from logging runs, including overlapping surveys, are entered and stored in the systems database. The definitive wellbore is finally created by specifying proximity calculation and travelling cylinder plots. 3D views to/from depths for each survey section can be performed in order to eventually decide on a definitive and wellbore position and its final positional uncertainty. Once the final survey has been loaded, it is locked, thus ensuring the integrity of the database for anti-collision analysis or future side-tracks and new well drillings thereafter.

When the drilling is underway, a current drilling on real-time trend feed from measuring- and logging-while-drilling tools (MWD, LWD) can be analysed with the so-called project–ahead functionality in order to determine whether drilling corrective action on course is needed. If a correction is required, a revised trajectory is usually calculated by the drilling engineer based upon one of the selected modes 'return to plan', 'nudge/steer or 'project to target' definitions. Projections, including positional uncertainty, are at this stage visualized in 3D viewers and can be compared to the drillers' target or the earth model from the G&G suite for clarity and decision-taking purposes. All projections at this stage should be saved for quality-control (QC) purposes for later engineering analysis and decision-taking on the rig.

Ideally, the deepening progress of the actual wellbore can be interactively monitored in the 3D viewer and continuously compared to the planned wellbore and other wells in the vicinity. Thus, geological surfaces, casings, positions of uncertainty and drillers' targets are incorporated in the 3D viewer. The data should be written in electronic HTML format, allowing interactive viewing in a standard Web browser by other groups of researchers who can then remotely log into the database. All visualisations and calculations ought to be documented by an advanced well-planning software package through an extensive set of pre-defined plot and report templates. Users should be able to define plots and reports that can be saved and their settings later re-used. Customizable plan section, travelling cylinder, 3D and survey comparison plots should be standard by the majority of the advanced drilling planning software tools.

Bottom-Hole-Assembly Design

One of the first steps in drilling engineering is to validate the selected well trajectory by analysing the well bore profile mechanically and dynamically including the Bottom Hole Assembly (BHA). This helps to ensure that the drilling can actually achieve its objectives without drill string failure, injuries to people and loss of rig time. For this task the Torque (TQ) & Drag optimization and analysis software package is typically used by the drilling planning engineer in order to model all types of Bottom-Hole drilling Assemblies (BHA), casing and completion strings with respect to their suitability (Fig 4.2.12). This design phase provides a clear overview of the mechanical performance of the tools and the suitable wellbore trajectory and geometry, which will influence project budget. A pick & choose BHA string constructor is embedded in these engineering packages allowing complex BHA's to be quickly constructed by rapidly filtering through and selecting from extensive catalogues of industry supplied drilling equipment. The PIs should always consider the complexity of the calculation made by the engineer to take decisions or make suggestions to optimize resources while keeping high performance and quality. The software allows the engineer to create virtual simulations of using different tools and geosteering technologies and find the most suitable application targeting performance and cost.

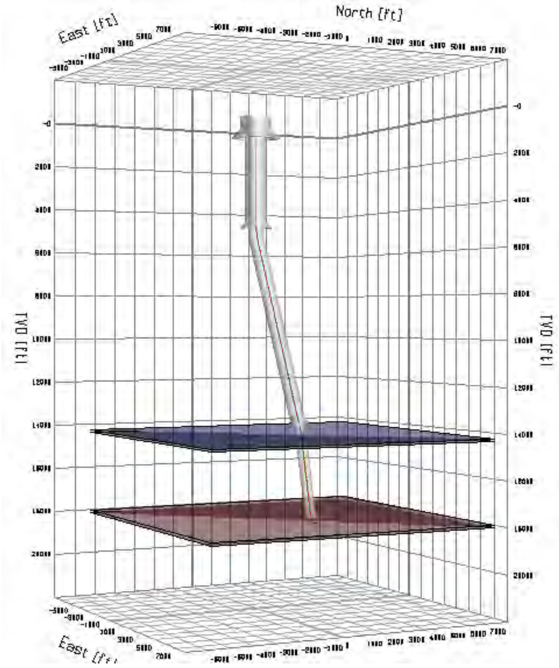

Fig. 4.2.12: Casing scheme with 3D well profile and geologic targets in Monte Civitello project in Italy

Often a customizable material selector user interface allows new grades of steel to be incorporated into the drill assembly. The functionality of API (American Petroleum Institute) rotary shouldered drill pipe as well as the most common API casing connections should be pre-loaded in the software, which is capable of being individually extended by the user. This allows the calculation of connection thread properties and connection strength of customized thread connections. BHAs that have been created in past projects preserve selected catalogues for future re-use, as well as new industry catalogues, which can be added upon availability. The planning engineer should be able to generate a customizable graphical view in order to combine mechanical properties and physical dimension plots.

BHAs must not only be analysed for their mechanical suitability, but as well for predicting their directional behaviour. Soft -& stiff string analysis options allow calculating all forces acting upon the BHA during the drilling process, including torque, drag, stresses and side forces (Fig. 4.2.13). The calculated loads are compared to buckling, string yield and rig operating limits, and the results presented to the drilling engineer using a 'traffic light' approach for quick identification of potentially hazardous drilling conditions.

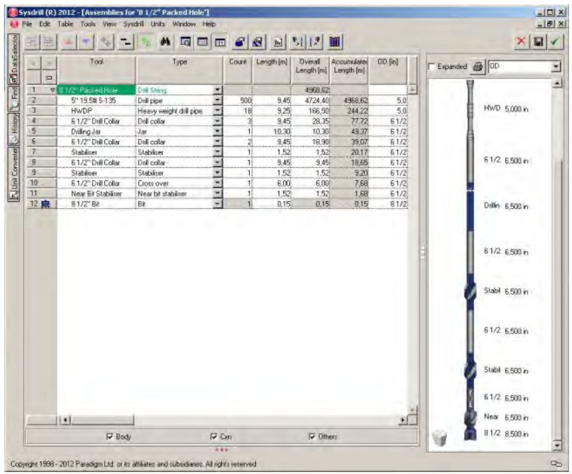

Fig. 4.2.13: BHA builder with Sysdrill well planning and engineering software suite

User-defined operating modes, like reaming, sliding, steering or rotary can be incorporated in the calculation, allowing forward-modelling of the drilling process and generated loads for a given hole-section. In relation to directional prediction of BHAs, a range calculation performs a full drilling dynamic analysis at varying depth and provides a summary of surface results. Hook load and surface torque readings gained from the rig site are entered and displayed in such range graphs. This allows comparing modelled with observed loads during drilling.

The modelling and analysis of axial and torsional friction factor conditions and reduction effects from special torque-reducing drilling tools is a further important output of a TQ & Drag engineering package. Initial friction factors will be obtained from industry reports or by using well data from previously drilled wells. While drilling the well, friction factors are back-calculated, allowing realistic analysis and prediction for sections ahead and future wells in the area to come. By including hydraulic effects, the additional viscous forces and pressure induced stresses can be further included in this advanced analysis.

One of the most valued products of real-time drilling dynamics is the stuck-pipe calculator, which is used to predict a potential stuck point depth during the drilling process. Its analysis is based on measured surface torque, pipe twist, and surface over pull and stretch, taking into consideration hole inclination friction factors and borehole stability conditions. Modelling results are typically presented in traffic light display for ease of reaction to upcoming hazards.

Another important output of the TQ & Drag package is the critical rotary speed analysis. It predicts the rotational speeds at which resonant frequencies may develop. This analysis is taking into account axial, lateral and torsional vibration modes, and highlights rotary speeds to increase chances of avoiding and preventing excessive string damage and BHA failure during drilling.

Drilling hydraulics

The aim of a hydraulics optimization and analysis package is to model downhole circulating pressures during drilling, tripping and running casing in order to enhance bit hydraulic performance and ensure effective hole-cleaning as well as bit cutter cooling.

Basis for hydraulic engineering is the rheology model selection, a software-supported fluid builder device, which allows accurate definition of fluid properties for use in all subsequent hydraulic engineering calculations.

Properties of selected drilling fluids are typically stored in catalogues for re-use in other analysis models. A rheology modelling tool, for example, can analyse drilling fluids and automatically selects the most suitable rheology model based upon viscometer readings. Power Law, Bingham Plastic, Herschel Bulkley & Robertson Stiff models are supported by most hydraulic packages.

Swab/surge and equivalent circulating density (ECD) analysis are performed to reduce the risk of formation breakdown or swab-induced influxes during tripping operation and drilling. Drill string geometries and cuttings concentration in the mud column are equally considered in the ECD calculation for defining the operable mud window. Cuttings transport ratio and annular critical velocities are additional outputs of the model.

Most hydraulic software packages feature a fluid temperature modelling functionality, which provides a quasi-steady state temperature model, incorporating an advanced compositional density and HPHT rheology model. This allows to simulating a number of drilling scenarios, i.e. complex geothermal gradients, horizontal wells and dual-gradient mud systems. This functionality is, in particular, required for an accurate prediction of ECDs, and equivalent downhole mud density as well as rheology under high-pressure, high-temperature (HP/HT) conditions.

As an output, the hydraulic software package includes several modes of optimization, including pump pressure,