Drilling Process & Design Fundamentals

Preview

In this topic the student is introduced to the milestone activities associated with planning for and executing a well construction programme. They will also discover in more detail the roles and responsibilities of core personnel required to plan and execute a well. Different organisational structures to deliver a well are also discussed. In addition, the student learns about generic objectives for a well and what specific information is required to allow comprehensive well planning.

Activities Timeline

Generic Activities

The time required to plan and execute a well construction programme is dependent on many variables including sub-surface complexity, location and type of well. For any well, however, there are common activities which must be addressed to enable comprehensive planning and operational control. For the purposes of this topic we will assume a single well, drilled from a semi-submersible rig. The main activities are:

- Receipt of well planning request / well objectives;
- Allocation of engineering / operational resources;
- Review of special considerations (licence requirements, physical restrictions);
- Well design;
- Government/legislative requirements;
- Sourcing of materials and services including rig;
- Site survey;
- Operational plan;
- Risk identification and mitigation;
- Time /cost generation;
- Pre-operational review;
- Operational phase;
- Post well activities.

While it would be ideal if the activities shown above could be laid out in an ordered sequence it is more often the case that many of the activities occur in parallel. Also it is common for plans to evolve and change as operational definition is refined. In particular the generation of the time/cost estimate does not tend to be a one off event. Invariably costs are required at an early stage where little detailed planning or review has been performed. Hence accuracy of the estimate develops throughout the planning phase and different classes of estimate are often provided dependent on position on the planning/execution timeline.

The main activities listed above are discussed in more detail throughout this module but there follows a summary of the important aspects of each activity and what deliverables might be expected.

Activity Descriptions

Well Planning Request / Well Objectives

The main purpose of a well planning request is to provide the agreed basis for design. This document should form the start point for the planning process and should be referred back to throughout the planning and execution phases to ensure that all decisions take into account the original basis for the well.

Ideally the request should be a formal document signed off by the appropriate levels of authority in both the requesting and executing organisations.

Who generates the final, formally agreed request is not necessarily important. It may be that the party responsible for well design compiles the request after discussions with the requestor (or 'Client'). Perhaps the Client prepares the document. What is important, however, is that the request is jointly reviewed and accepted.

An integral part of the request document should be a prioritised list of objectives for the well. In both the planning and operational phases of a well, decisions and compromises may be required and a clear understanding of the priorities of the well will help to make the appropriate choices. The identification of objectives also provides the basis for performance evaluation at the completion of the well.

Allocation of Engineering/Operational Resources

No well can be planned and drilled without the allocation of the required skills to turn a request into reality. Many skills and talents are required but probably the most important key to success is to ensure that clear accountability is assigned for delivery of the well.

Typically the core resources required to deliver a well would include the following:

- Well Operations Supervision – onshore and offshore;
- Well Design Engineering;
- Well Operations Engineering;
- Welltest/Completions Design Engineering;
- Welltest/Completions Operations Engineering.

Dependent on scale and maturity of operations the roles can be combined or indeed may require multiple positions to fulfil the plan. The above roles could be considered core within a well construction organisation. There are, however, many other roles which support delivery of a well:

- Contracts preparation and negotiation;
- Environmental preparation and monitoring;
- Materials purchase;

- Audit and quality control of suppliers;
- Invoice processing;
- Health and safety expertise;
- Cost management;
- Marine specialisation;
- Administrative and technical support;
- Logistics and transport.

The requirements for resources vary dependent on the current stage in the delivery process. It is vital to have a clear plan for timely access to resources.

Review of Special Considerations

Once aware of a possible well a review of any special considerations should be performed. These could include:

- more stringent notification requirements;
- more stringent environmental requirements (i.e, drilling in an environmentally sensitive area);
- physical constraints (e.g, pipelines, proximity of other installations);
- seasonal access restrictions;
- severe environment (High Pressure High temperature (HPHT), deepwater, high hydrogen Sulphide (H_2S – 'sour').

This initial review allows a quick response if the nature of the well requires greater planning time or resources (or both).

Government/Legislative Requirements

All wells are subject to government approvals in various guises. For the purpose of this module the requirements for the United Kingdom Continental Shelf (UKCS) will be considered. Different countries will have their own requirements.

In general the planning requirements for the UKCS fall into the following categories:

- Consent to drill wells (Department of Trade and Industry);
- Consent to site mobile installations (Department of Transport, Local government and the Regions);
- Well Notification (Health and Safety Executive);

Environmental consent (DTI)

It is illegal to commence operations without the relevant approvals or notifications in place.

Further requirements exist during the operational phase:

- Rig move notification (various);
- Well commencement notification (DTI);

- Weekly Activity Report (HSE);
- Incident reporting (DTI/HSE);

Any material change to design or chemical usage (HSE/DTI).

After the end of operations communications to close out a specific well include:

- Chemical Discharge Records (DTI or agent);
- Rig Emissions Data (DTI or agent);
- Conclusion of work (HSE).

It is also important to be aware of the life cycle approach to well integrity adopted in the UKCS which means that even after a well has been finished a responsibility remains to ensure that the well is fit for its intended purpose until it is finally abandoned.

Well Design

The following questions have to be adequately addressed before a design can be considered to be acceptable:

- Does the design allow for the expected life of the well?
- Are the materials used to construct the well suitable for the fluids and conditions expected throughout the well's life?
- Do any unusual risks to people, plant or the environment result due to the chosen design? If so have alternatives been considered? Has risk been mitigated?
- Has the operability of the design been considered in terms of operational risk or cost? Is the risked cost acceptable? Have both the construction and post completion phases been considered?
- Will the client objectives be met by the design?

The basic requirement for any well design is to meet the client's requirements at an economic cost while maintaining the risk to peoples' health and the environment below acceptable limits.

Sourcing of Materials and Services

The execution of a well programme requires a complex interaction of suppliers, materials and equipment. It may be that all supplies and services have been pre-arranged or that no purchase or supply agreements are in place at all. In any event arrangements must be made to ensure that the required products and services are available. These could include:

- Rig and crew hire including catering;
- Marine transport;
- Anchor Handling Vessels (AHVs);
- Rig move planning, navigation and anchoring equipment;
- All casing and tubulars;
- Wellheads and associated rental equipment;

- Xmas trees;
- Completion components;
- Mud materials and engineering;
- Cement materials and engineering;
- Directional drilling equipment and personnel;
- Measurement While Drilling (MWD) and Logging While Drilling (LWD) equipment and personnel;
- Directional Surveying equipment and personnel;
- Electric line logging equipment and personnel;
- Mud Logging equipment and personnel;
- Solids control equipment and personnel;
- Drill bits;
- Drill string rentals;
- Fishing / abandonment equipment and personnel;
- Casing and tubing handling equipment and personnel;
- Coring equipment and personnel;
- Perforating equipment and personnel;
- Weather forecasting;
- Communications service and equipment;
- Site survey vessel, equipment and personnel.

Prior to commencement of operations a detailed load-out list should be prepared which lists all equipment required for the well. This assists in the callout of the required equipment at the appropriate time during the well and also serves as a check that nothing has been forgotten.

Site Survey

The requirement for a site survey prior to moving a rig onto a location must be determined. If a survey is required then it must be organised and performed in time to allow delivery of, and reaction to, the results.

A site survey is normally performed to acquire data for the following reasons:

- To identify significant debris on the seabed at the intended location;
- To assess the seabed anchor holding characteristics;
- To assess the potential for shallow gas in surface hole.

For the UKCS it is a requirement to notify the DTI at least 28 days prior to the work. For certain areas there may be a seasonal limitation on the shooting of site survey seismic.

The survey itself is carried out from a specialised vessel. Typically the work involves shooting seismic of varying definition over a pre-planned grid which will cover the anchor pattern area and include a more concentrated grid around the

proposed location for shallow gas definition. It is common for a consultant to be hired to provide third party quality assurance during site survey work.

Outcomes from a site survey could include:

- Everything looks fine to anchor up and drill at the location;
- There are indications of shallow gas which may justify moving surface location or adopting special shallow gas procedures;
- Re-selection of anchor type, fluke angle or requirement to reinforce certain anchors with 'piggy backs' (additional anchor run of the main anchor to provide additional hold).

Operational Plan

Ultimately the well design has to be translated into an operational plan, or programme. This provides the approved reference for those charged with constructing the well. Programmes come in many different styles and formats but, typically, should include the following:

- Appropriate approvals and distribution;
- Purpose of well;
- Prioritised objectives for the well;
- Budget data (time and cost);
- Description of the well design (e.g, casing specification and setting depths, directional profile, intended cement coverage)
- Details of expected geology;
- Operational procedure;
- Anticipated hazards, risks, mitigation and contingencies;
- Data acquisition requirements (e.g, logging, sampling);
- Summary of third party programmes such as cementing, drilling fluids and directional plan;
- Contact details.

The format and detail for a programme will also depend on the type of well to be drilled. For example the fortieth well on a development programme may require little more than a one page summary sheet whereas the first High Pressure High Temperature (HPHT) well in a virgin area could warrant the well construction equivalent of War and Peace. In consideration of the detail required it is useful to put yourself in the place of the well-site supervisor charged with delivering the well objectives.

Risk Identification and Mitigation

The management of risk for a well construction process covers Health, Safety and Environment (HS&E) risk and operational risk. The former is concerned with protection of people and the environment the latter with protection of the business plan which incorporates promises for budget and schedule. As HS&E and business cultures have developed there has been a tendency to separate these features in terms of how they are dealt with in the planning process.

Ultimately, however, there appears to be growing consensus that good HSE management means good operational management and vice versa. Therefore, instead of having separate processes to consider HS&E and operational risk, all forms of risk are considered in the one risk management process.

Management of risk is an iterative process. No matter at what stage in the well construction process identification and understanding of risk should never be far from the mind. The processes required involve anything from the awareness of experienced personnel while compiling plans to full blown hazard operability and analysis studies involving multi-disciplined teams, formal processes and many days of scrutiny. The scale, complexity and novelty of the project also should determine the scale, complexity and novelty of the risk management process.

In simple terms there are two important times where full accountability of risk should be formally considered. Firstly at the concept selection phase where the various options are being reviewed; secondly, once the proposed design and operational process have been sufficiently defined to allow in depth review.

Time / Cost Estimate Generation

The time / cost estimate is the cornerstone of a well construction organisations' commitment to the business it serves. It is a promise that the objectives will be delivered at a given cost. The fundamental issue with time/cost estimation is that business plans are often drawn up before the well is sufficiently defined both in terms of objectives and design. This is not such a concern if the well in question is a repeat of previous types but when dealing with new well types it is difficult to give precise information.

Estimates are often classified to reflect the level of uncertainty. Examples of classifications and their likely variance could be:

- Budgetary: +/- 30%
- Appropriation: +/- 10%
- Pre operational: +/- 5%

As with risk management, the estimation process is iterative. The key advice is to ensure that the client group are kept closely in the loop as estimates evolve and no room is left for misunderstanding the current cost situation for the well.

Pre-operational Review

Prior to commencement of operations it is good practice to review the programme with those closely involved with its implementation. This is commonly referred to as a Pre Spud Meeting referring to the common term for commencement of drilling. The main aims are to ensure that the objectives and performance measures for the well are understood, the operational plan and operational risks are communicated and lines of communication are established for the operational phase. The gathering also serves to help build team rapport which can greatly enhance the ultimate performance on the well.

The review is also an opportunity to capture any last minute input which could contribute to improving the plan. Typically meeting attendees would include those responsible creating the well plan, representatives from the client group,

wellsite supervisors, office and wellsite based service providers including rig crew and logistics co-ordinators.

A final opportunity for communication prior to commencement of operations is for the plan to presented to crews at the wellsite either by the well planners or the wellsite supervisors.

Operational Phase

The main requirements during the construction phase are:

- To implement the plan as intended;
- To effectively manage any deviation from the intended plan whatever the cause (e.g, operational problems, geology not as predicted, change in objectives);
- To comply with all reporting requirements internal and external to the organisation;
- To monitor and report current and forecast costs;
- To manage logistics such that all equipment and personnel are available at wellsite as required.

Post Well Activities

Once finished the following activities are required to effectively close out the well construction process:

- Receive and review all third party operational reports;
- Hold 'wash-up' meeting to discuss results;
- Produce final well cost;
- Obtain Client feedback on performance;
- Prepare well history to include:
- Appropriate approvals and distribution;
- Original purpose of well;
- Measure of attainment of objectives;
- Actual vs. planned time and cost data
- Description of the well as built (e.g, casing specification and setting depths, directional profile, cement coverage)
- Details of encountered geology;
- Operational review including recommendations for future work;
- Encountered hazards/risks, mitigation and contingencies employed;
- Breakdown of non productive time during well;
- Data acquisition performed (e.g, logging, sampling);
- Summary of third party reports such as cementing, drilling fluids and directional plan;

- For development wells ensure appropriate handover to production organisation including basis for design, operational limits and monitoring requirements;
- Finalise any external reporting requirements;
- Distribute reports and archive as required.

Although the major portion of the well construction process is complete by this stage it should be remembered that a responsibility for the well remains with the well construction organisation until it is finally abandoned. This should include ensuring that well conditions are monitored to check the well is being operated within the original design basis. It may be a requirement to re-enter the well at some point to repair or change the completion components. There may also be a future utility to act as a host well for a sidetrack to a new sub-surface location. Ultimately the well will be abandoned at the end of its productive life. All of these activities require a similar process to that used for the original well construction.

Time Line

Having identified the main activities associated with the well construction process it would appear straightforward to show a generic timeline incorporating these activities. Unfortunately the variable nature of wells means that for each project a different timeline can be drawn up. In fact it is good practice to draw up a timeline for each well you become involved with to recognise its uniqueness and highlight the planning issues at an early stage. Some of the main variables to consider are as follows:

- Government approval processes, especially environmental, could take times ranging from 4 weeks up to a year or more dependent on license conditions, requirement for full blown consultation etc.;
- Dependent on materials required deliveries could range from zero time because equipment is available in stock to in excess of 12 months;
- Is the well to be drilled in a mature, well serviced location or in a remote location? The provision of support infrastructure may have to be added into the equation.
- Complexity of well design has a major bearing. Is the well a follow on from similar types using the same design or is it brand new, complex and requiring detailed design work?

Organisation

Roles and Responsibilities of Core Personnel

There follows a summary of roles and responsibilities for personnel which could be considered core to a well construction organisation. Note that titles are by no means standard and that there are probably as many ways to organise for well construction as there are oil companies. While the positions may not be replicated, the responsibilities and accountabilities should be addressed in any organisation.

Drilling Manager

The Drilling Manager has overall responsibility for a well construction department or discipline to manage its business objectives within the greater organisation it serves. Specific responsibilities should include:

- Overall accountability for safety of operations;
- Setting, monitoring and reporting of performance measures for the department or discipline;
- Making sure that adequate resources exist to fulfil business plans (e.g, personnel, rigs, equipment);
- Ensuring that processes and procedures exist which comply with local legislative requirements and internal standards;
- Recruitment, personnel development and appraisal;
- Representation of the well construction organisation internally and externally including management of conflict.

Drilling Superintendent

The Drilling Superintendent normally has direct operational responsibility for one or more rigs. Specific responsibilities should include:

- Line management responsibility for safety of operations;
- Accountability for operational performance including cost management;
- Ensuring wells are planned and constructed as per internal processes;
- Operational supervision;
- Line management of operational personnel;
- Performance management of third party services;
- Client, partner and government liaison.

Dependent on the size of the organisation and scope of work the Drilling Manager and Drilling Superintendent roles may merge.

Engineering Manager

The Engineering Manager has responsibility for the engineering discipline and standards within a well construction organisation. The main responsibilities are:

- Maintenance of technical standards and procedures for engineering activities;
- Audit/review/approval of well design proposals;
- Technical overview of special studies and early project activities;
- Maintenance of technical competence for engineering staff;
- Technical development of engineers;
- Knowledge transfer;
- Implementation and management of work systems.

Drilling Engineer

The Drilling Engineer is responsible to the Drilling Superintendent for the safe engineering and design of the wells. Specific responsibilities are:

- Act as the 'Focal Point' for Clients to ensure all well objectives are identified and met;
- Production of safe / achievable design taking into account known or probable hazards;
- Production of detailed Time Cost Estimates for the well, and monitoring well costs to ensure that they are accurate;
- Production of operational programmes;
- Ensuring that the relevant Government Notifications and Approval requests are submitted it time to achieve the planned start date, and confirming that they are in place before the relevant work commences;
- Sourcing all relevant material and services;
- Presentation and participation at relevant planning, pre-spud and wellsite meetings;
- Provision of office based support during operations;
- Timely compilation of well history and ad-hoc reports;
- Final archiving of well material and handover information to production organisation.

As well as having direct accountability to the Drilling Superintendent the Drilling Engineer should also be accountable to the Engineering Manager for the following:

- Providing all necessary information, backup, and input to the engineering audit process;
- Ensuring that any requirements arising from risk assessments, peer reviews, audits etc. are actioned;
- Notification of any potential change to programme which requires review and approval;
- Adherence to approved technical standards and procedures.

Dependent on organisational preference the Drilling Engineering role may be split whereby one engineer (or group) is responsible for the planning phase handing over to another engineer (or group) for the implementation phase. In this case clear demarcation is required to ensure that all responsibilities are assigned and understood.

Completions / Well Test Engineer

Increasingly the role of Completions or Well Test Engineer is differentiated from that of Drilling Engineer especially in larger organisations and for more complex operations. These roles specialise in the activities performed after a well has been drilled. The Completions Engineer deals with the design and installation of the permanent conduit which allows production from or injection to the well. The Well Test Engineer deals with the design and operation of temporary completions

and surface equipment to allow short term production from or injection to a well for evaluation purposes. Because the knowledge and skills required for each role are largely complimentary they are treated as one for the purpose of this module.

Although a specialised role within the overall Well Construction process it should not be surprising that the generic responsibilities are identical to those for the Drilling Engineer as listed above.

Drilling Supervisors

Drilling Supervisors are responsible to the Drilling Superintendent for the safe, cost effective and environmentally aware delivery of the well programme. The position acts as the on site co-ordinator responsible for translation of the overall work programme into the finished product. In particular, they are responsible for:

- Direct liaison with the offshore rig management for all aspects of company business. This includes monitoring safe working practices.
- Liaison with the Drilling Superintendent during operations including formal reporting;
- Monitoring of progress against the well programme and advising the Drilling Superintendent of any deviation from the programme;
- Preparation of specific work instructions for the rig crew;
- Evaluating and reporting on the quality of service and HS&E performance of the rig contractor and service companies;
- Liaison between the installation and the onshore emergency response room in the event of an incident, emergency, or oil spill;
- Specialist advice and guidance to the rig on well control;
- Technical control of third party contractors on the rig;
- Calling off and returning materials and services;
- Controlling costs within their sphere of responsibility;
- Timely compilation of daily and ad-hoc reports for transmission to the base office;
- Supervision and development of wellsite engineers.

To assist in their duties Drilling Supervisors may be supplemented with wellsite engineers and materials / logistics co-ordinators.

Roles and Responsibilities of Support Organisations

Client Group

The client group is invariably the central customer for supply of well construction services so it may seem strange to list them here as support. It is, however, helpful to regard this group as support when considering all inputs required to plan and execute a successful operation. The main requirements from the client group are:

- Supply of well objectives;

- Supply of prognosed geology;
- Determination of expected sub-surface hazards;
- Details of evaluation requirements during the construction process;
- Assistance with site survey planning and evaluation (especially geophysical support);
- Scheduling information;
- Wellsite support for geological evaluation;
- Evaluation of well performance.

Health, Safety and Environmental

In the ever developing area of Health, Safety and the Environmental awareness and compliance, it is important to have access to strong support which ensures that full consideration is given during the planning and execution of well activities. Required areas of support include:

- Development of HS&E policy, plans and goals;
- Promotion of an active HS&E culture;
- Monitoring of HS&E performance, both internal and of suppliers;
- Organisation of audits and investigations;
- Legislation awareness and implementation;
- Emergency and oil spill response.

Fiscal

Control of financial matters is central to any construction project and this is no different for the well construction business. Areas for which support is required include:

- Creation and maintenance of cost control systems;
- Participation in cost estimation;
- Cost tracking and forecasting including final estimate once work complete;
- Financial audit participation and reporting;
- Invoice processing and payment;
- Reconciliation of charged costs to final estimated costs.

Contracts

The materials and services required for a well operation are many and complex. It is important to cover supply with clear contractual arrangements which are understood by both parties (supplier and receiver). Support is required in the following areas:

- Compilation of tender documentation;
- Issuance of bid documents and focal point for related communications;
- Non-technical aspects of bid evaluation;

- Negotiation of terms and conditions;
- Evaluation compilation;
- Ongoing contract administration and interpretation;
- Provision of market information, especially for rigs.

Materials / Logistics

One of the most challenging aspects of delivering a well executed operational programme is to ensure the availability of the correct equipment at the correct time. In order to achieve this support is required as follows:

- Maintenance of stock equipment lists;
- Storage of equipment;
- Assistance in preparation of load out lists;
- Co-ordination of Quality Control / Quality Assurance processes;
- Organisation of transport (land, helicopters, boats);
- Liaison with suppliers for delivery of equipment and personnel.

Organisational Structure

There are as many ways to accommodate the well construction function within a larger Exploration and Production (E&P) organisation as there are companies. With all the potential complexities, however, there are two distinct variants which are useful to appreciate. There is no right or wrong with organisation and it is not the purpose here to recommend one over the other. It should also be recognised that hybrids which mix the features of the two variants are more common than not with varying degrees of success.

The important thing to remember is that good and bad performance is not necessarily differentiated by organisational structure but more by the clarity of accountabilities and the willingness of people to work towards common goals.

The Function Based Organisation

The Function Based Organisation is characterised by the autonomy of management to deliver well construction services. The department will be self-contained to deliver the core requirements and will not report directly to the client group. It will be a self-contained group normally responsible for supply of services to several clients. Policy and systems will be uniformly applied to all work. Members of the department will typically be co-located as a discipline rather than dispersed into client groups. Responsibility for department performance and individual appraisal will lie with the department management. The ability to support development within the department is normally high due to a variety of activities and control over the movements. This organisation may expand to bring in the support roles previously discussed under direct management (except, of course, the client group).

The main justification for this organisation is the power of co-location and common standards to ensure uniform application of best practice. The main criticism is the potential for client's priorities to be overridden by a powerful operational group.

The Imbedded Organisation

The Imbedded Organisation sits within the Client Group's organisation and reports to some level within this group. It is organised to meet the needs of this specific client. Usually well construction and client personnel will be co-located. It will possibly have access to a discipline support group either locally or internationally depending on company size but will not be controlled by the support group. Individual development and appraisal will, at least in some part, be the responsibility of the Client Group organisation. The potential for movement may be lessened due to continuity considerations. This organisation may tend to develop its own specific practices and standards. Support will tend to come from distinct, independent groups. Responsibility for well construction performance will clearly lie with the Client Group's management.

The main justification for the imbedded organisation is the strong alignment with the Client Group's objectives and ease of communication. The main criticism is the potential for being blinkered to a wider appreciation of best practice leading to value loss for the client. Also the company may appear to have a disjointed approach when viewed by outside bodies.

Commonly seen in today's industry is an organisation which attempts to reap the benefits of both organisations discussed above while negating their negative attributes. This can be referred to as The Matrix Organisation. This organisation relies on a central well construction discipline which implants teams into the client's organisation. The discipline is responsible for recruitment and development of personnel and the provision of common standards and procedures. It is also a technical resource for the specific teams. The team itself, however, is accountable to the client group for delivery of business objectives.

As previously stated the purpose here is not to favour any particular organisation. All can work well and all can fail miserably. The key is that the individuals concerned all want to succeed. Although not definitive the following could be considered strong factors in the success of any organisation:

- Objectives and goals are clearly established and achievable;
- All required activities are clearly assigned to specific individuals;
- The rewards of success or failure are shared by all involved from both the well construction and client sides.

Well Definition

Well Objectives

The importance of agreed, prioritised well objectives cannot be overstated. Clear understanding at the outset underpins all decision making during the design and execution of a well and leaves no room for misunderstanding between the Client and the Well Construction group. Note that not all the wishes of the Client are within the control of the construction group. It is, therefore, vital to ensure that objectives are realistic. For example an objective to provide 500 feet of good quality reservoir is not achievable if the good quality reservoir isn't there in the first place. What the construction group can control is provision of a well-bore which allows the extent of reservoir to be evaluated at the location desired.

Elements for a comprehensive list of objectives could include the following:

Depth Requirements

Definition is provided for the depth of the proposed target formations and the total depth of the well. The depths in themselves are not normally enough but should be backed with the Client's intention. For example target depth could be 10000 feet below sea level at prognosed top reservoir. Obviously 'Top Reservoir' is the real intent of the objective. Total depth for the well could be 10,500 feet below sea level, 100 feet below base reservoir. The desire here is to penetrate a certain distance below base reservoir, perhaps to enable full coverage of the reservoir by logging tools. As with all objectives it is important to establish the real intent of the Client.

Target Definition

The Client will normally want the well path to penetrate the target depths at a specific aerial location within a specified target tolerance. This could be one target point at top reservoir or could be made up of several, connected points throughout the reservoir section. A simple example would be to penetrate top reservoir within a circle, radius 250 feet centred on co-ordinates x, y. A couple of important considerations should be assessed when setting target objectives. Firstly it should be recognised that wellbore surveying techniques introduce an inherent error which leads to a definable uncertainty for wellbore position. This uncertainty needs to be subtracted from the Client supplied (or geological) target tolerance to give a drilling target. As long as the well is positioned within the drilling target then it must also be within the geological target. The second consideration is to assess the degree of difficulty in achieving the target. Too tight a tolerance, especially for deeper wells, means tighter operational control and ultimately more cost. Does the Client really want to spend the extra money required to hit the target or are they amenable to relaxation of the target?

Evaluation Requirements

Details for evaluation during the construction phase of the well should be clearly stated. These include Logging While Drilling (LWD), Electric Logging, Mud Logging, Coring and Fluid Sampling requirements. Also to be considered is the requirement for well testing and any associated evaluation requirements during that phase (e.g, production logging).

Schedule

The Client may have particular requirements for the timely delivery of the well. It may be that, for a production well, their overall business plan assumes production from the well from a particular date. If the well is exploratory or appraisal in nature the overall prospect evaluation plan may require the well data to be available by a particular time to enable milestones to be met. There is no point in committing to expectations which are unrealistic so it is for the benefit of all that a sensible delivery time is set.

Well Utility

The ultimate utility for the well requires clear definition. Is the well to be exploratory, appraisal or development? Is it to be a producer or injector? Is it to be abandoned or suspended after initially drilled? For a development well what is

the life requirement for the well? Is there a requirement to alter well utility at a later date after initial objectives are achieved (e.g, convert producer to water injector, plug back lower sections of well, sidetrack to a different location)? The answers to these questions have a direct impact on the design of the well and must be clearly identified up front.

Most specifically for the construction phase of a well's life it is important that objectives are prioritised. This is for the simple reason that things may not go to plan and operational difficulties may require a compromise to objectives. It is better to establish the relative importance of well objectives prior to drilling the well and for 'what if' scenarios to be worked with the Client. In the event of operational difficulties the decision process should be greatly enhanced by prior understanding of what can give under specific circumstances. For example it may be that in the event of deteriorating hole conditions certain logs take precedence. Perhaps coring can be sacrificed to ensure the reservoir section can be completed efficiently. Maybe attainment of total depth would put other objectives at risk.

As a gentle reminder, however, the well construction group should not accept objectives which it does not believe to be deliverable from the onset of planning. This only serves to create disappointment somewhere down the line.

Information Required as Basis for Design

It is important to realise that the Client objectives as discussed above are not in themselves sufficient as a basis for design. The Client's objectives will be focussed on the end results of the well and particularly around the reservoir section. In order to get down there, however, the well construction group requires more detailed information which could, at least in part, be supplied by the Client. This includes:

Surface Location Details

The most obvious impact of surface location is the consequent shape of the well required to reach the Client's target objectives. For an exploration well the surface and target areal locations usually coincide resulting in a vertical well. The same may apply for an appraisal well but, if there is a requirement for future utility as a development well it may be drilled from close to existing appraisal wells or from a location deemed suitable for future production facilities. In this event the well will take on a deviated from vertical shape. Development wells are normally drilled from the location of existing production facilities again resulting in a deviated well to reach intended locations.

The adopted surface location impacts the requirements for a site survey. If being drilled from existing facilities it is unlikely a survey will be required. If from a virgin location then a full survey may be necessary. Ultimately the understanding of anchoring conditions and potential for shallow gas or other sub-surface hazards may require adjustment of the surface location to mitigate the risk.

Subsea well clusters tied back to fixed production facilities provide their own considerations. A balance between cost of subsea pipelines and control systems and the incremental cost of drilling directional wells must be made to determine optimum location.

Geological Prognosis

The client must supply a detailed listing and description of the geological sequence anticipated for the well. This should include the underlying uncertainty associated with geological tops and thicknesses. Types of formation should be specified along with any inherent hazards such as shale instability or unconsolidated sand. Water depth should also be included.

Temperature Profile

Definition of the temperature profile anticipated for the well is necessary. This will impact design of well casing, selection of equipment, cement composition, mud formulation and surface management. The profile may point towards operational difficulties such as hydrates potential in the presence of gas.

Offset data is the most reliable source for temperature profile data (and other location specific data such as pore pressure and formation strength profiles) and the Client can assist in supply of data recorded from previous wells. For an entirely new location empirical predictions can be made but may not be too reliable. It should be remembered that the objectives of drilling from a brand new (or wildcat) location will include definition of parameters required for future design basis.

Pore Pressure Profile

A pore pressure versus depth profile is required as a pre-requisite for casing point selection, and casing design. The character of this profile is largely dependent on the mechanics of deposition and subsequent geological, fluid and chemical activity at the intended location. Obviously the expertise in this area lies with the Client Group who should be able to provide the necessary information. Offset operational experience, however, plays an important part in the refinement of this data and should be considered before finalising the data. For areas with little or no offset data predictive methods exist which require detailed and specialised input.

Formation Strength Profile

Two aspects of formation strength are primarily required as a basis for design. Firstly the maximum pressure the formation can withstand before failing in the tensile mode and secondly the minimum pressure required to prevent failure in the shear mode. Failure in the tensile mode leads to lost circulation and in the shear mode leads to wellbore instability. The determination of formation mechanical properties is worthy of a degree course in its own right. It is probably fair to say that refinement is normally a direct result of operational experience. Log data, core samples and operational experience all feed into the definition of wellbore stability limits.

Figure 1 shows a schematic representation of prognosed lithology, pore pressure and formation strength against depth. This becomes the key document for subsequent design activities. Getting this right provides the foundation for successful design and as such extreme care must be taken in the production of the source data.

Anticipated Reservoir Fluids

The Client should supply details of anticipated reservoir fluids. This includes:

- Fluid type (e.g, oil, gas, condensate);
- Fluid density;
- Contaminants and concentrations (e.g, H_2S, CO_2);
- Predicted production rates.

The fluid type, composition and rate influences design in many ways which include:

- Metallurgy selection;
- Casing point selection;
- Casing size to accommodate production techniques (e.g, natural flow, gas lift, submersible pumps).

Additional Information to Complete the Picture

It is good practice to produce a Well Planning Request, signed by both Client and Well Construction representatives, to formally record the objectives and basis for design. This also forms the start point for production of time and cost information for drilling the well. The document should also record additional information which will be useful for the planning and execution phases. This could include:

- General well information (e.g, Licence number, Field/Prospect, Block Number, Geological Reference, anticipated commencement date);
- Known licence constraints and special considerations (or a copy of the licence agreement);
- Classification (e.g, wildcat, appraisal, development);
- Confidentiality status (e.g, normal, tight);
- Partner information;
- Client and Well Construction contacts;
- Principle offset wells;
- Co-ordinate system reference;
- Anticipated production testing programme if required;
- Any other known potential hazards not previously covered.

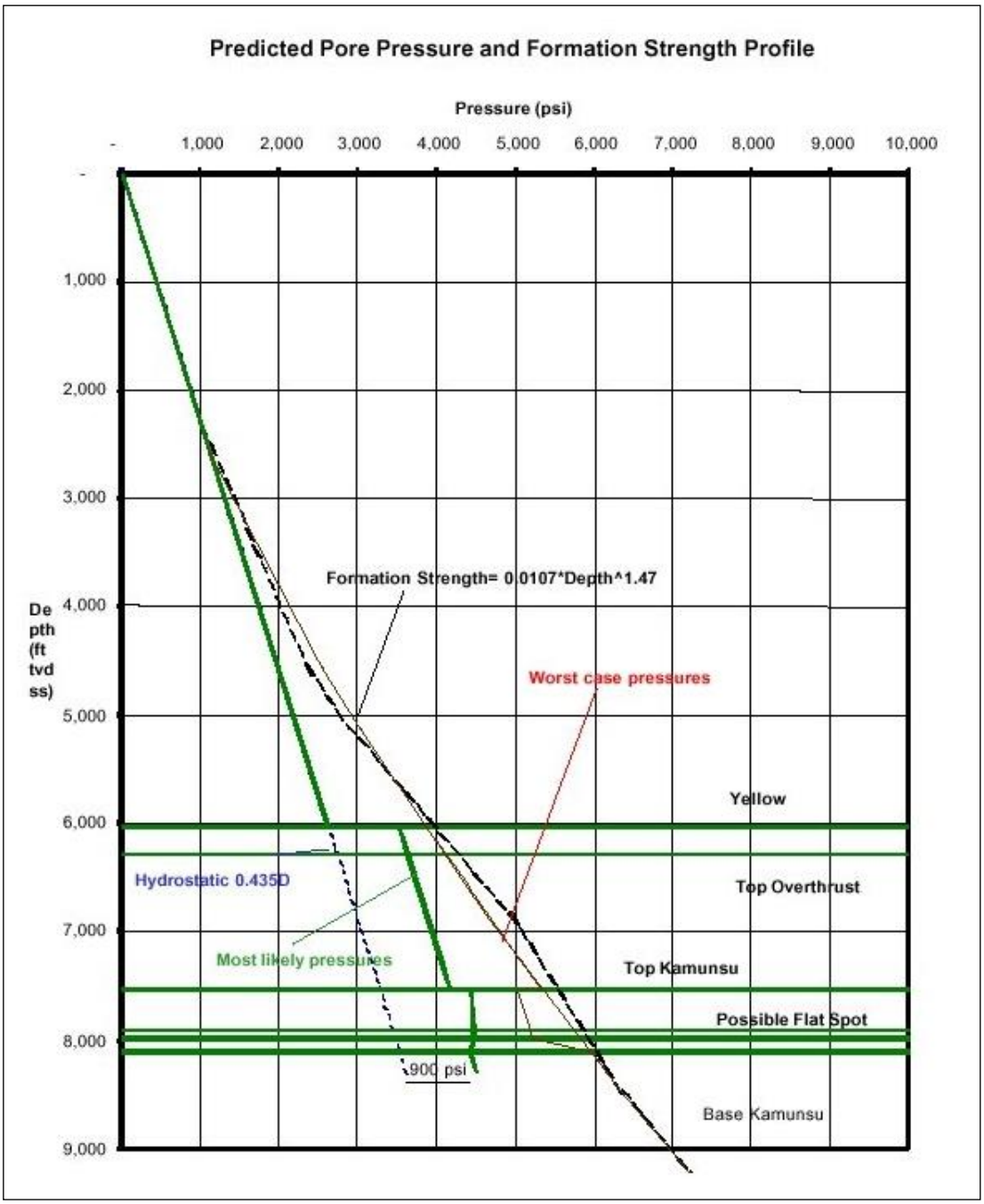

Figure 1. Schematic Representation of Prognosed Lithology, Pore Pressure and Formation Strength against Depth.