CHAPTER 5
DRILLING FLUIDS

TABLE OF CONTENTS

5.1 OBJECTIVES

Selection of the correct drilling fluids is essential to:

- Drill wells safely.
- Drill wells economically whilst avoiding damage to the reservoir or adversely affecting the quality of the evaluation programme.

Every well must have a Drilling Fluids Program which shall be designed to:

- Prevent the influx of formation fluids.
- Minimise reservoir damage.
- Enable the efficient acquisition of data for evaluation.
- Economically overcome potential hole problems by providing the necessary properties for pressure control, hole stability, hole cleaning and formation inhibition.
- Limit the environmental damage caused by discharges of materials and fluids.

The basic API drilling fluids tests shall be conducted at least twice daily during drilling operations and the latest test included on the Daily Drilling Report.

The environmental impact of the drilling fluids system must be evaluated and disposal of drill cuttings, drilling fluids and other wastes must be carried out in accordance with GSLM's guidelines and relevant Government legislation.

All toxicological properties of drilling fluids additives must be understood and controlled. Copies of the MSDS must be held at the wellsite for ALL mud chemicals on location.

5.2 RESPONSIBILITIES

The general responsibilities for planning, preparing and maintaining drilling fluids are outlined in the table below.

Task	Performed by	Verified by
Prepare Drilling Fluids Program	Drilling Fluids Contractor	DM
Monitor and maintain the drilling fluid properties in accordance with the Drilling Fluids Program	Drilling Fluids Engineer	DSV
Conduct routine testing and reporting, advise on any related problems	Drilling Fluids Engineer	DSV
Provide technical and commercial overview of the drilling fluids operation and make recommendations for improvements	DSV/ Drilling Fluids Engineer	DM
Treat the drilling fluids and ensure relevant personnel adhere to the safe handling procedures for chemicals and equipment	Drilling Fluids Engineer / Derrickman	DSV
Ensure that the Barite and drilling fluids stocks are maintained above the minimum levels as per 3.3.2	Drilling Fluids Engineer	DSV
Maintain equipment associated with the handling and treatment of drilling fluids	Drilling Contractor	Drilling Fluids Engineer / DSV
Ensure that health safety and environmental requirements are complied with on site	Drilling Fluids Engineer / Drilling Contractor	DSV
Ensure mud chemicals are correctly stored and transported.	Drilling Fluids Engineer / Drilling Contractor	DSV
Compile Daily Reports	Drilling Fluids Engineer	DSV

Table 19. Responsibilities for Planning, Preparing and Maintaining Drilling Fluids.

The parties responsible for performing the work must ensure that they understand all relevant procedures. They must pre-plan the work, issue instructions for all tasks and be responsible for coordinating the pre-job meeting which shall detail all aspects of the activity.

5.2.1 Detailed Responsibilities for Key Personnel

The Drilling Contractor, Drilling Fluids Engineer and DSV shall work together to ensure that the drilling fluids are handled, maintained and treated in a manner which fulfils the requirements and objectives of GSLM, as outlined in the Drilling Program.

5.2.1.1 Drilling Contractor

The Drilling Contractor shall ensure that all the equipment associated with the handling and treatment of drilling fluids is functioning correctly and is regularly checked and maintained. In addition, the Drilling Contractor shall also liaise with the Drilling Fluids Engineer when:

- Making regular drilling fluids checks.
- Mixing drilling fluids.
- Monitoring drilling fluids.
- Storing and handling chemicals.
- Operation and maintenance of solids control equipment.
- Maintaining an inventory of spares/back-up equipment for the solids control equipment.

5.2.1.2 Drilling Fluids Engineer

The Drilling Fluids Engineer shall be responsible for all issues relating to drilling fluids, including storage at the wellsite, transport and usage during a well operation. The Drilling Fluids Engineer shall ensure the following functions are performed in accordance with the GSLM operational guidelines contained in this Chapter.

- Ensure that the Drilling Fluids Program is followed and that costs are closely monitored.
- Maintain and monitor the drilling fluids properties to specifications outlined in the Drilling Program. Any parameter outside of specification should be noted on the daily mud report.
- Ensure routine testing and reporting is carried out and advise the DSV of all related problems as and when they occur, recommending the appropriate treatment for the drilling fluids. Provide the DSV with the technical and commercial overview of the drilling fluids operation and make recommendations for improving the program or operations as and when necessary.
- Recommend, manage and supervise all treatments to the drilling fluids that shall be based on sound technical and commercial evaluation and pilot testing.
- Ensure all relevant personnel are aware of, and adhere to, the safe handling procedures of all drilling fluids chemicals and equipment (reference Chapter 1 of this Manual).
- Determine the required drilling fluid materials and recommended equipment (e.g. chemicals, shaker screens etc.). Communicate to the DSV to ensure timely requisitioning of same.
- Optimise the solids control equipment to minimise losses and control low gravity solids levels in the drilling fluids. All such equipment suctions, returns and discharges shall be monitored and their performance reported daily to the DSV.
- Together with the Drilling Contractor, ensure that the health, safety and environmental objectives of the Drilling Fluids Program are met at the wellsite.
- In conjunction with this, ensure that the disposal of waste fluid and wellbore materials conforms with all relevant GSLM's procedures and Government regulations.

- Ensure that a current copy of Material Safety Data Sheet (MSDS) for each chemical is kept at the rig (Chapter 1 of this Manual).
- Compile all reports required by the Company and the regulatory authorities relating to the transfer, storage, use and maintenance of all drilling fluids and related additives and equipment (Chapter 1, this Manual).
- Compile all drilling fluid Recaps on time and ensure that they contain information required for future well planning.
- Manage stock – Cycle ageing products, ensure stocks are covered, packed, stored and transported correctly so as to minimise damage.
- Record the number of hours the solids control equipment is run each day.
- Record shaker screen usage.

5.2.1.3 Drilling Supervisor

The DSV shall ensure that the quality control of drilling fluids operation, maintenance and treatment is performed and adhered to in a manner that fulfils the well requirements. This shall include, but not be limited to the following:

- In conjunction with the Drilling Fluids Engineer recommend adjustments to the drilling fluid properties to ensure optimal mud performance.
- Perform quality checks on the drilling fluids testing carried out by the Drilling Fluids Engineer.
- Ensure that the Drilling Fluids Engineer submits the required accurate reports on time.
- Ensure that the Drilling Fluids Engineer carries out mud mixing in accordance with the Drilling Fluids Program.
- Ensure that the Drilling Fluids Engineer assists with the optimisation of the solids control equipment.
- Ensure the Drilling Contractor maintains, and optimises the solids control equipment.
- Verify that the Drilling Fluids Engineer maintains an up to date inventory of all drilling fluids material and testing equipment.
- Monitor the usage of shaker screens.

5.3 STANDARDS

This section describes the generic drilling fluids types used during drilling operations and the minimum drilling fluids requirements to be held at the wellsite..

5.3.1 Drilling Fluids Standards

This section describes the standard drilling fluids types, ingredients and formulations of drilling fluids used in drilling operations.

5.3.1.1 Drilling Fluid Types

The generic drilling fluids types that may be used by GSLM are listed below. Additional detail is provided in the remainder of this Chapter:

- Prehydrated Gel (PHG)/ Spud mud.
- Enhanced Spud mud.
- KCl/ PHPA Polymer.
- KCl/Polymer.
- KCl Brines.

5.3.1.2 Primary Ingredients

The primary fluid systems ingredients and their applications are outlined in the table below.

An overview of formulation ranges for each drilling fluid type is shown in Section 5.3.1.3.

Primary Function	Generic / Common Name	Chemical Composition	Typical Uses
Alkalinity Control	Caustic Soda	Sodium Hydroxide NaOH	Adjust pH; treat out Magnesium hardness
	Caustic Potash / KOH	Potassium Hydroxide KOH	Adjust pH; treat out Magnesium hardness; K+ source
	Soda Ash	Sodium carbonate	Treat out Calcium hardness/ cement in low pH muds.
	Bicarb	Sodium Bicarbonate	Treat out cement contamination in high pH muds
	(Slaked) lime	Calcium Hydroxide	Increase viscosity by flocculation of clays; raise pH; treat Carbonate / CO2 gelation problem; Ca++ source
	Citric Acid	Citric Acid	Decrease pH and stop polymer burn -out/ degradation
	SAPP	Sodium Acid Pyro Phosphate	Cement pre-flush additive: thinner sequesters calcium
Biocide	Alkyl Dithiocarbamates		
	Glutaraldehyde	Glutaraldehyde	Prevent bacterial decay of polymers
Corrosion Control	Filming Amine	Proprietary blend	Minimise corrosion of tubulars from oxygen, CO2 and/or H2S
	Multi- component	Proprietary blend	Minimise corrosion of tubulars from oxygen, CO2 and/or H2S
	Zinc Carbonate	Zinc Carbonate	Hydrogen Sulphide scavenger
	Liquid Oxygen Scavenger	Ammonium Bisulphite	Minimise corrosion of tubulars from oxygen
	Solid Oxygen Scavenger	Sodium Sulphite	Minimise corrosion of tubulars from oxygen
Defoamer	Defoam	Proprietary	Defoam aerated muds, surfactant
	Stearate	Aluminium sterate	Defoam aerated muds
Detergent	Mud detergent, DD, etc.	Metallic salty of fatty acid (soap)	Minimise bit balling, emulsifier, rig wash
Dispersant	CF Ligno	Chrome free Lignosulphate	Thinner; reduces fluid loss, emulsifier, shale inhibitor
Fluid Loss Control	PAC LV and/ or PAC REG	Polyanionic cellulose	Reduces fluid loss: viscosifier (YP).
	Starch	Carbohydrate	Reduces fluid loss; inhibits shale hydration / dispersion
	Lignites (Lignon Tannathin, etc)	Lignin resins	Reduces fluid loss; thinner
	CMC LV, CMC REG and/ or CMC HV	Sodium Carboxymethyl cellulose	Reduces fluid loss; viscosifier
	Acrylate (SP 101, Cypan, etc	Sodium Polyacrylae	Reduces high temperature fluid loss; thinner
	Modified polymers	Proprietary Organic polymers	Reduces high temperature fluid loss; thinner
Shale Inhibitor	PHPA	Partially hydrolysed polyacrylimide	Reduce shale hydration by encapsulation; viscosifier
	Salt	Sodium Chloride NaCl	Inhibits shale hydration brine additive (max. 10.0 ppg)
	KCl	Potassium Chloride KCl	Inhibits shale hydration brine additive (max. 9.7 ppg); K+ source
	Polyol	Glycol / Glycerol	shale inhibitor, lubricant blend

Table 20. Primary Drilling Fluids Ingredients (i)

Primary Function	Generic / Common Name	Chemical Composition	Typical Cooper Basin Uses
Viscosifiers	Trugel (various nos(	Locally processed Bentonite	Peptised/ polymerised gel viscosifier (FWYP/gels)
	Wyoming Bentonite	Imported pure Bentonite	Used as cement additive (extender) no polymers
	Biopolymers (XC, XCD, etc.)	Xanthium gum and/ or derivatives	Raise viscosity (YP, gels and low-end rheology)
Weighting Agents	Barite	Barium Sulphate (+ minor metallic ores)	Inert Weighting material (max 20 ppg)
	Limestone	Calcium Carbonate	Acid soluble weighting material (typical / max 12.0 / 16.5 ppg
Miscellane-ous	Calcium Chloride	Calcium Chloride	Brine additive (max. 11.7 ppg); cement accelerator
Lost Circulation Material	Mica – coarse, medium, fine	Muscovite flakes	Reduce seepage losses – total lost circulation
	Cereal husks	Cellulosic fibre materials	Reduce seepage losses – total lost circulation
	Ground shells	Ground Walnut hulls	Reduce seepage losses – total lost circulation
	Limestone	Calcium Carbonate	Reduce seepage losses – total lost circulation
	Fibrous blend	Fibrous flakes and granular blend	Reduce seepage losses – total lost circulation
Pipe Free Agent		Proprietary surfactant blend	Soak solution for differentially stuck pipe

Table 20 (cont'd) Primary Drilling Fluids Ingredients (ii)

5.3.1.3 Standard Formulations

The relevant Drilling Fluids Program takes precedent over the formulations shown in the Drilling Operations Manual.

5.3.2 LCM Standards

Lost circulation or lost returns is defined as the loss to the formation of either drilling fluids or cement slurry used during the drilling or completing of wells.

The recommended Lost Circulation Material (LCM) that may be used across reservoirs etc. to minimise formation damage is normally a cellulose type product such as Enerseal super fine, Sandseal .

5.3.3 Stuck Pipe Spotting Fluids (Pipe Free Pills)

Spotting fluids should only be used when so directed by the DM.
Spotting fluids should be mixed and pumped according to the manufacturer's recommended formulation and procedures, under the following guidelines:

- The pill should be prepared in a clean tank on surface. The volume required shall be determined by the DSV and shall be 50 - 100 % excess over the annular volume around the drill collars.
- Consideration should be given to the density of the pill, which should ideally be the same or greater than the density of the drilling fluids, to minimise the migration of the pill through the static mud column.

Standard spotting fluid volumes and compositions are shown below:

Mixing - 20 bbl pill: mix 1 drum (55 gals) surfactant in 19 bbl diesel.
40 bbl pill: mix 2 drums surfactant in 38 bbls diesel.

5.3.4 Minimum Chemical Stock Requirements

The following are the minimum chemical stocks that shall be available for use on the rig. These may either be kept on the rig or at a nearby supply base if transport is readily available.

- Mud chemical stocks adequate to re-build 1½ times the maximum hole volume plus the minimum surface volume of the mud system in use and the interval being drilled.
- The mud system in use and the interval being drilled.
- Emergency barite stocks to be able to weight the total mud system by at least 1.0 ppg.
- Sufficient stocks of LCM material for both above and across the reservoir.
- Sufficient stock of surfactant, weightable pipe freeing agent, Biocide and corrosion inhibitor materials.

The DSV and DM shall individually review specific well requirements.

5.4 SOLIDS CONTROL AND MUD RELATED EQUIPMENT

Solids contamination of drilling fluids is the single most costly drilling fluids control problem. Mechanical treatment is the most economical means of treatment (shakers, desanders, desilters, and centrifuge). The quantity of solids removed must be maximised. However, complete removal of undesirable solids is not practicably feasible.

Mechanical treatment must begin immediately drilling commences rather than to delay until the mud properties start to deteriorate as this will result in the requirement for dilution or treatment with costly chemicals.

The following are the GSLM's solids control guidelines:

- All applicable equipment shall be operating and functional before drilling begins.
- Solids control equipment shall be maintained to appropriate standards.
- Efficiency checks shall be made daily when equipment is in use.
- Manufacturers Maintenance and Operating Manuals for all solids control equipment shall be available at the wellsite.
- Instructions for use and maintenance shall be strictly adhered to at all times.
- Linear motion shakers are the preferred shaker type.
- The vacuum degasser system (where available) should be tested at the start of each well and prior to any DST's.
- The finest practical shaker screens will be used.
- Shaker screens should be inspected frequently and any damaged screens repaired or replaced. The mud engineer should record screen usage on the daily mud report.
- The settling tanks should never be bypassed and should be dumped regularly.
- Desanders and Desilters should be balanced to produce a spray discharge.
- Reuse sump water where possible.

5.4.1 Operations Guidelines for Solids Removal and Equipment

This section describes equipment provided by the Drilling Contractor and the methods for the removal of solids.

5.4.1.1 Flowlines and Jet lines

Flowlines, shaker header boxes (possum bellies) etc., shall be inspected regularly and cleaned out as required, to prevent solids build-up.
Jet lines, if fitted, shall also be inspected regularly to ensure that they function properly.

5.4.1.2 Shale Shakers

Equipment	Operational Guidelines
Shale Shaker	• Must be operated as efficiently as possible, at all times, in order to maximise the amount of solids removed after exiting the wellbore. • Must be switched on immediately before running in the hole to clean the mud displaced by the drill string and BHA. • Flow shall be distributed evenly over all available shakers. • Shakers shall be switched off immediately prior to tripping out of the hole. Care must be taken to ensure that the shakers are started before breaking circulation for any reason, e.g. backreaming and pumping out. • Cuttings should not be allowed to dry hard upon the screens. • Shakers shall not be by-passed, unless absolutely necessary and as authorised by the DSV • Shakers should not be run dry as this leads to increased wear and premature screen failure
Shaker Screens	• The finest mesh screens shall be selected, taking into consideration maximum solids separation whilst minimising the loss of whole mud, and ensuring that screens are not overloaded. • Screens shall be inspected regularly and changed out or patched immediately when defects are identified. • Operations should not be allowed to continue with a torn or ineffective screen. • Screens shall be washed down regularly e.g. on connections, prior to tripping out of the hole and before shakers are switched off. • Adequate stocks of screens, in an appropriate range of sizes, shall be maintained on location at all times. • The mud engineer should record the number of screens used on the daily mud report. • Ensure shaker screens are installed and tensioned as per the manufactures procedures

Table 21. Operational Guidelines for Shale Shakers

With new water based polymer mud, screen blinding may occur during the initial period of circulation. After one or two circulations, the shakers may be redressed with finer screens as the polymer shears , or the mud heats up.

A reduction in circulation rate and/or changing to coarser screens should alleviate screen blinding problems and drilling fluid losses arising from high viscosity drilling fluids and/or solids-laden drilling fluid after trips. However, circulation rate must only be reduced if it is absolutely certain that effective hole cleaning can be maintained.

5.4.1.3 Settling Tanks

This section describes the operational guidelines for settling tanks. Settling tanks shall:

- Not be by-passed.
- Be checked and dumped regularly.
- Not be dumped while circulating, as a dump valve malfunction could result in suspension of operations.

The operation of the dump valve shall be checked every time the settling tank is dumped and cleaned out. It is not always necessary to dump the complete contents of the settling tank, since this results in the immediate need for a large replacement volume within the circulating system. It may be easier to operate if smaller volumes of solids are dumped at more regular intervals.

Settling may be assisted by dilution, with water, to the returns flowline. However, this practice should not be routinely used with a weighted mud system.

5.4.1.4 Desanders and Desilters

The table below highlights the performance characteristics of the hydrocyclone equipment used for desanders and desilters, and provides an operational troubleshooting guide which may be used to rebalance a unit that is not correctly set up. Incorrect operation is extremely inefficient, and normally results in an excessive wastage of whole mud.

Underflow	Cause	Wear Pattern	Remedy
Spray discharge	Correctly set up	Grooving over lower two inches	None required.
Rope discharge	Overload of solids in feed and/or undersized cone apex (possibly caused by plugging)	Sharp grooving 1/3 way up cone and erosion of cone top due to solids in overflow	Increase apex size until spray dischargeis achieved. If unsuccessful remove cone and clean out underflow blockage
Continuous flow discharge	Low inlet velocity that could be due to low feed head. Could also be caused by partial or total plugging of feeder head	Excessive wear at cone apex	Strip and clean feed header and regulate pump to provide + 75ft of head
Plugged discharge	Underflow plugging at cone apex caused by solids overload and/or restriction in underflow opening	Sharp grooving 1/8 way up cone and erosion of cone top due to solids in overflow	Strip down cone. Clean out blockage and reset apex size

Table 22. Hydrocyclone Troubleshooting Guide

In principle, desanders and desilters should only be run with unweighted water-based muds, and consideration should also be given to their use with polymer muds, as a significant proportion of material can be discarded in the process. It is essential that they are properly set up and adjusted.

Desanders and desilters shall be run under the following guidelines:

- Run on a continuous basis when appropriate, to assist in maintaining a low mud weight.
- Balanced to produce a spray discharge.
- Periodically flushed with water (particularly if they have been shut down for a period), to remove any caked solids that could lead to plugging of the feed nozzles or apex bushings.
- For optimum performance, the desander overflow should be rigged up to discharge into the desilter suction tank.
- Each desander and desilter shall be assigned a dedicated pump.
- Where possible, ultra-fine mesh screens should be used on the high speed shakers.This will minimise the requirement for hydrocyclones.

The following guidelines regarding the operation of the cones shall be followed:

- Cones shall be stripped and cleaned after every period of continuous (e.g. at the end of each well) use, particularly the feed nozzle, the two apex adjusting bushings and the body liner. Wear can critically affect hydrocyclone performance.
- The pressure operating within a cone is adjusted by the two apex bushings or the triangular bushing on each cone, and their size also affects the pressure. If large opening bushings are used, a higher capacity centrifugal pump may be required to maintain the optimum feed pressure.
- Required running pressure is as follows: Pr(psi) = (MW/8.34)*75*0.433

5.5 MONITORING, REPORTING AND TESTING

This section describes the monitoring, reporting and testing of drilling fluids as performed by the Drilling Fluids Engineer.

5.5.1 Drilling Fluids Monitoring

The Toolpusher shall designate a suitably trained rig crew member to monitor the shale shakers and mud pits at all times while circulating. Part of the designated duties shall be to measure and record the mud density and funnel viscosity of the drilling fluid at the times shown in the Monitoring Report.

Mud weight and Funnel Viscosity tests shall be carried out on samples taken from the flowline and the suction pit every 30 minutes, or more frequently as determined by the Drilling Fluids Engineer and DSV.

The Drilling Contractor designated personnel shall record all drilling fluids test results and pit levels, where appropriate, in a book containing a format similar to that shown above.

The book shall:

- Be kept in a convenient place for ease of inspection by supervisory personnel.
- Contain all instructions passed to the designated crew member by the Drilling Fluids Engineer or DSV, clearly marking the time and date of the instruction.

The DSV shall determine the required mud weight to ensure safety of personnel and integrity of the wellbore, and shall advise the Drilling Fluids Engineer and the Drilling Contractor of this value.

When any departure from the mud weight specification is detected, the Drilling Fluids Engineer or Drilling Contractor shall inform the DSV immediately..

5.5.2 Drilling Fluids Testing and Reporting

The Drilling Fluids Engineer shall perform a full mud check at least twice daily during drilling operations and record the results on the Daily Mud Report Form. The mud check run closest to the 06:00 depth will be used on the Daily Drilling Report.

Additional reporting on the management of the drilling fluids, chemical usage and solids control equipment shall be performed by the Drilling Fluids Engineer or the DSV on a daily, per well and as required basis. Copies of all reports shall be submitted to the DSV for verification.

The Drilling Fluids Recap shall be continually updated by the Drilling Fluids Engineer during the course of the well. Upon completion of the well, the edited and checked document shall be forwarded at the earliest opportunity to the DM.

5.5.3 Water Based Mud Testing Requirements

The table below summarises the minimum drilling fluids tests required during drilling operations. Additional tests are at the discretion of the DM and DSV, and may also be planned on a well by well basis. All test results shall be recorded on the Daily Mud Report in API Standard Units. These shall be performed by the Drilling Fluids Engineer in accordance with the testing frequency.

Drilling Fluids Property	Unit of Measurement	Standard or Calibration	Measuring Equipment / Method
Mud Weight	ppg	8.34 ppg with fresh water	Mud balance
Funnel Viscosity	sec/qt	26.5 sec with fresh water	Marsh funnel and mud cup
Rheology	rpm	600,300, 200, 100, 6 & 3 rpm.	Six speed rheometer and heating cup
Plastic Viscosity (PV)	cps	600 minus 300	"
Yield Point (YP)	lbs/100sq.ft	300 rpm - PV	"
Gel Strength	lbs/100sq.ft	3 rpm at 10sec, 10min and 30min	"
API Fluid Loss	cc(or ml) per 30 min	Performed at 100psi and ambient temperature	API
HPHT Fluid Loss	cc(or ml) per 30 min multiplied by 2	Performed at 500psi and maximum TD temperature	HTHP filter press
Filter Cake	mm or 32nd inch	Description	From fluid loss test
Oil/Water/Solids	% (HGS and LGS) by volume	Test with water (100%)	Retort kit
Sand Content	% by volume	Test with known solutions	Sand kit
pH	acid / alkalinity (0 to 14 scale)	pH test meter	pH meter, colour strips / litmus paper.
Methlyene Blue Test (MBT)	lbs/bbl (5 x cation exchange capacity)	Test with known solution	MBT test kit
Chlorides	Mg/l	Test with known solution	Filtrate titration
Potassium Ion / KCl	Mg/l / %	Test with known solution	Titration / centrifugal precipitation
Hardness (Ca and Mg)	Mg/l	Test with known solution	Filtrate titration
Alkalinity (Mud & Filtrate, Pm, Pf, Mf)	ml standard sulfuric acid	Test with known solution	Mud and filtrate titration
PHPA	lbs/bbls (ml or cc precipitation)	Test with known solution	Centrifugal precipitation

Table 24. Minimum Drilling Fluids Testing Requirements, Units and Standards

CHAPTER 6
TRAJECTORY CONTROL

TABLE OF CONTENTS

6.1 OBJECTIVES

The objectives for trajectory control are as follows:

- Attain the required bottom hole position within the required tolerance.
- Achieve the planned trajectory without a Dogleg Severity that exceeds the programmed specification.

In most cases, well trajectory control simply means ensuring that a planned vertical wellbore is drilled vertically.

Note: GSLM shall survey all wellbores from surface to TD, with instruments suitable for this use.

6.2 RESPONSIBILITIES

Responsibilities for the implementation, supervision and verification of directional drilling and surveying are tabulated below.

Task	Performed by	Verified by
Specification of target and surface location	Geology Dept	DM
Preparation of well trajectory plan and kick-off point	Directional Contractor	DM
Equipment selection	DM	DM
Call out of contractor supplied equipment	DM	DM
Monitoring well trajectory	DSV	DM
BHA design and bit selection	DSV / DM	Dm
Wellbore surveying	DSV / Drilling contractor	DSV / DM

Table 25. Responsibilities for Implementation, Supervision and Verification of Directional Drilling and Surveying.

6.3 GENERAL SURVEY REQUIREMENTS

The surveying program shall be defined in the Drilling Program, based on the guidelines below.

Surveys are normally performed using the Totco or Magnetic Single Shot (MSS) tool. Directional surveys can also be run as part of the wireline logging program.

Survey tool selection may be reviewed however, depending on target size and depth, and the level of accuracy required. Survey intervals shall be specified for each well.

The following table provides an outline of the minimum standard survey parameters for vertical wells. Note: Survey frequency may be increased if the deviation increases above the specified limits.

Interval	Survey Tool	Frequency	Maximum Inclination	Maximum DLS
Surface hole	MSS/Totco	Every 150 m	3 degrees	1.5 degrees/30 m
Intermediate hole	MSS/Totco	Every 150 m	5 degrees	1.5 degrees/30 m
Production hole	MSS/Totco	Every 150 m	6 degrees	1.5 degrees/30 m

Table 28. Standard Survey Parameters for Vertical Wells

If the surveys fall outside the above parameters the DM should be notified. No corrective action should be taken without consulting with the DM. Confirm with DM before running surveys through or below known depleted zones.

All survey instruments shall be run as close to the bit as possible. The hole must be sufficiently circulated prior to running surveys (this will normally be at least 1x bottoms up), to ensure that hole conditions are stable and the drill string is kept stationery for as little time as possible.

All surveys recorded on the daily drilling report shall be referenced to Magnetic North, not True North or Grid North. Surveys will be corrected to true north by the DM. Directional surveys will normally reference grid north.

6.4 DIRECTIONAL DRILLING

This section describes the planning, implementation and verification of surveying requirements during drilling operations on deviated or high angle wells.

6.4.1 Planning Requirements

The Drilling Program contains all the information necessary for the preparation and commencement of directional operations. As such the DSV shall check the Drilling Program and associated documentation to ensure that it contains the following:

- Assumed ground level elevation above M.S.L.
- Target co-ordinates, target size and tolerance(s).
- Origin Reference Points for the applicable well surface location.
- Kick-off point, build and turn rates.
- Survey Program.
- Recommended BHA's to be used including agreed dogleg severity potential values for each assembly. The BHA's quoted are to be used as a guide and modified as drilling conditions and directional requirements dictate.

Where the above data has been omitted, it shall be requested by the DSV before the start of operations. The DSV shall ensure that all well plots are available. However no well plots are required for standard vertical wells.

6.4.2 Survey Requirements

All wells shall be surveyed from the wellhead to TD using the guidelines specified in Section 6.3 of this Manual and those below.

Task	Description
Planning	• Survey type shall be based on the anti-collision requirements (if applicable), survey tool accuracy, target size and depth. • Survey accuracy objectives shall be specified for each well.
Calculations	• The preferred method of survey calculation is the Minimum Curvature method. Other calculation methods may be used to verify survey results. • Magnetic interference calculations based on region and well orientation shall be performed by the Directional Contractor to determine the minimum length of non-magnetic drill collars and stabilisers if required for clean magnetic surveys.
Reporting	• All survey data reported to on the Daily Drilling report shall be UNCORRECTED (e.g. referenced to magnetic north). • The Azimuth shall be reported in degrees and not quadrants (i.e. will be reported as 190° not S10°W). • The values for convergence and declination used shall be reported on all definitive surveys. Survey tool accuracy shall be specified on all definitive surveys presented to GSLM. • Survey results shall be referenced to the local grid for reporting purposes.
Verification	• The quality of all multi-shot surveys taken shall be checked by the Surveying

	Contractor and verified by the DSV using the approved acceptance criteria (Refer 6.5.1).

Table 27. Survey Requirements.

6.4.3 Magnetic Survey Equipment

All downhole survey instruments shall have a valid inspection certificate and shall conform to standard DS-1 Drilling Service Category 4. For normal use, certificates shall be valid for a period of up to 18 months; however if any tool has been subjected to rough treatment or has produced erroneous survey data, then it shall be returned to the certified re-calibration facility for re-calibration and testing.

Magnetic interference calculations based on region and well orientation shall be performed by the Directional Contractor to determine the minimum length of non-magnetic drill collars (and stabilisers if applicable) required for clean magnetic surveys.

All tools supplied to the rig shall be accompanied by the appropriate documentation. In accordance with good oilfield practice, all pin connections shall be stress-relieved and all boxes bored back.

From time to time, as operations progress, additional information will be required by the Directional Contractor to facilitate accurate monitoring and reporting of the borehole position. The DM shall ensure that this information is transmitted to the rig, marked for the attention of the DSV, as and when required.

📖 Standard DS-1 Drilling Service Category 4.

6.4.4 Tie-In Data

For directional wells, tie-in data shall be provided by the Directional Contractor after completion of quality assurance checks on each multi-shot survey.

The Directional Contractor shall forward the data to the DM, who shall validate the results and issue the following data to the rig:

- Tie-in depth RT (m).
- Inclination (degrees).
- Azimuth (degrees).
- TVD RT (m) - True Vertical Depth Rotary Table.
- Northing (m).
- Easting (m).
- Ground Level (m asl)

6.4.5 Position Uncertainty

Borehole position uncertainty can be evaluated in the lateral, radial and vertical directions for both 'good' and 'poor' quality magnetic and gyro surveys. For most practical cases, lateral position uncertainty is the greatest and therefore can be used to estimate borehole position uncertainty.

Computed survey errors have been used to produce curves showing the lateral position uncertainty for various survey tools. These have been normalised to express the relative position uncertainties in feet per 300 m AHD against average inclinations.