.
- Access to both mainbore and lateral leg.
- Ability to plug either mainbore or lateral above the junction.

The average installation time for the dual lateral ITBS™ is 5.23 days (**Figure 3**).

The First Level 5 Tri-lateral

The continuing need for greater drainage and production in the shortest amount of time is driver for the installation of a three-branched system (**Figure 4**). The trilateral objectives encompass all of the objectives outlined above except that the estimate for the installation time, to account for additional phases associated with the lower junction, was changed to seven days. Production figures also had to reflect the additional drainage capability and justify the project. Well 31/2-X-13, was chosen for installation of the world's first TAML Level 5 trilateral well.

In order to provide two exits, the existing ITBS™ technology was modified by incorporating two premilled, aluminium-wrapped 9-5/8-in. window joints as components of a tapered 10 3/4-in. x 9 5/8-in. liner string. A Drillable Alignment Bushing, a 60cm slotted aluminium sleeve, is incorporated into the window joint and aligned to the window. The orienting key sub of the inner string engages the slot and aligns the inner string to the direction of the window. The key sub in turn is aligned to an MWD tool below it and is the means by which the window orientation is determined.

Most of the horizontal wells in the Troll Olje Field have been drilled 0.5m to 1m above the OWC in order to optimise the drainage. To allow the laterals to be drilled out highside and still reach the optimum possible TVD by maintaining as much of the oil column as possible, the unique decision was taken to land the horizontal section of the well 1m below the OWC. Landing below the OWC has been important as the geometry of the well bore, when drilling the first 10m of the lateral, is designed as a build with a constant dogleg of 2.5°/30m before leveling off at the desired TVD. Optimal field drainage required that the longest branch was drilled to the south of the mainbore, i.e. exiting the mainbore to the right. As the upper junction would have the aid of the alignment crossover no restrictions were placed on the length of section with regards to having to pull out of hole again. The lower branch was to be drilled to the north therefore

exiting the mainbore to the left (**Figure 5.**).

The 8-1/2-in. mainbore section was drilled horizontally using a rotary steerable system. The mainbore section was completed with a dual string of 6-5/8-in. and 5 1/2-in. screens. The screens were landed using a setting sleeve and PBR (no hanger or packer is required at this stage).

The second phase of the ITBS™ trilateral operation was to install the lower drilling whipstock and mill out the aluminium window sleeve in preparation for drilling the lower lateral, Y2H. A dedicated clean-up run was performed prior to whipstock installation in light of recent debris/junk concerns.

The whipstock was run bolted to the window mill and oriented past the upper latch coupling to avoid inadvertent latch-in. The whipstock was installed and oriented toward the window by engaging into the lower 9 5/8-in. latch coupling of the liner. The mills were then sheared free of the whipstock, and the aluminium sleeve was milled to open the lower window exit. After pulling out with the milling assembly, the Y2H lower lateral bore was drilled with a rotary steerable system and the lateral left open ready to receive the sand screens and the lower ITBS™ Flexible Junction assembly.

The third phase of the ITBS™ trilateral installation consisted of four sub operations:

1. The retrieval of the ITBS™ drilling whipstock by using a conventional fishing spear deployed and inserted in the hollow bore of the whipstock. The whipstock was simply pulled free of the coupling engagement and recovered to surface.
2. Wash and brush both latch coupling areas with a junk basket/brush assembly prior to the lower deflector installation.
3. The installation of the lower ITBS™ deflector and seal stem assembly. In this way, the deflector is aligned to the window in a similar fashion to the whipstock. The well was considered to be in a prepared condition to receive the sand screens for the Y2H lateral.
4. The installation of the ITBS™ flexible junction together with a dual string of 6 5/8-in. and 5 1/2-in. screens. The operation took place without the mechanical aid of the slot guide because there was no 10 3/4-in. x 9 5/8-in. alignment crossover.

The screens and lower flexible junction were landed successfully and, by simultaneously stinging into the deflector, created a common flow path between the mainbore and lateral section. The running tool was released to leave a PBR (no hanger or packer) ready to

receive the upper seal stem assembly.

The fourth phase in the trilateral operation was to install the upper drilling whipstock and mill out the aluminium window, in preparation for drilling the upper lateral Y3H. The whipstock was run in a similar fashion to the lower whipstock installation.

After pulling out with the milling assembly, the Y3H upper lateral bore was drilled with a rotary steerable system and the lateral left open ready to receive the sand screens and the upper ITBS™ flexible junction assembly.

The fifth phase of the ITBS™ trilateral installation consisted of operations similar to those described above in the third phase (Steps 1-4)

A middle completion consisting of isolation valve (acting as a downhole barrier to allow for BOP removal), packer, slips, and PBR was installed by stinging into the PBR above the flexible junction. The horizontal Xmas tree was installed and the BOP re-run prior to installation of the upper completion.

Total time attributed to ITBS™ installation, calculated by Norsk Hydro, amounted to 7.2 days. Excluding lost time, the direct ITBS™ operations were completed in 5 days; associated operations were completed in 2.1 days and lost time amounted to 4 hours.

Results

The X-13 well currently produces 22,000 bbls/d from the longest total production screen section in the Troll field (6580m). The draw down of 0.5 bars is lower than that in traditional horizontal wells, delaying gas break through,

The project has fulfilled its objectives and is regarded as a major success and on the strength of this success at least two more trilateral wells are planned and a suitable candidate area to install a quad-lateral has been identified (31/2 - I-13).

Development of Troll Olje will eventually involve the drilling of over thirty two multilateral wells, which will contribute to additional reserves in the region of 75 million barrels of oil. The multilateral solution will recover more oil from the four-well template than conventional monobores due to the greater density of wells that can be placed in the low permeability sands. Greater well density creates better drainage and makes it economic to drain sands that have a permeability of as low as 100 millidarcy.

Applications in other Deep Water Areas

Where does this lead for other deep water areas? Troll

is somewhat unique as a deep water development in that the reservoir properties allow for the use of screens-only as a method of sand control. Other deep water areas around the world will need to have more extensive sand-control methods including gravel-packing. This system can readily be adapted to allow for gravel-packing the main-bore and the laterals. Expandable sand screens are also an option. However the need for extensive sand control may be mitigated by the drainage architecture. Extensive drainage areas allow for lower draw-downs. This not only helps with coning, but also decreases the fluid velocities that create sand problems.

This reservoir drainage capability is where the real value is. It is possible to place reservoir drainage patterns much closer than was previously considered economical or practical. It is also possible to access secondary, less prolific targets in the same well bore. This can either accelerate production or maintain a more even production profile for a given area, making some marginal fields economic (Lowering the hurdle rate)

Future Developments

But this is just the tip of the iceberg. Multilateral Technology is ever expanding in its' scope and capabilities. Current systems have broad applications, but a new generation of MLT is emerging that will broaden the horizons even further. Multilateral wells incorporating intelligent completions and expandable tubulars are just a few of examples of the synergy that will take place in the wells of the future.

Conclusions

Norsk-Hydro has been successful because of their innovative nature and recognition of the rewards of implementing this technology. But, there are many other places around the world that have potential use for the ITBS™ system as well as other emerging MLT technologies. Frontier areas such as other North Sea fields, West Africa, Brazil, the Caspian, the East Coast of Canada, and the Gulf of Mexico — all can benefit from the application of this system. In fact, any area that has expensive rig rates, facilities costs, or other high capital costs associated should examine the impact that the application of MLT has on their field development plans.

Norsk-Hydro is planning to continue the development of the oil rim in the Troll Olje field with a total of 20 additional ITBS™ system installations. This program demonstrates the large financial impact on this and other deepwater developments.

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Nomenclature

ITBS™ = *Isolated Tie-Back System*

RMLS™ = *Retrievable MultiLateral System*

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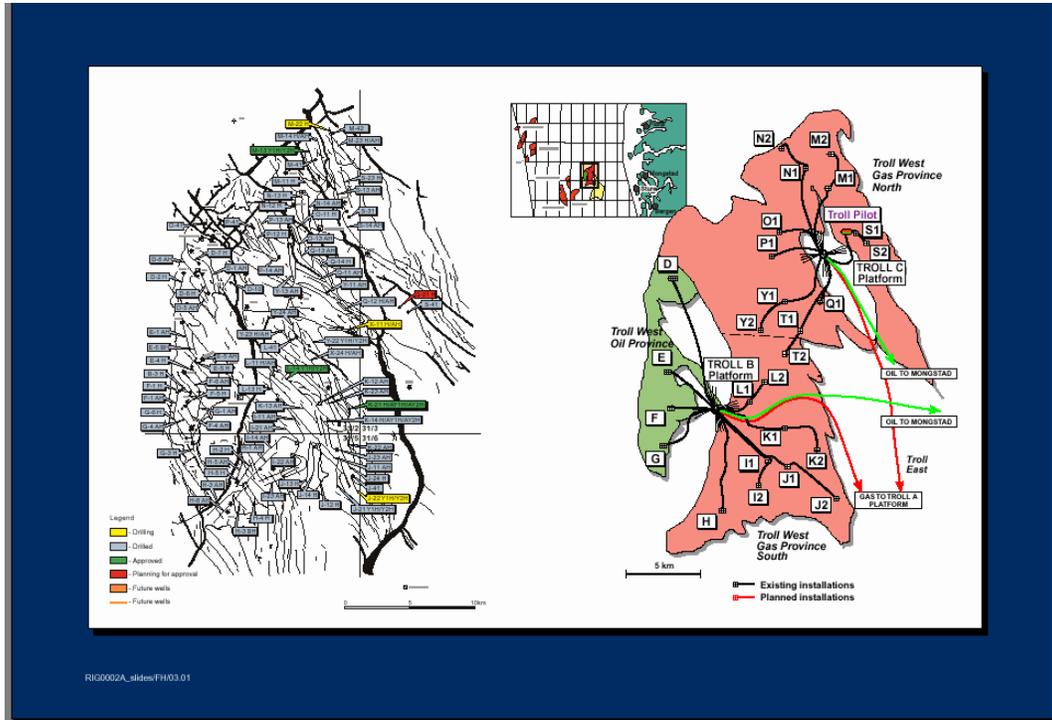


Figure 1. Troll Olje

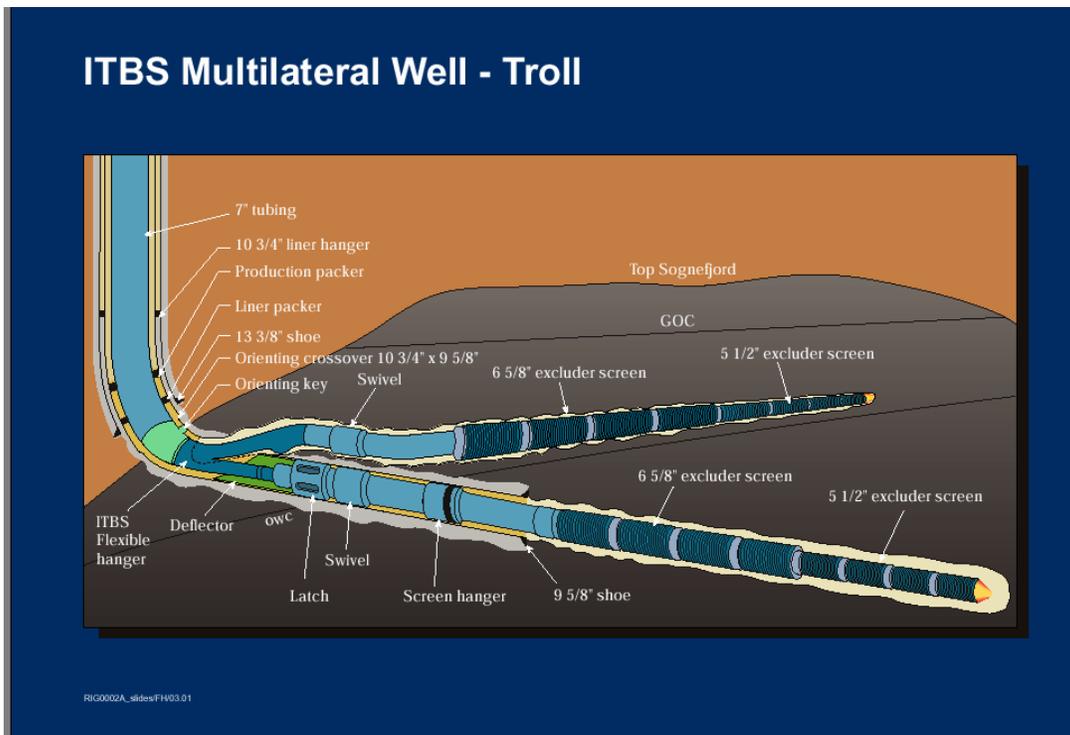


Figure 2. ITBS™ Installation

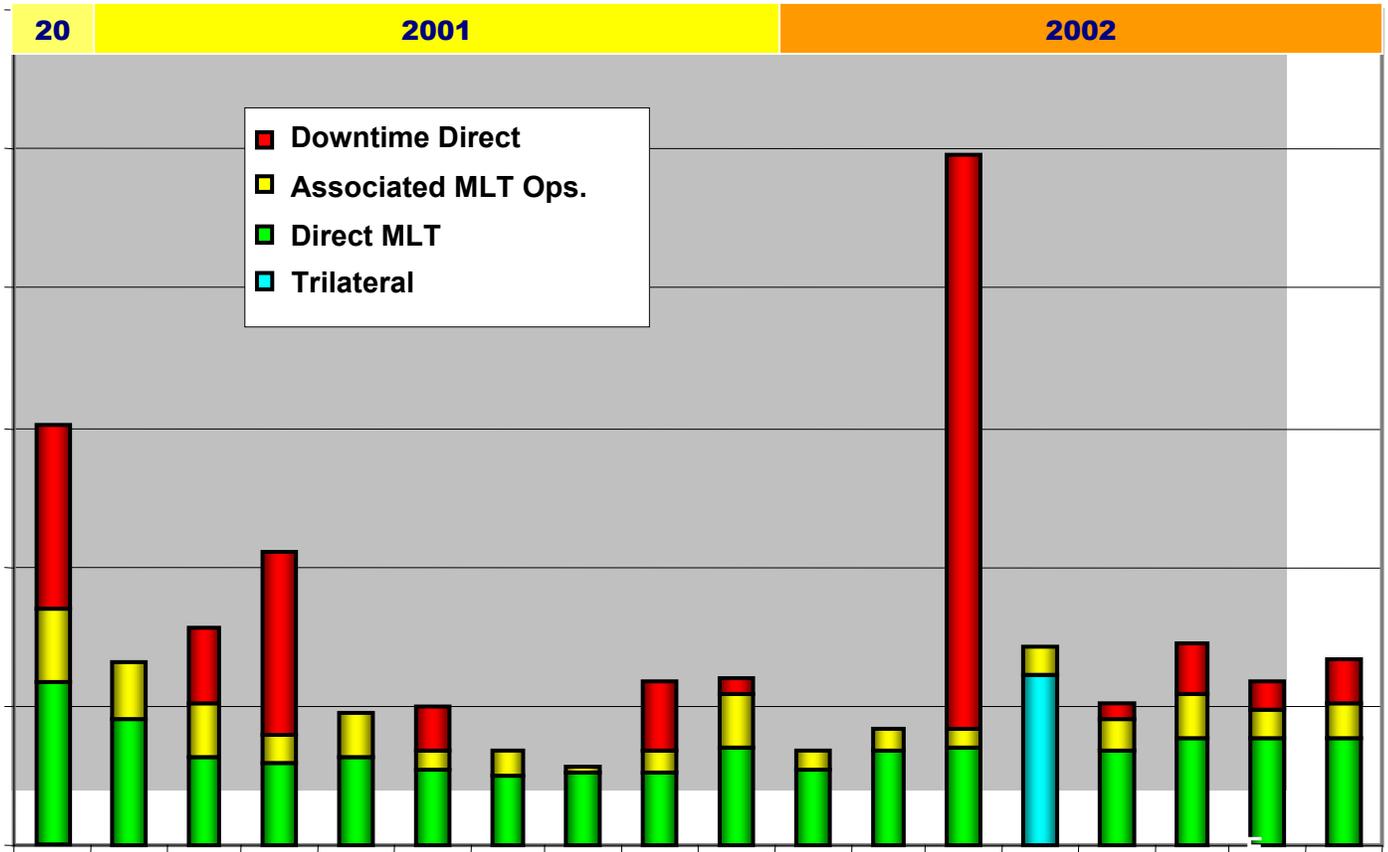


Figure 3. ITBS™ Installation Times

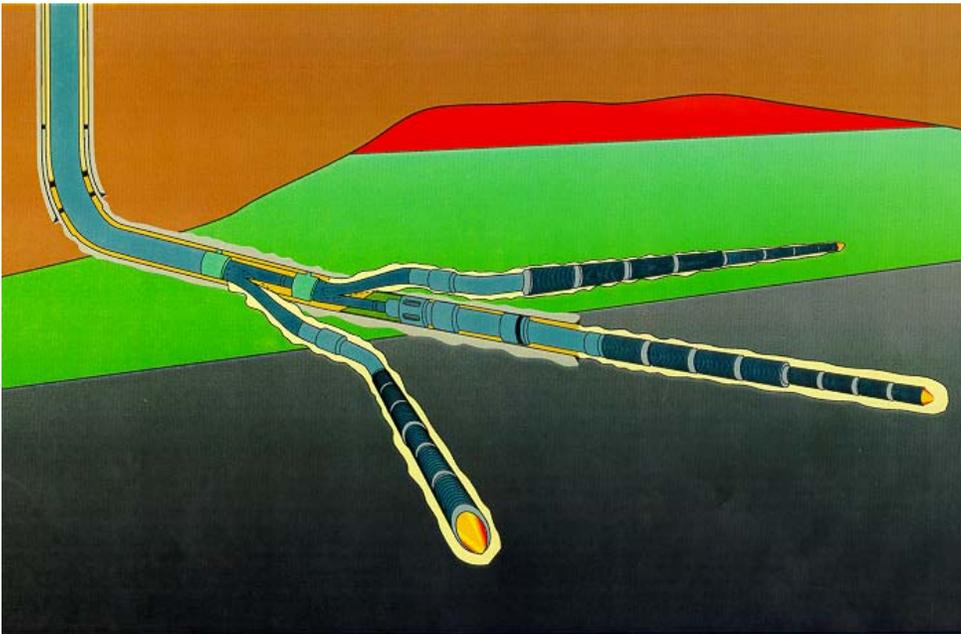


Figure 4. ITBS™ Triple Lateral

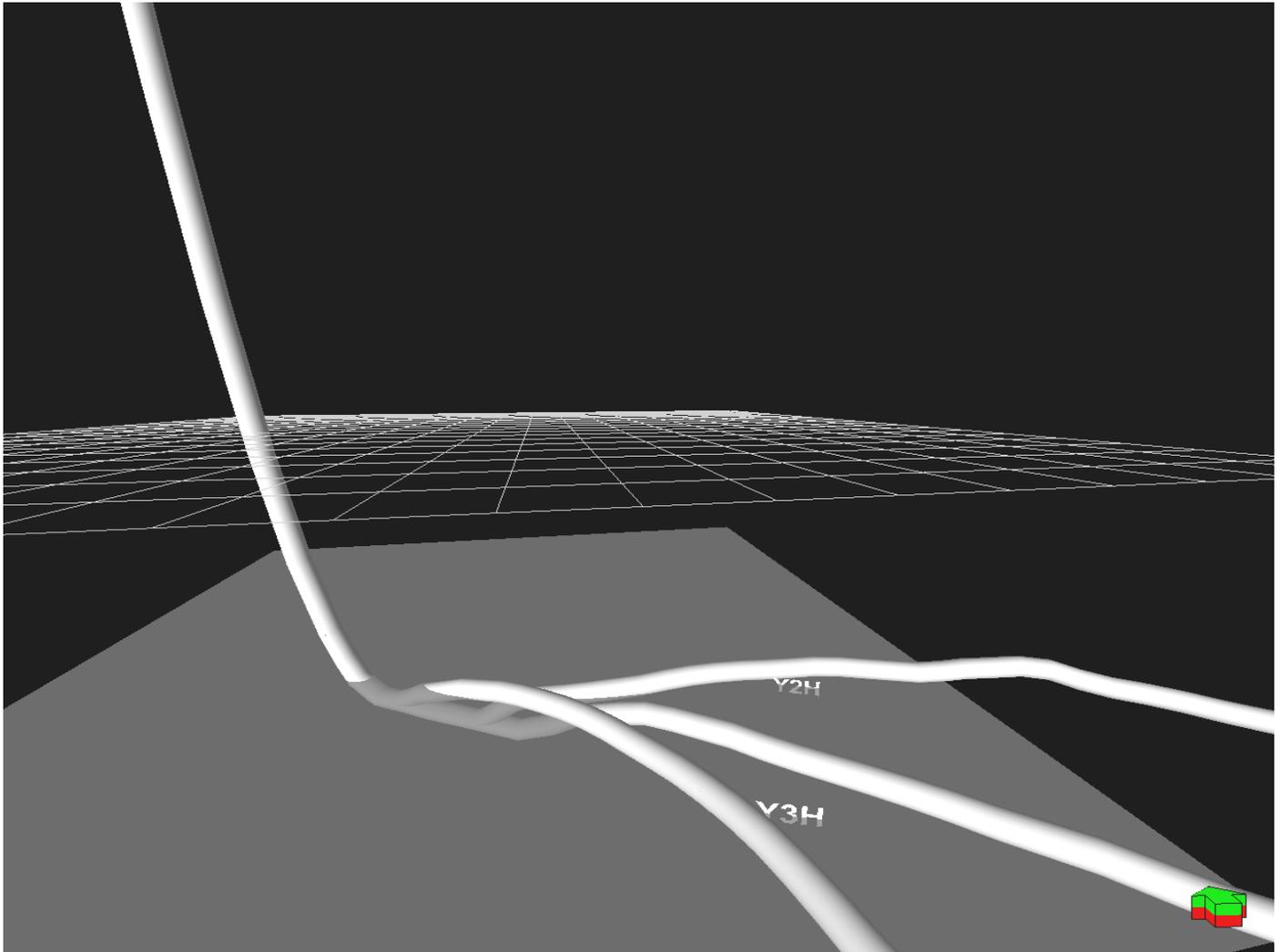


Figure 5. Geometry of ITBS Triple Lateral in Relation to GOC and GWC