



Survey Management Provides A Safer Drilling Environment With Reduced Drilling Costs

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Abstract

Survey Management is a growing and vital part of the drilling service industry. Database management and quality control are key components of the survey management service, providing validated survey data for proper risk assessment. Multi-station analysis and in-hole referencing are used to correct for magnetic tool error and offer reduced uncertainty in positioning. Real-time survey management is a dynamic service designed to achieve well positioning objectives while providing overall cost benefits to the operator. By utilizing services like geomagnetic referencing, it is possible to drill further and more precisely with MWD tools, reducing gyro runs and subsequent rig time to achieve the required survey accuracy. This paper will demonstrate how survey management can reduce the risk of collision and meet geological target objectives faster and at reduced costs.

Introduction

Historically, all that was required of wellbore surveying was to sufficiently describe the position of the well trajectory to ensure that property boundaries were observed, and that the well path had not strayed in an undesired direction. As our ability to place directional wells improved, so did the need to more accurately survey the well trajectory. Today, we need to ensure that the well trajectory penetrates the desired geological target, and that the well path is sufficiently well known such that collisions with other wells are prevented and relief well drilling is achieved.

As drilling techniques developed, so did the requirement for better and better surveying tools. These have developed from simple inclination-only tools like Totcos; through magnetic surveys that provide both azimuth and inclination measurements in the shape of magnetic single shots and magnetic multi-shots; through sophisticated Gyroscope-based tools to the sophisticated but more robust tool, the MWD, which is rugged enough to operate in the bha while drilling.

The drilling industry has matured so that surveying and surveying techniques now have to deal with more congested platforms, more congested surface locations,

higher well densities, and be able to penetrate smaller and more distant geological targets safely and cost-effectively, often from facilities that have huge daily running costs. At the same time that the complexity increases, there is still a need to deal with the less-sophisticated, less-well-documented and often lost survey legacy data.

The key to this increasingly complex and costly process is Survey Management.

Survey Management

Survey Management is a term which has evolved in the directional services industry to refer to the management, overseeing and development of wellbore surveying, survey planning procedures, survey data quality control, and the management and custodianship of the directional planning survey database.

Survey management includes many diverse aspects:

- Clean-up of historical, legacy survey databases
- Management and custodianship of the definitive directional planning database
- Survey program planning for anti-collision and target sizing
- QA and QC of survey data from all survey providers
- Reporting for state and federal regulatory agencies

There are often financial and safety benefits that come with the application of Survey Management. Any reduction in surveying time, or elimination of survey runs, that leads to reduced open-hole exposure automatically leads to less exposure to stuck-pipe possibilities. Better anti-collision procedures reduce safety and environmental risk exposure. All these mean reduced drilling and remedial costs.

Surveying accuracy and positional uncertainty

Well surveys have often been misunderstood when describing exactly the underground trajectory of a well, with no consideration taken of the survey tool

inaccuracies or all the other components that make up the uncertainty in that position.

Survey tools have vastly improved in their intrinsic accuracies over the years, and fortunately the ability to assess the positional uncertainties has also managed to keep up.

The Industry Steering Committee for Wellbore Surveying Accuracy is an informally constituted group of companies and individuals from oil companies and the directional services industry whose broad objective is to produce and maintain standards for the industry related to wellbore survey accuracy.

Part of this brief is for ISCWSA, which is an industry attempt to correctly model surveying positional uncertainties and replace the simplistic and archaic tools previously available. Currently the best error models available to the industry, which have now become the industry standard, are these ISCWSA models.

An outcome of more accurate surveys and better description of positional uncertainty is a reduction in error ellipse size. This is very desirable from a driller's perspective, since it translates into bigger driller's targets for any geological target. This means greater drillability and often drilling time and subsequently cost reduction. The geologists and geophysicists also benefit by having a higher confidence level of being able to successfully penetrate the geological targets.

The use of more accurate survey instruments and more sophisticated survey uncertainty descriptions becomes very powerful in achieving better survey accuracy when combined with a number of operational techniques that will now be described.

Geomagnetic Referencing Service

The majority of surveys run in the oilfield today, and in the past, are magnetic surveys; these can variously take the form of MWD surveys, magnetic single and multi-shot surveys, and EMS survey services.

Magnetic survey instruments have become extremely accurate but have one perceived weakness, which is the varying nature of the magnetic reference.

Magnetic surveys use the Earth's magnetic field as reference, and can, therefore, only be as good as the description of the Earth's field. The Earth's field is typically modeled by what is known as a main field model, such as the BGGM, which predicts the Earth's magnetic field strength and direction based on the date and location on the Earth's surface or below. These

main field models do not take into account any anomaly in the Earth's crust less than hundreds of kilometers across, nor take into account any time-varying features beyond the secular variations. The secular variations are the long-term changes corresponding to the changes in the magnetic field produced by the Earth's core and which are exemplified by the gradual movement of the magnetic poles.

How much reference error is there? This greatly depends on the location on the Earth, both for the magnitude of any localized crustal anomaly and for the time-varying effect.

As an example of the time-varying effect, **Fig. 1** shows the daily maximums and minimums of the measured magnetic declination from a magnetic observatory on the coast of the Gulf of Mexico (GOM) during the year 2000. This data is taken from minute-by-minute measurements over an entire year. This shows that the declination, which is the angular difference between true and magnetic North, varies by $\frac{1}{4}$ degree every day of the year, even in a low latitude, magnetically-benign region like the GOM. The maximum observed daily variation during the year, taken during a period of high sun spot activity was 1.13 degrees. The chart clearly shows that the normal daily variation is of the same order of magnitude as the secular variation over the whole year. The variations at locations on the Earth which are more magnetically active such as Alaska, may have a daily variation of 10 degrees or more! **Fig. 2** shows the declination variations for an Alaskan observatory over a 24 hour period taken on one day in February 2003 and **Fig. 3** shows the declination variation over the same period for an observatory in the Gulf of Mexico, on an increased declination scale.

Geomagnetic referencing addresses these two sources of error.

The process is set up in two phases:

- Collection of an aeromagnetic survey for offshore locations or a local magnetic survey for onshore locations
- Calculation of a local magnetic field model suitable for correcting magnetic survey data

The local magnetic field model may take account of both crustal anomalies and time-varying effects, or just crustal anomalies, depending on level of correction desired.

Either way the declination error term, which makes up a large part of the error budget of a magnetic survey, can be greatly reduced.

The benefits of using this advanced technique are:

- Vastly improved survey accuracy in real-time
- Reduction in EOU sizes
- Improved target sizing
- Elimination of wireline or pipe-conveyed Gyro surveys
- Reduction in open-hole exposure during those Gyro operations and subsequent reduction in safety and environmental risk
- Cost savings in rig-time and direct survey charges
- Real-time nature of corrections meaning less correction runs

Geomagnetic referencing may also be applied retrospectively for the correction of survey data from previously drilled wells.

The application of GRS techniques to MWD surveys allows for the provision of Gyro-quality azimuthal control in a robust drilling package to achieve geological objectives in real-time.

Multi-station analysis

Multi-station analysis is a technique which allows for the correction of drill-string magnetic interference and its corresponding effect on magnetic azimuth. It is a more sophisticated approach than single-station magnetic compensation and does not suffer from the no-go areas that prevent the application of single-station analysis in certain wellbore directions, such as close to East-West.

With larger bha diameters and the consequent large magnetic signatures of bha components such as motors, it is sometimes practically impossible to get free of drill-string interference. The large number of non-magnetic drill collars required to provide a magnetically clean environment for the MWD sensors means that the MWD is placed too far from the bit, and the subsequent bha's are impractical due to directional concerns.

MS analysis may effectively provide a reduction in non-mag requirements in this situation.

Survey frequency

A well trajectory is described mathematically by a set of discrete surveys, consisting of an azimuth, inclination and measured depth with some sort of interpolated path between those stations. There are many ways of arriving at that interpolation and each method approaches more or less closely to the actual well path; minimum curvature has become an industry standard as a pretty good trajectory description in most circumstances. Increased frequency of surveying will improve that approximation, but at a cost of more rig-time. That cost may or may not be justified by the amount of incremental

positional accuracy obtained by those additional surveys, and that issue depends on the point reached in the trajectory, e.g. a build or hold section, and the positional precision dictated by the target type and conditions.

Thus the consideration of survey frequency is an important aspect of survey management.

The ultimate in terms of survey frequency must be a continuous survey from an MWD tool while drilling. The nature of survey acquisition while the drill string is drilling, (i.e. moving), means that the survey accuracy of each of those continuous surveys cannot be as good as a stationary survey. Consequently cDnl surveys do provide more information in describing the well bore trajectory, but their uncertainties have not yet been sufficiently described to enable them to be used to provide a definitive survey. cDnl finds great application in Geosteering operations.

In-hole referencing

Magnetic declination and drill-string interference are two major sources of error in MWD surveying. In-hole referencing is a technique used to address these two error sources, whereby the MWD survey azimuths are effectively replaced by gyro azimuths. By taking overlapping gyro surveys over an MWD surveyed hole section, an azimuth correction is derived which is applied to subsequent surveys taken by the MWD. The use of this technique is generally restricted to tangent sections (and at inclinations greater than 20 deg.) since the validity of this azimuthal replacement is based on the assumption that the two error sources are systematic over a single bit run as long as the hole direction does not change. One major disadvantage to this method is that an error in the gyro survey will propagate down the hole since there is no comparison of independent surveys. Great care must be taken when using In-hole referencing.

MAP

The Most Accurate Position (MAP) technique combines multiple wellbore surveys in order to obtain a single composite, "most accurate" well position. Established methods for defining the wellbore position and its associated uncertainty, rely on accepting the position obtained from the most accurate survey instrument used on each section of the wellbore and discarding all other measurements. The advantage of the MAP technique is that when all the surveys on a particular well are combined, the final uncertainty is smaller than the uncertainty associated with any of the constituent surveys. This leading edge technology is being developed and tested now for field introduction.

Examples of EOU reduction

Fig. 4 represents in tabular form the results of EOU reduction for 4 wells drilled in the GOM for which the GRS service was applied to MWD surveys. As a comparison for the GRS ellipses of uncertainty, the raw MWD EOUs are supplied plus the EOUs that would be calculated for two types of Gyro survey tools.

These are:

- Ring-laser inertial Gyro (RIGS), which is about the most accurate gyro tool currently available, but only in certain tool sizes.
- Continuous North-Seeking Gyro (CNSG-DP) run in drill pipe, operating in dynamic continuous North-seeking mode

All EOU sizes are calculated in 3-D at a 95% confidence with ISCWSA tool error models.

Fig. 5 and **Fig. 6** are a simple graphical representation, showing the effect of EOU reduction greatly increasing the driller's target. These are taken from the ellipse sizes of example well #4 in the table, and show the driller's target as calculated with a 1000 ft by 500 ft rectangular geological target using MWD and GRS uncertainties.

Conclusions

The proper application of Survey Management and its associated techniques provides these benefits:

- More accurate well position descriptions
- Reduced uncertainties in those well positions
- Reduced drilling correction runs
- Reduced exposure to open-hole procedures prone to fishing incidents
- Reduced well-to-well collision risk
- Reduced safety risk
- Reduced environmental risk
- Reduction or elimination of some survey runs and subsequent rig-time and survey cost savings
- Ability to drill wells closer together, while avoiding collision risk
- Ability to drill to smaller targets allowing greater economic exploitation of smaller reservoirs
- Reduced volumetric uncertainty allowing more effective reservoir characterization
- Ability to place wells in locations that were previously unavailable

Nomenclature

<i>BHA</i>	= bottom hole assembly
<i>MWD</i>	= Measurement while drilling
<i>EMS</i>	= electronic multi-shot
<i>BGGM</i>	= British Geological Survey Global Geomagnetic Model
<i>ISCWSA</i>	= Industry Steering Committee on Wellbore Survey Accuracy
<i>QA</i>	= quality assurance
<i>QC</i>	= quality control
<i>EOU</i>	= ellipse of uncertainty
<i>GRS</i>	= Geomagnetic Referencing Service
<i>MS</i>	= multi-station
<i>AC</i>	= anti-collision
<i>TD</i>	= total depth
<i>TVD</i>	= true vertical depth
<i>VS</i>	= vertical section
<i>D&M</i>	= Drilling and Measurements
<i>cDnl</i>	= continuous direction and inclination

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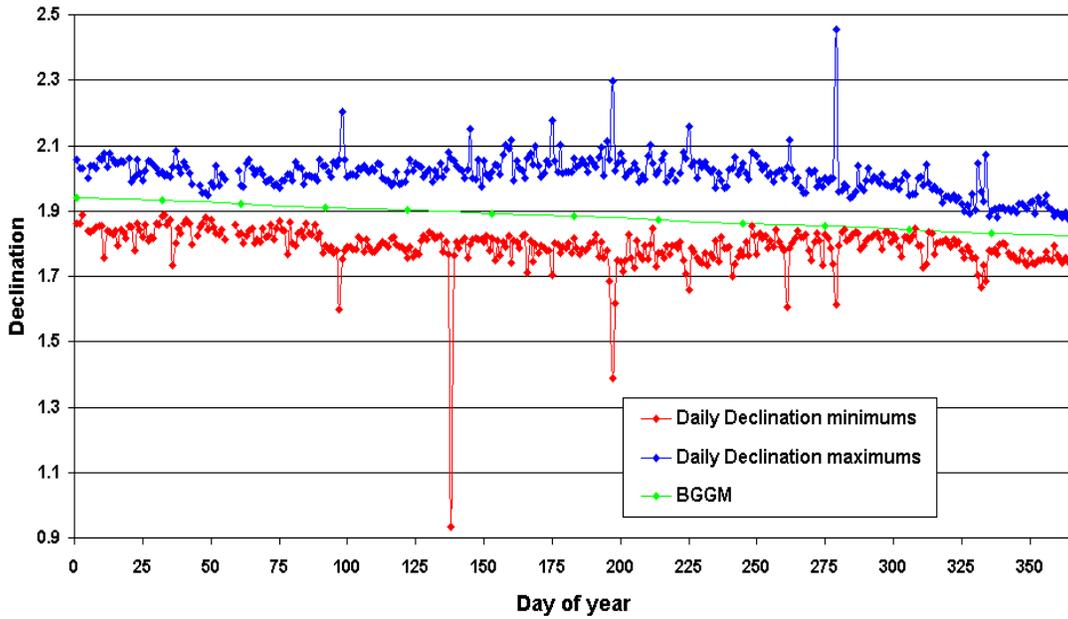


Fig. 1 - Daily Declination Variation 2000

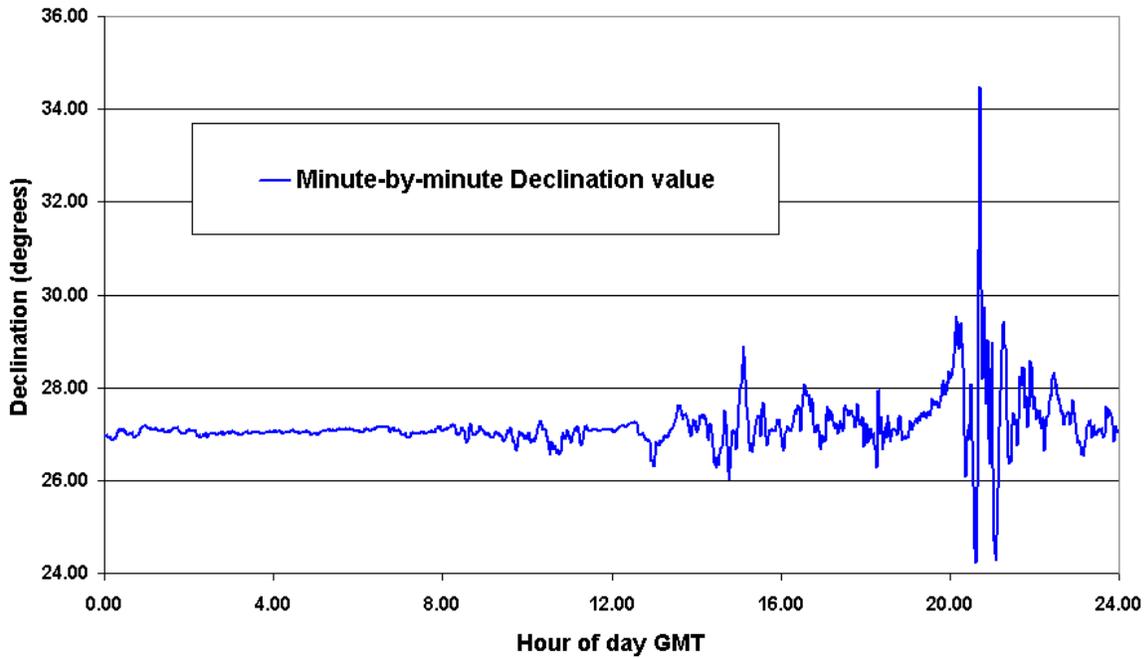


Fig. 2 – Declination Variation over 24 hours in Alaska

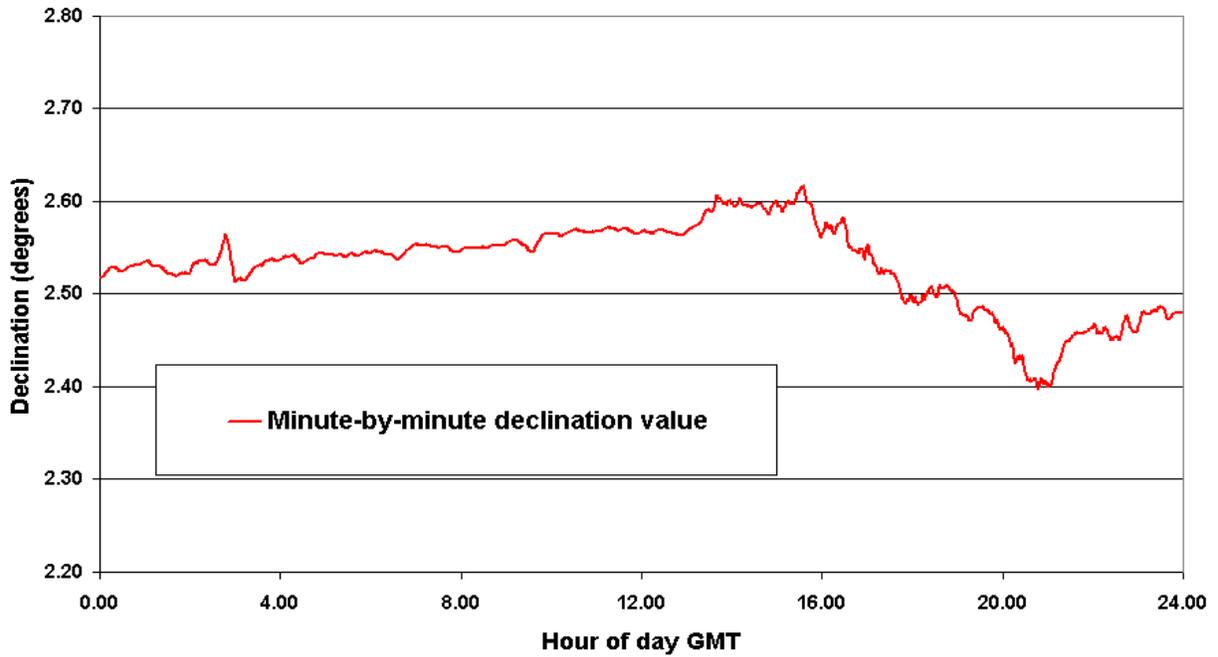


Fig. 3 – Declination Variation over 24 hours in the Gulf of Mexico



Example Well #	TD	TVD	VS @ azimuth	EOU major and minor axis dimensions at 95% confidence							
				GRS		Raw MWD		RIGS Gyro		CNSG in Drill pipe	
				Major	Minor	Major	Minor	Major	Minor	Major	Minor
1	23518'	23434'	833' @ 179°	7.5'	5.8'	21.6'	19.8'	15.7'	13'	37.7'	24.6'
2	23093'	22305'	3141' @ 219°	28'	18.2'	108.8'	43.9'	35.9'	22.6'	37.3'	26.9'
3	23805'	21860'	6236' @ 219°	50.8'	29.8'	321.2'	54.9'	72'	27'	113.8'	47.5'
4	26921'	25160'	6888' @ 67°	56.1	33.7'	383.7'	64.8'	85.4'	32'	132.8'	65'

Fig. 4 - Comparison of EOU sizes with various survey tool types

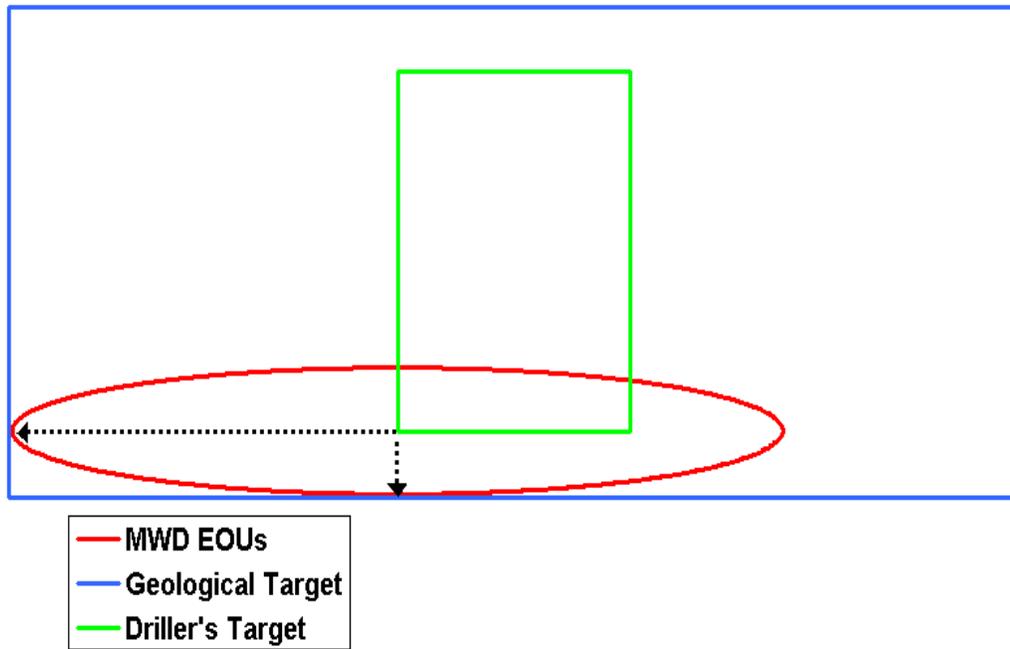


Fig. 5 - Target Sizing with MWD Ellipses

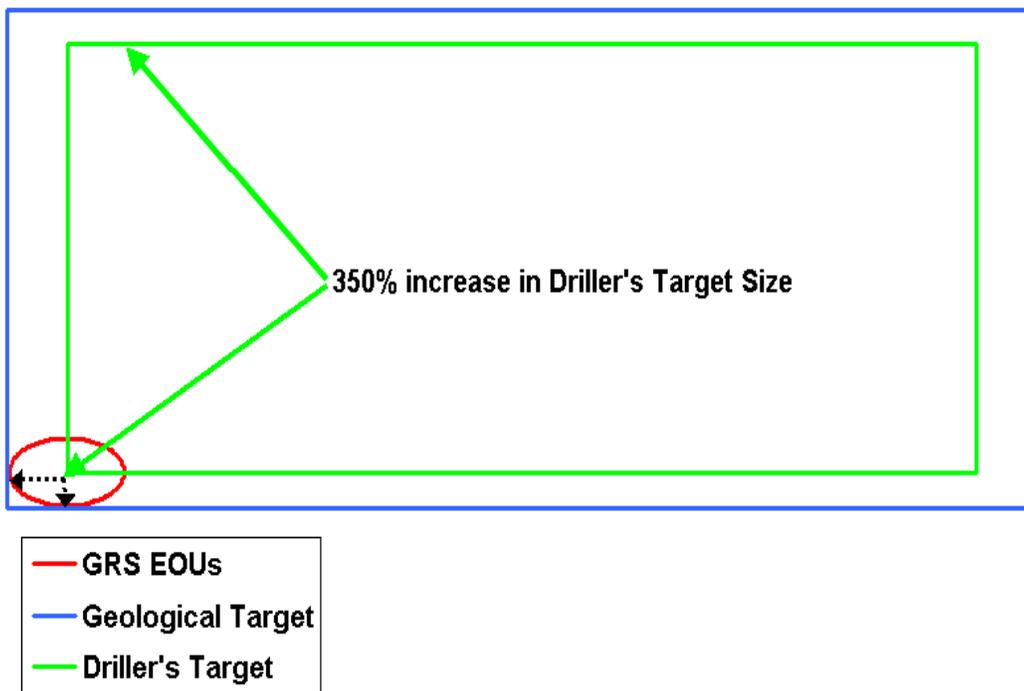


Fig. 6 - Target Sizing with GRS Ellipses

