# Appendix G: Gyroscopic Groundwater Well Deviation Report

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# Gyroscopic Well Deviation Surveys for the US Ecology Site

by

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to

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# Gyroscope Well Deviation Surveys for the U.S. Ecology Site

## 1 Introduction

Pacific Northwest Geophysics (PNG) acquired well path deviation surveys using a gyroscope logging probe in seven (7) wells at the U.S. Ecology site in Benton County, Washington.

This report includes the Gyro survey results for each well in tabular format (see section 3) and in graphical format (see Appendix A).

The gyroscope survey data was acquired to assay the well's deviation characteristics from vertical. Discussions of the gyro equipment and data processing are presented in section 2. Zero depth reference is at top of casing.

## 2 Gyroscope Equipment and Processing

The gyroscope probe is designed to assay deviations in the path of both dipping and vertical boreholes. The gyroscope probe has a diameter of 40 mm (1.575 in), a length of 1.65 m (5.42 ft), and weight of 5.9 kg (13 lbs). Two centralizers are used in holes with a diameter greater than 3.5 in.

The gyroscope survey was recorded both as the sonde was lowered into the borehole (in-run) and as it was retrieved (out-run). Data from the probe sensors are recorded in metric units at the rate of two samples per second. The logging speed is 10 meters/minute or less. At least four times each hour, during the survey, the hoist is momentarily halted to record the gyroscope drift rate at these stationary locations.

The gyroscope probe contains two high precision components: an inclinometer and a gyroscope. The inclinometer records the probe tilt (dip) with a precision of 0.01 degrees. The probe's orientation is determined by a very precise rate-gyro, with a precision of 0.0001 degrees.

The path of the borehole is derived by post-processing of the raw survey data, which is performed as follows:

- Identify the gyroscope drift rate and remove the drift component from the survey data.
- Use X-Y data from the inclinometer to compute probe dip (vertical is -90 degrees).
- Compute path of borehole: (Northing, Easting, Elevation [vertical depth], and Dip [tangent to borehole at each survey depth position]).

The survey result is the well path, which is presented graphically and has these components:

- 3-D Trajectory plot of XYZ (Northing and Easting versus Elevation).
- Plan view projection of Northing and Easting path of wellbore, looking down from the surface.
- X and Y deviation plots (2D plots of Northing versus depth and Easting versus depth).
- Gyro Survey Information in text format:
    - Coordinates at survey Top,
    - Coordinates at survey Base,
    - Maximum deviation (dip) angle and depth location,
    - Measured depth and Vertical depth at survey Base.

# 3 Gyro Survey Results

The following tables summarize the Gyroscope survey results. Table 1 contains the maximum deviation (dip) and the relationship between measure and vertical depth for each well. The remaining tables summarize the Gyroscope survey results, one table for each well.

**Table 1 Well Summaries**

| Well Name | Max Deviation & Depth [Dip, Depth] (degrees, meters) | Depth Measured (meters & feet) | Depth Vertical (meters & feet) | Difference Measure – Vertical (meters & feet) |
|---|---|---|---|---|
| MW-3 | 2.1 degrees at 93.5 meters | 93.476m (306.678ft) | 93.454m (306.606ft) | 0.022m (0.072ft) |
| MW-5 | 3.7 degrees at 94.1 meters | 94.117m (308.781ft) | 94.100m (308.725ft) | 0.017m (0.056ft) |
| MW-8 | 3.4 degrees at 97.1 meters | 97.115m (318.617ft) | 97.032m (318.345ft) | 0.083m (0.272ft) |
| MW-9 | 1.3 degrees at 97.5 meters | 97.532m (319.985ft) | 97.504m (319.893ft) | 0.028m (0.092ft) |
| MW-9A | 0.8 degrees at 97.5 meters | 97.522m (319.952ft) | 97.513m (319.923ft) | 0.009m (0.030ft) |
| MW-10 | 1.9 degrees at 98.3 meters | 98.347m (322.659ft) | 98.329m (322.600ft) | 0.018m (0.059ft) |
| MW-13 | 3.4 degrees at 94.0 meters | 93.998m (308.391ft) | 93.966m (308.286ft) | 0.032m (0.105ft) |

**Table 2 Gyroscope Survey Summary for Well MW-3**

| Depth (meters) | Northing (meters) | Easting (meters) | Elevation (meters) | Dip (degrees) |
|---|---|---|---|---|
| 1.022 | 0.02 | 0.00 | -1.022 | -88.98 |
| 10.008 | 0.09 | 0.04 | -10.007 | -89.67 |
| 20.037 | 0.09 | 0.10 | -20.036 | -89.54 |
| 30.004 | 0.04 | 0.17 | -30.003 | -89.36 |
| 40.034 | -0.02 | 0.24 | -40.032 | -89.38 |
| 50.037 | -0.10 | 0.38 | -50.034 | -88.61 |
| 60.031 | -0.24 | 0.55 | -60.026 | -88.54 |
| 70.008 | -0.39 | 0.77 | -69.999 | -88.32 |
| 80.020 | -0.59 | 1.04 | -80.005 | -87.85 |
| 90.031 | -0.78 | 1.30 | -90.011 | -88.02 |
| 93.476 | -0.84 | 1.41 | -93.454 | -87.88 |

**Table 3 Gyroscope Survey Summary for Well MW-5**

| Depth (meters) | Northing (meters) | Easting (meters) | Elevation (meters) | Dip (degrees) |
|---|---|---|---|---|
| 1.007 | 0.01 | 0 | -1.010 | -89.23 |
| 10.028 | 0.10 | 0.06 | -10.027 | -89.15 |
| 20.001 | 0.07 | 0.22 | -20.000 | -89.06 |
| 30.043 | -0.04 | 0.27 | -30.040 | -88.23 |
| 40.012 | -0.19 | 0.2 | -40.010 | -89.46 |
| 50.039 | -0.25 | 0.27 | -50.033 | -89.15 |
| 60.004 | -0.31 | 0.21 | -59.997 | -89.56 |
| 70.052 | -0.30 | 0.20 | -70.045 | -89.86 |
| 80.006 | -0.29 | 0.02 | -80.000 | -88.52 |
| 90.005 | -0.21 | -0.27 | -89.991 | -87.64 |
| 94.117 | -0.22 | -0.48 | -94.100 | -86.25 |

**Table 4 Gyroscope Survey Summary for Well MW-8**

| Depth (meters) | Northing (meters) | Easting (meters) | Elevation (meters) | Dip (degrees) |
|---|---|---|---|---|
| 1.014 | 0.02 | 0.00 | -1.014 | -88.90 |
| 10.015 | 0.16 | 0.00 | -10.014 | -89.11 |
| 20.012 | 0.37 | 0.06 | -20.008 | -88.51 |
| 30.025 | 0.61 | 0.21 | -30.017 | -88.44 |
| 39.997 | 0.84 | 0.38 | -39.985 | -88.30 |
| 50.035 | 1.10 | 0.54 | -50.018 | -87.99 |
| 60.035 | 1.46 | 0.71 | -60.010 | -87.33 |
| 70.021 | 1.88 | 0.94 | -69.985 | -87.08 |
| 80.039 | 2.32 | 1.27 | -79.987 | -86.52 |
| 90.039 | 2.76 | 1.70 | -89.969 | -86.54 |
| 97.115 | 3.02 | 2.03 | -97.032 | -86.58 |

**Table 5 Gyroscope Survey Summary for Well MW-9**

| Depth (meters) | Northing (meters) | Easting (meters) | Elevation (meters) | Dip (degrees) |
|---|---|---|---|---|
| 1.022 | 0.01 | 0.00 | -1.022 | -89.59 |
| 10.022 | 0.07 | -0.07 | -10.021 | -89.04 |
| 20.015 | 0.17 | -0.19 | -20.013 | -89.17 |
| 30.016 | 0.31 | -0.13 | -30.013 | -89.16 |
| 40.010 | 0.36 | 0.00 | -40.006 | -89.02 |
| 50.030 | 0.49 | 0.10 | -50.024 | -88.78 |
| 60.007 | 0.71 | 0.19 | -59.998 | -88.22 |
| 70.003 | 1.02 | 0.31 | -69.988 | -88.20 |
| 80.005 | 1.31 | 0.40 | -79.986 | -87.49 |
| 90.015 | 1.66 | 0.47 | -89.989 | -88.22 |
| 97.532 | 1.85 | 0.51 | -97.504 | -88.69 |

**Table 6 Gyroscope Survey Summary for Well MW-9A**

| Depth (meters) | Northing (meters) | Easting (meters) | Elevation (meters) | Dip (degrees) |
|---|---|---|---|---|
| 1.005 | 0.01 | 0.00 | -1.005 | -89.62 |
| 10.000 | 0.07 | 0.06 | -10.000 | -89.11 |
| 20.026 | 0.10 | 0.14 | -20.025 | -89.84 |
| 30.005 | 0.12 | 0.16 | -30.004 | -89.88 |
| 40.061 | 0.16 | 0.26 | -40.059 | -89.61 |
| 50.014 | 0.04 | 0.37 | -50.011 | -87.96 |
| 60.034 | -0.16 | 0.43 | -60.028 | -89.17 |
| 70.034 | -0.28 | 0.47 | -70.027 | -88.83 |
| 79.016 | -0.44 | 0.44 | -79.008 | -89.24 |
| 90.001 | -0.53 | 0.41 | -89.992 | -89.45 |
| 97.522 | -0.55 | 0.34 | -97.513 | -89.21 |

**Table 7 Gyroscope Survey Summary for Well MW-10**

| Depth (meters) | Northing (meters) | Easting (meters) | Elevation (meters) | Dip (degrees) |
|---|---|---|---|---|
| 1.017 | 0.01 | 0.00 | -1.017 | -89.22 |
| 10.010 | 0.17 | -0.01 | -10.008 | -88.59 |
| 20.014 | 0.34 | 0.05 | -20.011 | -88.85 |
| 30.005 | 0.48 | 0.06 | -30.001 | -89.39 |
| 40.058 | 0.58 | 0.13 | -40.053 | -89.35 |
| 50.038 | 0.69 | 0.26 | -50.031 | -88.78 |
| 60.017 | 0.83 | 0.44 | -60.008 | -88.69 |
| 70.029 | 0.94 | 0.60 | -70.018 | -89.07 |
| 80.033 | 1.05 | 0.73 | -80.020 | -89.03 |
| 90.047 | 1.20 | 0.86 | -90.032 | -88.45 |
| 98.347 | 1.39 | 1.01 | -98.329 | -88.13 |

**Table 8 Gyroscope Survey Summary for Well MW-13**

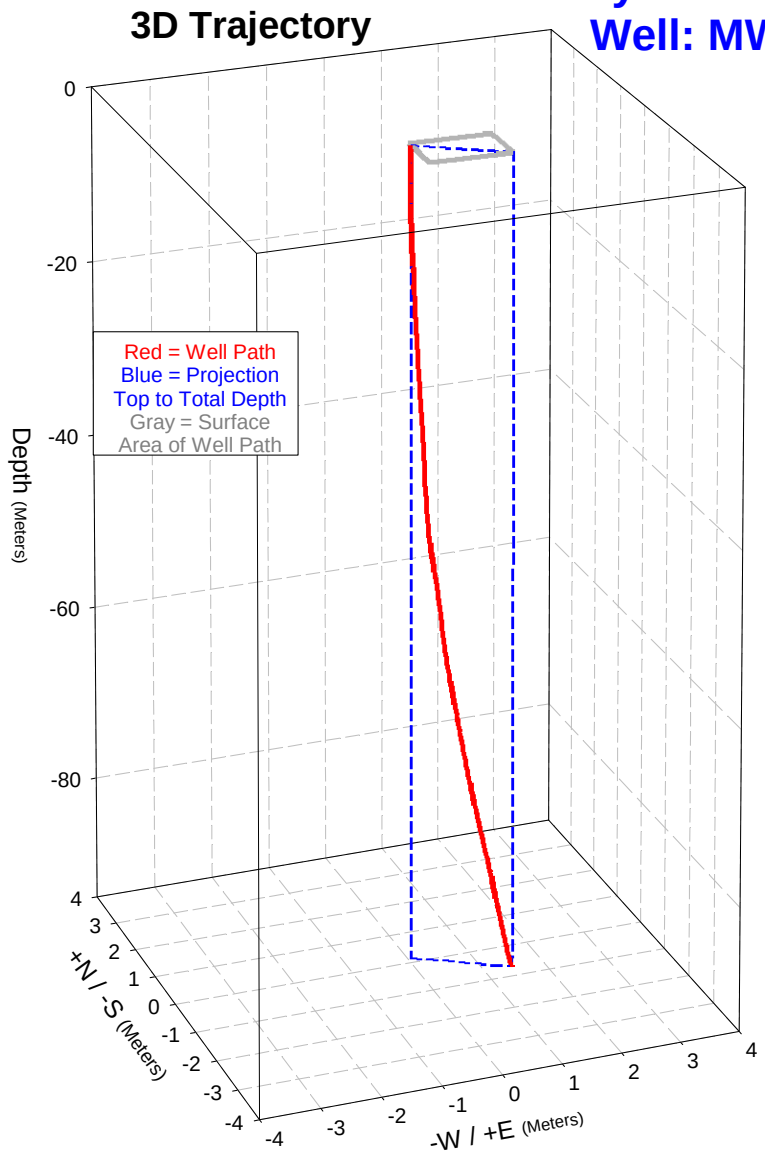
| Depth (meters) | Northing (meters) | Easting (meters) | Elevation (meters) | Dip (degrees) |
|---|---|---|---|---|
| 1.000 | 0.01 | 0.00 | -1.000 | -89.44 |
| 10.005 | 0.09 | 0.02 | -10.005 | -89.44 |
| 20.039 | 0.15 | 0.06 | -20.038 | -90.01 |
| 30.038 | 0.15 | 0.07 | -30.037 | -89.80 |
| 40.011 | 0.15 | 0.11 | -40.010 | -89.82 |
| 50.028 | 0.15 | 0.20 | -50.027 | -89.18 |
| 60.000 | 0.08 | 0.43 | -59.996 | -88.31 |
| 70.006 | 0.00 | 0.74 | -69.997 | -88.29 |
| 80.014 | -0.11 | 1.07 | -79.999 | -87.45 |
| 90.025 | -0.30 | 1.51 | -89.998 | -87.07 |
| 93.998 | -0.39 | 1.69 | -93.966 | -86.56 |

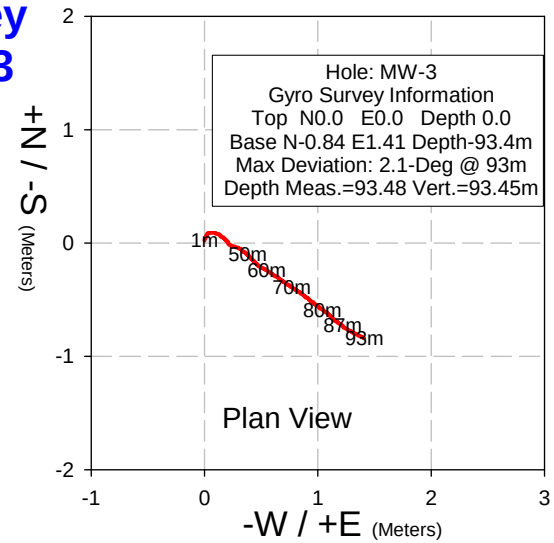
# Appendix A: Gyroscope Well Deviation Survey Results

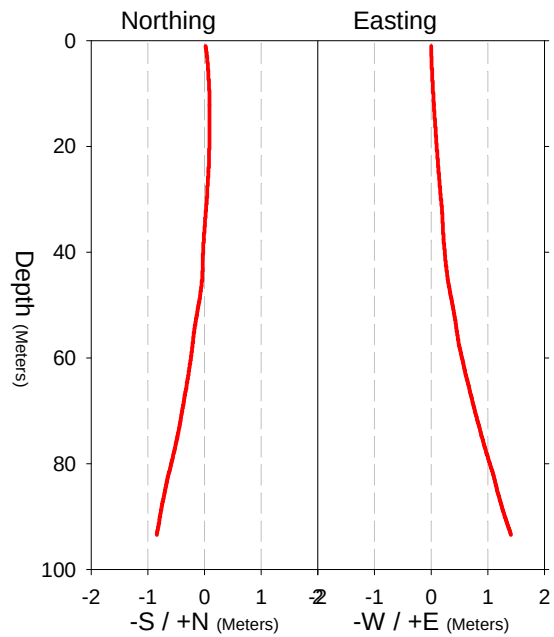
Survey plots for the Gyroscope well path logging sonde follow for the 7 wells. The plots show the borehole path as:

- 3-D Trajectory plot of XYZ (Northing and Easting versus Depth in meters). Also two projections are shown (1) Blue dashed line from start location to ending location of well path, (2) Gray solid line at surface is rectangle that encompasses the starting location and projected ending location of well.
- Plan view projection of Northing and Easting (looking down from the surface).
- X and Y deviation plots (2D plots of Northing and Easting versus Depth in meters).

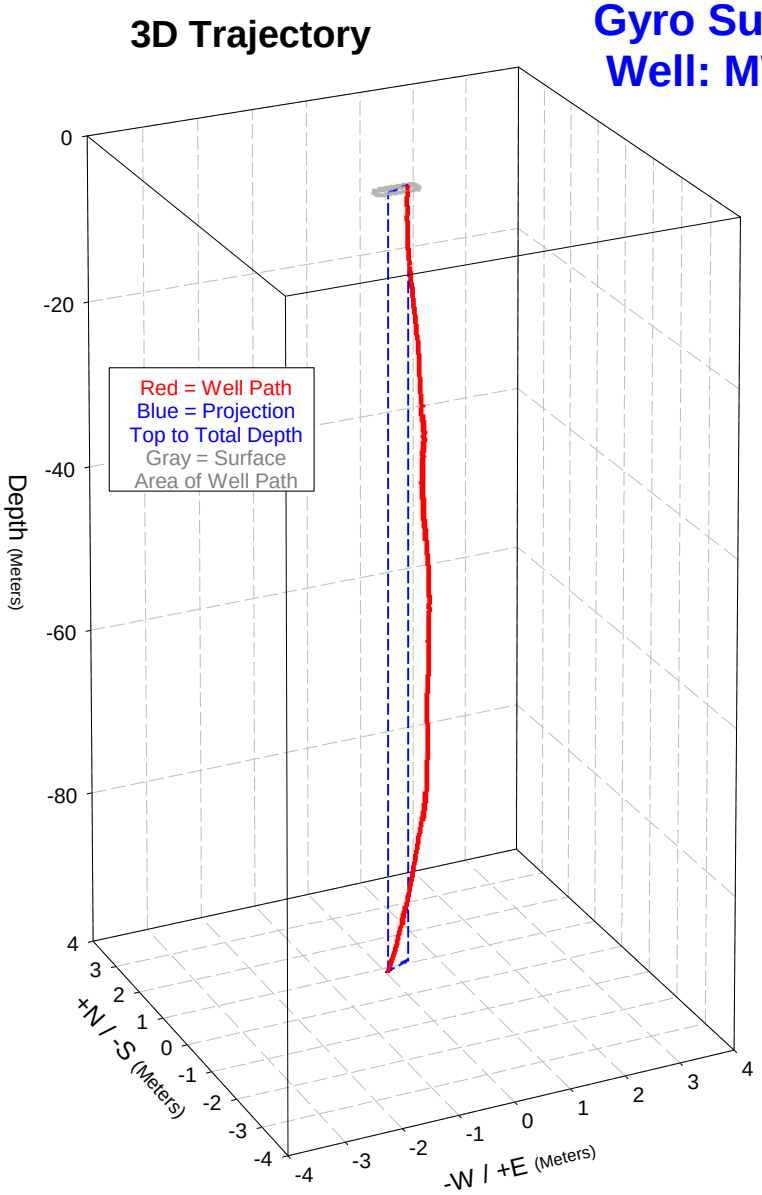
# Gyro Survey
# Well: MW-3

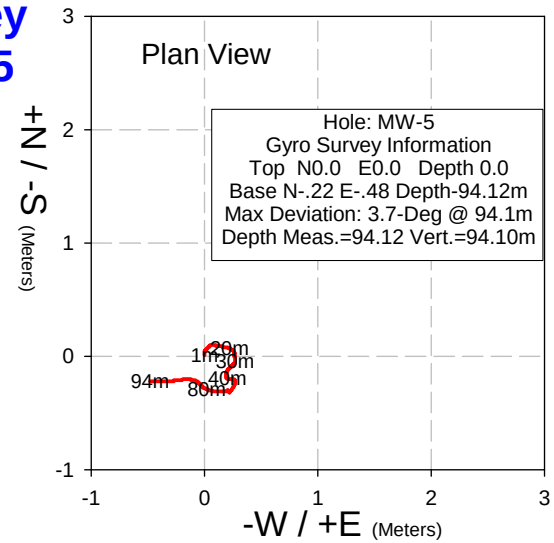


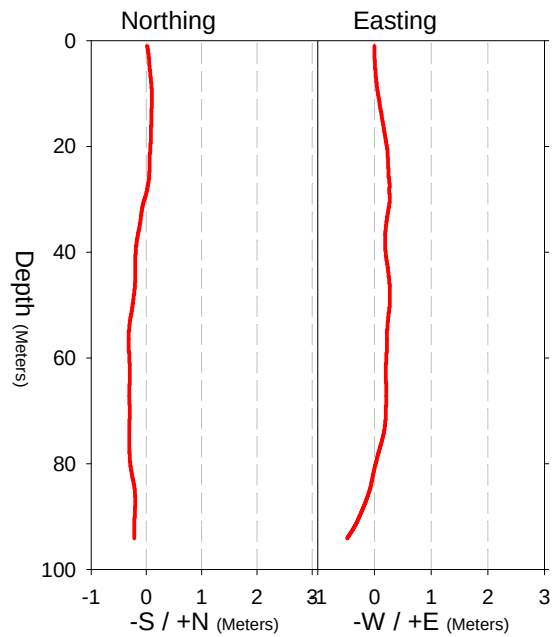



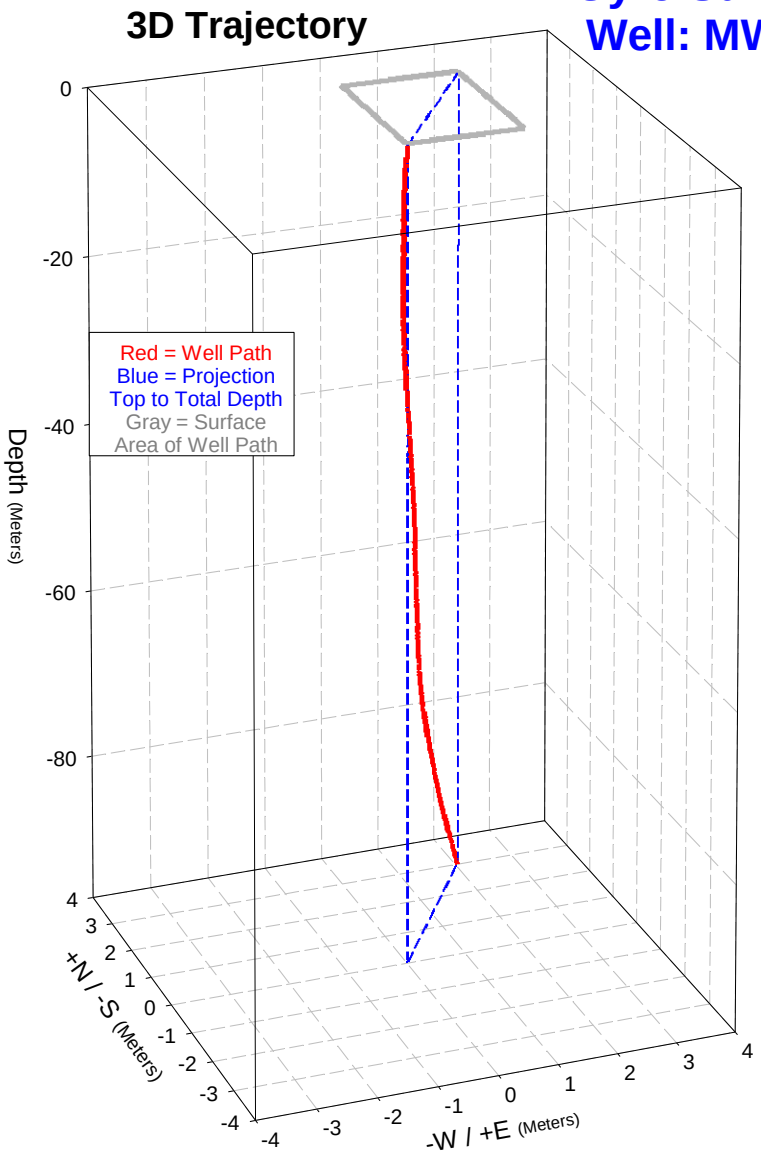
# Gyro Survey
# Well: MW-5

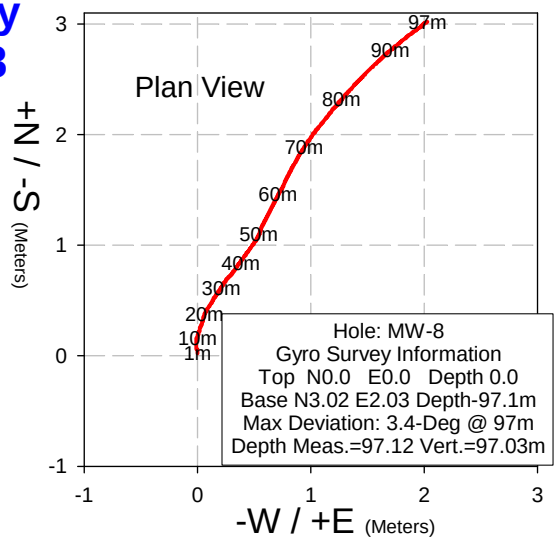


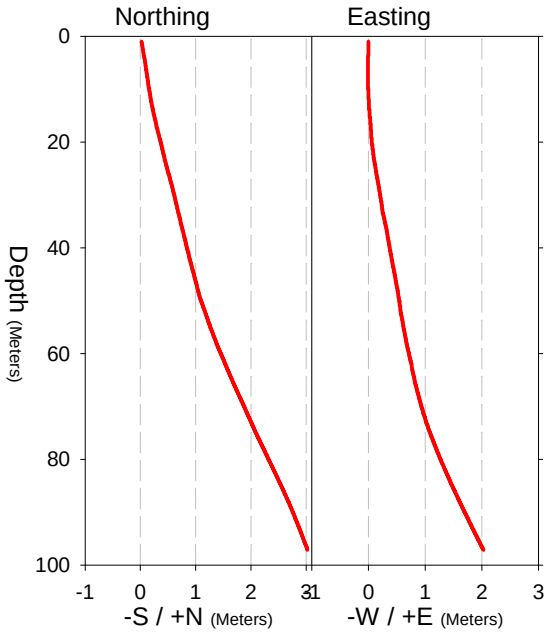



# Gyro Survey
# Well: MW-8



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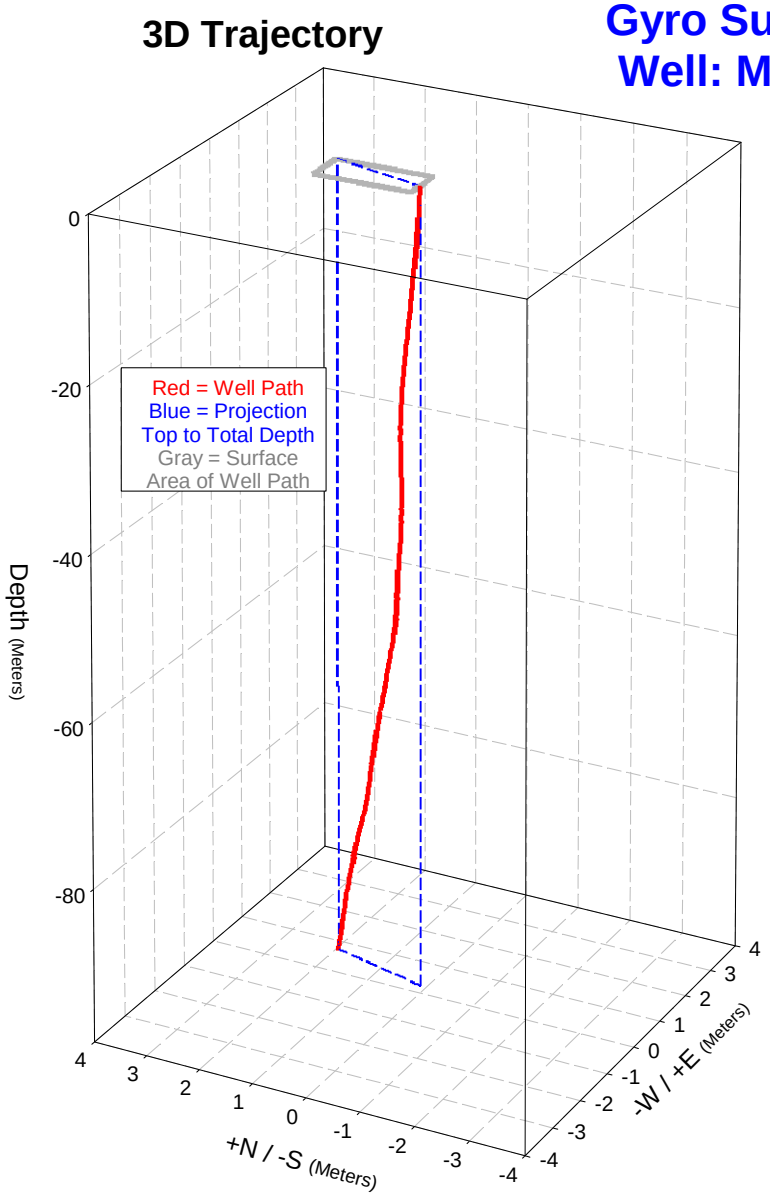
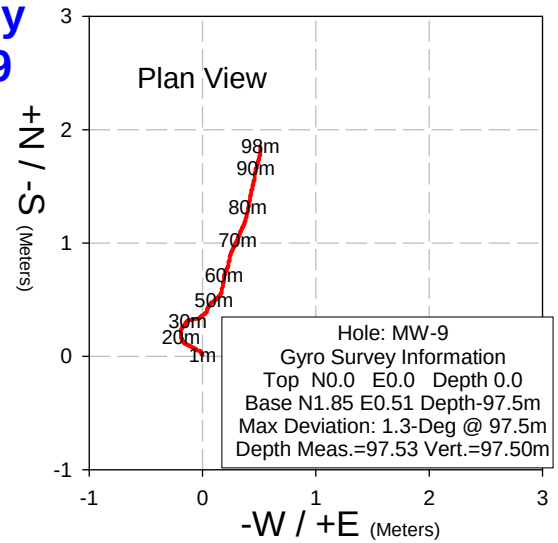
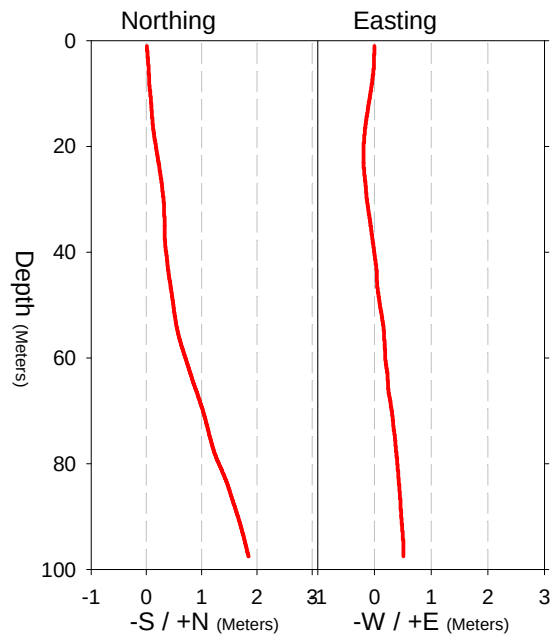
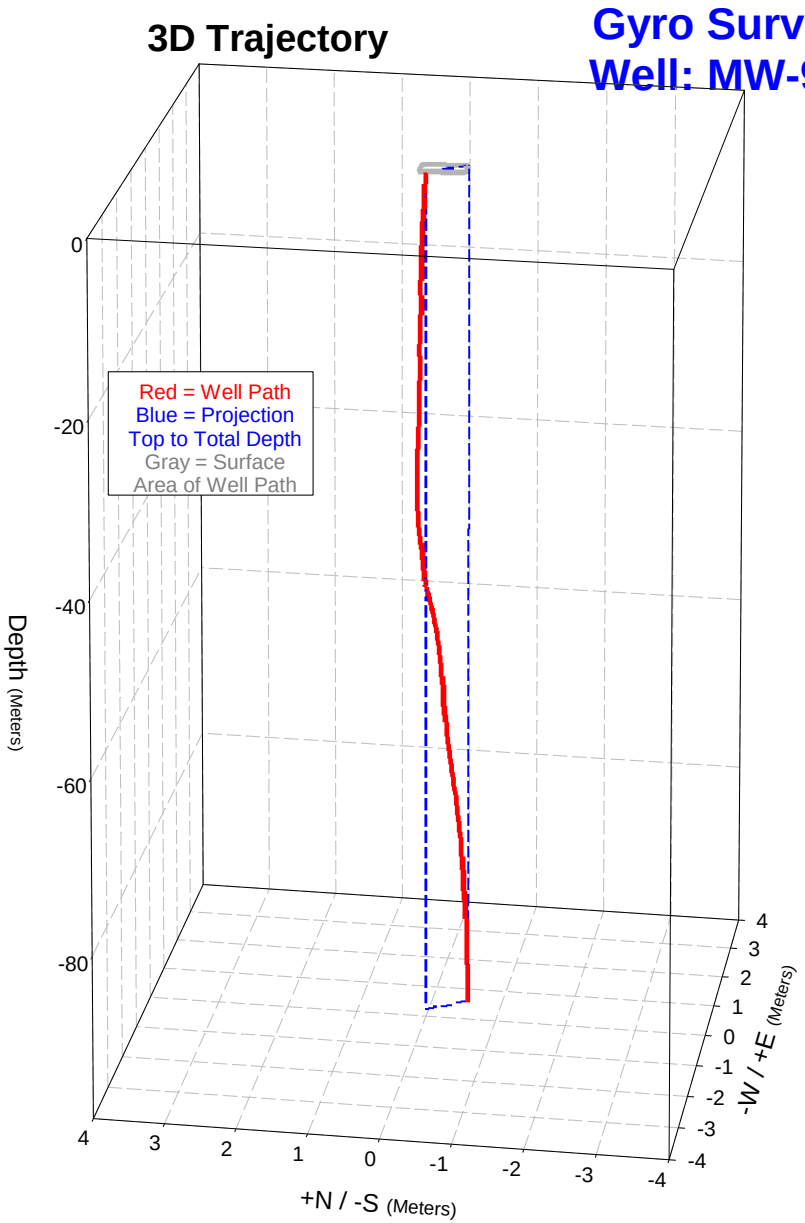
# Well: MW-9

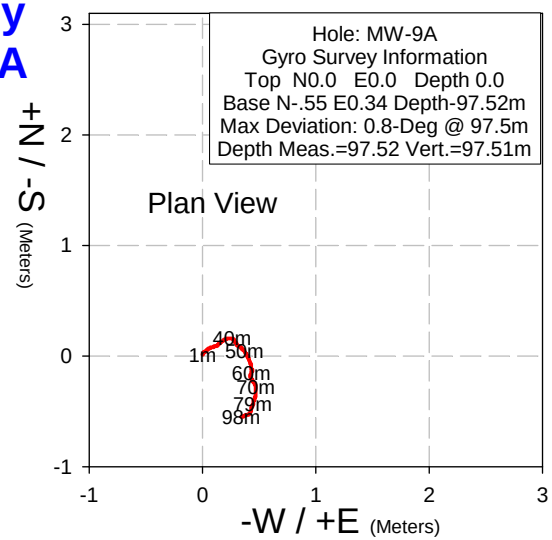


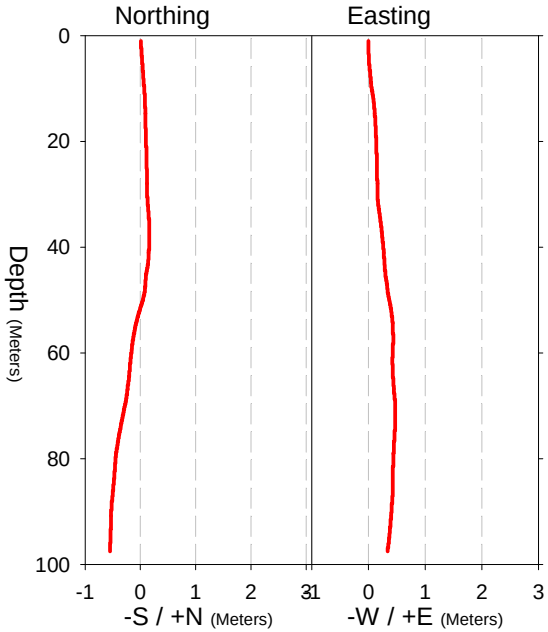



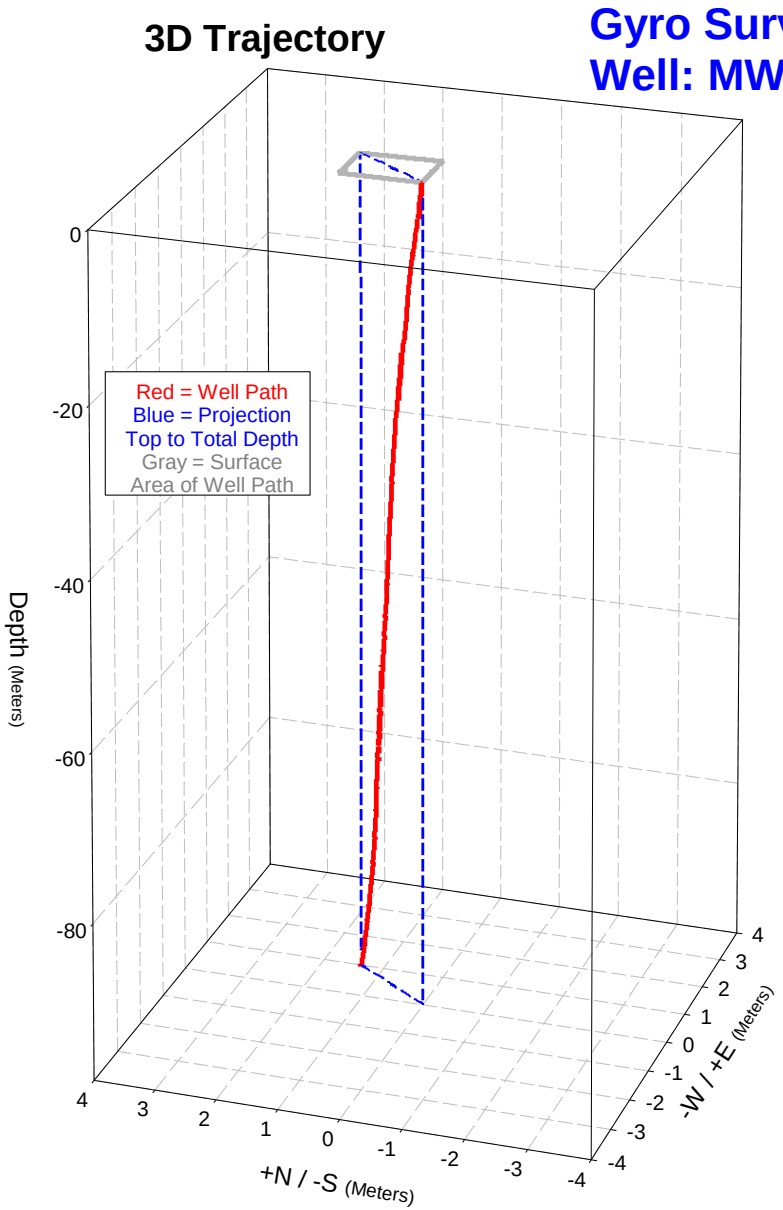
# Gyro Survey
# Well: MW-9A

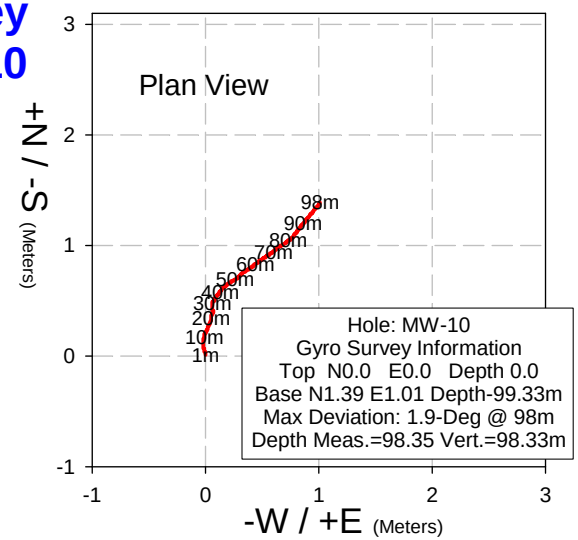


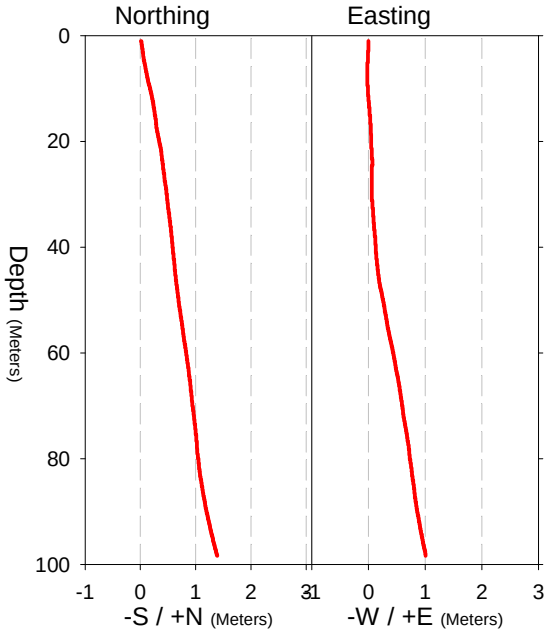
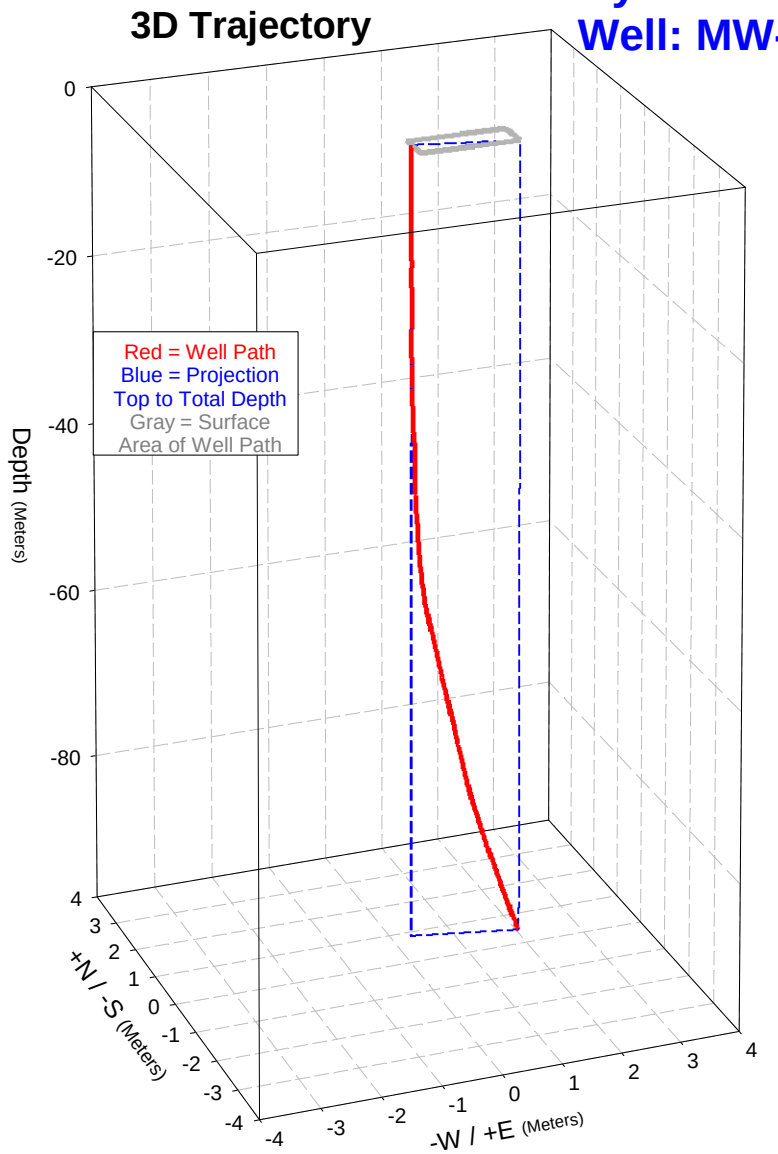
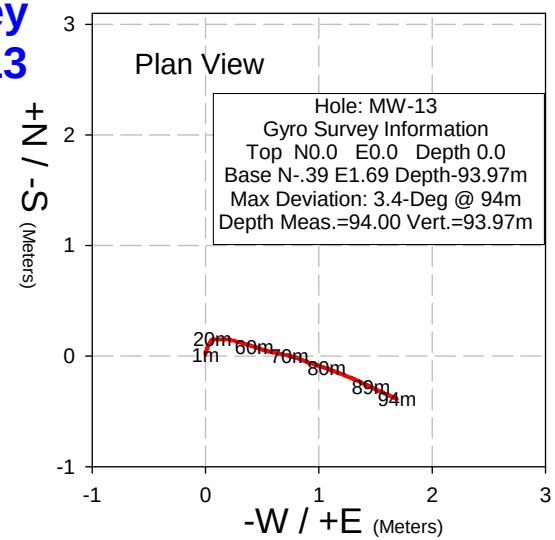
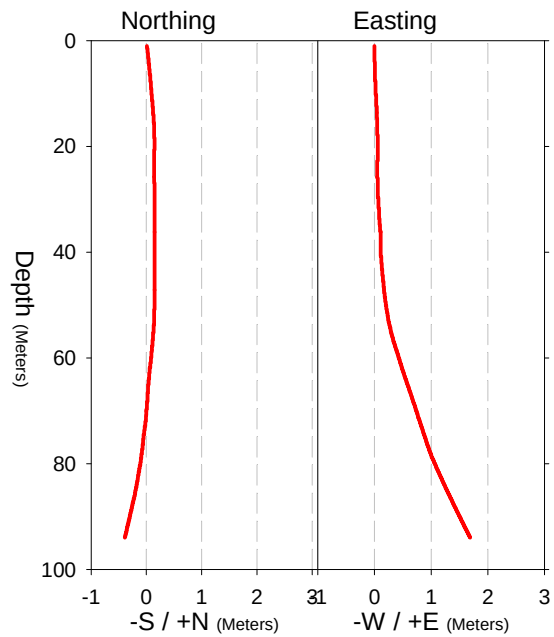



# Gyro Survey
# Well: MW-10






# Gyro Survey
# Well: MW-13