Statics

This chapter explains how datum statics are used in the ProMAX® processing system. The chapter contains information to compute datum trace statics, force the application of any fractional static values remaining in the trace header, apply monitor phone shift times and user statics, calculate static shifts to align seismic events, specify and apply lists of hand input static corrections, and apply statics to traces from header words or apply bulk shift statics. It also explains how to flatten a stacked section to a specified horizon, save monitor phone pick times, adjust previously applied statics to compensate for uphole surveys, and calculate static shifts necessary to align events on multiple shots.

In This Chapter

➲ Statics Overview
➲ Apply Elevation Statics
➲ Apply Fractional Static
➲ Apply Monitor Phone Shifts
➲ Apply User Statics
➲ Datum Statics Apply
➲ Datum Statics Calculation
➲ Event Alignment in Window
➲ Hand Statics
➲ Header Statics
➲ Horizon Flattening
➲ Save Monitor Phone Times
➲ Up-hole Statics Adjustment
➲ VSP Level Statics
Statics Overview

Static corrections are applied to seismic data to compensate for the effects of variations in elevation, weathering thickness, weathering velocity, or reference to a datum. The objective is to determine the reflection arrival times which would have been observed if all measurements had been made on a (usually) flat plane with no weathering or low-velocity material present. These corrections are based on uphole data, refraction first-breaks, or event smoothing.

ProMAX® Statics Processes

The ProMAX® processing system offers four processes to compute and apply elevation statics:

- **Apply Elevation Statics** calculates and applies shot and receiver statics to the floating or final datum.

- **Apply Refraction Statics** is used if shot and receiver statics to a final datum have been previously calculated using **Refraction Statics**. In this case, shot and receiver statics exist in the SIN and SRF OPFs.

- **Apply User Statics** is used if you have previously calculated shot and receiver statics by a method outside of the ProMAX® processing system, and imported the statics into the database. Statics must be imported to the OPF with the attribute name, USERSTAT.

- **Datum Statics Calculation** computes elevation statics or inputs refraction statics at final datum, and outputs source and receiver statics to final datum and CDP statistics to floating datum.

These processes accomplish the following steps for proper application of elevation statics:

1. Remove previously applied statics.

2. Compute elevation statics to shift the seismic data from original recorded times to a time reference, as if the data were recorded on a final datum using a replacement (usually constant) velocity.

3. Compute the floating datum to use as the processing datum. You must specify the final datum elevation, datum
velocity, and elevation smoother length for the floating datum calculation.

4. Partition the statics into two parts: the Pre NMO and Post NMO terms relative to the floating datum.

5. Apply the Pre NMO terms of the statics and update the trace headers, NA_STAT and TOT_STAT.

Glossary

Before we go into detail for computing and applying elevation statics, we provide the following diagrams, terminology, and definitions of the database attributes:

Datum Statics Terminology

Final Seismic Reference -- (Achieved Post Stack)
Datum
Datum Statics Attributes

N_DATUM = Floating Datum or NMO datum or Processing Datum
F_DATUM = Final Datum or Seismic Reference Datum
S_STATIC = \( \frac{F\_DATUM - ELEV + DEPTH}{DATUMVEL} \)
R_STATIC = \( \frac{F\_DATUM - ELEV + DEPTH}{DATUMVEL} \) \cdot UPHOLE
C_STATIC = \( 2 \cdot \frac{N\_DATUM - F\_DATUM}{DATUMVEL} \)

Trace Header Values
N_DATUM = floating datum or NMO datum
NMO_STAT = S_STATIC + R_STATIC + C_STATIC
FNL_STAT = - C_STATIC
TOT_STAT = cumulative applied statics
NA_STAT = statics less than one sample period which are not-yet-applied

For example, if TOT_STAT = 21.2 ms, and the sample period is 4 ms, NA_STAT = 1.2 ms
Database Attributes

The stat_math files establish the following database attributes:

- **N_DATUM** is the floating datum. It is established in the CDP database order. N_DATUM is set to equal F_DATUM if final datum is selected.

- **F_DATUM** is the final datum. You will enter this value. This datum may be constant or may vary laterally for 2D data. Traces are shifted to the final datum when data is stacked if you select a floating (NMO) datum.

- **DATUMVEL** is the replacement velocity. You will enter this velocity as a constant or laterally varying for 2D data.

- **VWEATH** is the weathering velocity from the surface to the base of the shothole. This velocity is used to calculate travelt ime to the base of the shot, if upholes are unreliable.

- **S_STATIC** is the shot static from base of shot to the final datum.

- **R_STATIC** is the receiver static from the elevation of the receiver station to the final datum.

- **C_STATIC** is a two-way static correction that shifts traces between final datum and floating datum. This static is set to 0 if a final datum is selected.

  \[ \text{Note: } FNL_{\text{STAT}} = - C_{\text{STATIC}}. \]

Trace Header Attributes

The stat_math files establish the following trace header attributes:

- **N_DATUM** is the floating datum. It is established in the CDP database order. N_DATUM is set to equal F_DATUM if the final datum is selected as the processing datum instead of using the NMO Datum. NDATUM in the trace headers and NDATUM in the database are equal.

- **FNL_STAT** is a two-way static correction that shifts traces between floating datum and final datum. This static is set to 0 if a final datum is selected as the processing datum instead of the NMO Datum.
**Note:** The trace header attribute FNL_STAT = -C_STATIC.

This static shift is applied to the traces during **CDP/Ensemble Stack, Stack 3D**, or **DMO Stack 3D** after the stack traces are completed.

- **NMO-STAT** is the portion of the total static correction to apply before NMO. This time correction redatums traces to appear as if the shots and receivers were on a smooth surface (N_DATUM) when the data were recorded. NMO_STAT is a high-frequency static, intended to remove the short period statics within a CDP that cause misalignment during stacking.

NMO_STAT is computed as follows:

\[
\text{NMO_STAT} = S_{\text{STATIC}} + R_{\text{STATIC}} + C_{\text{STATIC}}
\]

S_STATIC and R_STATIC are statics to the final datum, and C_STATIC shifts the trace from final datum to N_DATUM. This static shift is applied to all traces when you execute a ProMAX® statics correction process.

- **TOT_STAT** is the total cumulative static applied to the trace. For example, after executing **Apply Elevation Statics**, TOT_STAT is equal to the static applied by elevation statics. After executing **Apply Residual Statics**, TOT_STAT is updated to the sum of elevation statics and the residual statics for that trace. Each trace is shifted by the nearest integer number of samples in TOT_STAT. The fractional portion of TOT_STAT will be held in the header word NA_STAT.

- **NA_STAT** is the fractional portion of TOT_STAT not applied to the trace. This is normally a fraction of a sample interval. The NA_STAT static is normally applied as part of the NMO application, so data is interpolated once. When NMO is applied, NA_STAT will be set back to 0.

- **SKEWSTAT** is a channel-dependent static which corrects for multiplex channel skew. Skew is caused by the time delay in instruments as each channel is scanned. The value of this static ranges from a tiny fraction of the sample interval to just less than one sample interval. Most modern systems have near-zero skew statics.

**Note:** SKEWSTAT is automatically applied when TOT_STAT is initialized.
Computing Elevation Statics

These processes accomplish the following steps for computing elevation statics:

Remove Previously Apply Statics

In a situation where a static is applied to the data prior to elevation statics, such as a shot delay static, the TOT_STAT header entry must be set back to zero with Trace Header Math.

The static correction processes will shift trace data to remove static values in the TOT_STAT header entry and TOT_STAT will be set back to zero. To avoid this situation, it is advised that any hand statics be applied after executing the ProMAX® static correction processes.

Compute Elevation Statics

The following is a description of the standard method of computing elevation statics:

1. Stripping off the weathering layer.

   This step is used if reliable shot hole depths and uphole times exist. The shot datum is created by interpolating the shot hole depths to every surface location, and then subtracting each shot hole depth value from the surface location elevation. Shot elevations are defined as the elevation of the surface at the shot position. All receivers are then moved from the surface to the shot datum, using the uphole times and the difference between the shot elevations and the surface location elevations.

   If you do not use uphole times, you can use shot depths and enter a weathering velocity to compute the weathering times.

   You can also directly move shots and receivers from the surface to final datum for surface shooting such as vibroseis. See the next step.

2. Filling in (or stripping off) the topography.

   Topography is filled in by moving sources and receivers to the final datum using the replacement velocity. This step is used if the final datum is above the shot datum or stripped off if the final datum is below the shot datum.
Both the final datum and the replacement velocity may vary spatially.

3. Creating the NMO Datum.

NMO Datum is created by two methods. The first method computes the NMO datum by smoothing the surface elevations. In the second method, the NMO datum results from adding a vertical distance to the FNL_DATUM. This distance is computed by multiplying the replacement velocity times the average of source and receiver statics for each CDP, then smoothed the distances in the CDP domain. You can enter the length of the smoothing operator.

The purpose of the NMO datum is to allow velocity picking and NMO correction with minimal trace shifting. This minimizes the error in the model of hyperbolic reflection events.

4. Moving to the NMO Datum.

Before velocity picking or NMO correction, traces are moved to processing datum (N_DATUM) by CDP surface location, using C_STATIC= (Elevation of processing datum - Elevation of final datum) / Replacement Velocity.

5. Return to the Final datum.

After NMO correction and before residual statics or CDP stacking, the traces are moved from N_DATUM to the final datum by CDP surface location, using header value FNL_STAT = - C_STATIC.

Computing Elevation Statics Using a Stat_math File

The ProMAX® static correction processes use a stat_math file to compute elevation statics. These files use information previously supplied to the database by geometry assignment, as well as user-supplied parameters, such as final datum, replacement velocity, weathering velocity, and the number of stations to smooth to establish OPF attributes.

There are several stat_math files that you can use to calculate elevation statics, depending on the method you choose for calculation. The available stat_math files are:

- elev_stat_math is the default stat_math file. This file does conventional statics calculation using shot depths and uphole times. To use this method, select the **Shot**
Holes Using Uphole Info option for the Database math method parameter in Apply Elevation Statics.

- `noup_stat_math` is used to estimate uphole times based upon a weathering velocity that you enter plus shot depths. You use this method if you have little confidence in the uphole times in the observers logs. To use this method, select the Shot Holes Ignoring Uphole Times option to Database math method in Apply Elevation Statics.

- `surf_stat_math` is used when you do not want to weather strip. In this method, shots are assumed to be at or near the surface; uphole times and shot depths are not used. To use this method, select the Surface Source option to Database math method in Apply Elevation Statics.

- `ref_stat_math` is used by database math to calculate refraction statics. Apply Refraction Statics uses this file.

- `user_stat_math` is a file that you have customized to calculate elevation statics. This file is used in Apply Elevation Statics and Apply User Statics.

These files contain most of the same information and reside in $PROMAX_HOME/port/misc directory.

During elevation statics calculation, the stat_math files are imported, modified, and then output to an elev_statics file, which is created in your Area and Line subdirectory. The elev_statics file is then used to apply elevation statics. This file can also be used in DBTools to display and analyze the elevation statics.

**Note:** Since the ProMAX® statics correction processes output their modifications to elev_statics, you cannot run more than one of these processes in a flow.

The following is a description of the conventional procedure using the elev_stat_math file:

1. Establish receiver static to the final datum.

   Database values for shot depth and uphole times are projected into the receiver domain. Values for receiver locations are interpolated based on $x,y$ coordinates. The receiver static is initially set to the uphole time. This portion of the static is effectively stripping off the weathering. In the case of surface acquired data, this
portion of the receiver static is 0. The remainder of the receiver static is the travel time from the base of the shot to the final datum. This traveltime is the difference between ELEV - DEPTH and F_DATUM, divided by DATUMVEL. Units of time are converted to ms.

2. Establish shot static to the final datum.

In the shot domain, calculate W_ELEV=ELEV-DEPTH, or the surface elevation at each shot location, which is considered the base of weathering. S_STATIC is the difference between W_ELEV and F_DATUM divided by DATUMVEL. Units of time are converted to ms.

3. Establish static shift to the floating datum.

ELEV, F_DATUM, and DATUMVEL are projected into the CDP domain from SRF. Two methods are available to compute C_STATIC and N_DATUM:

- **Elevations**: Smooth N_DATUM and compute C_STATIC based on the difference between N_DATUM and F_DATUM using the replacement velocity.

  This option to create the NMO datum. Surface elevations are smoothed over a number of stations to create N_DATUM. The difference between floating datum and final datum divided by the replacement velocity is the one way traveltime from the final to the floating datum. This value is doubled and converted to ms to create C_STATIC. Each trace contributing to a CDP will get the same C_STATIC.

- **Mean statics**: Compute the mean of the source and receiver statics for each CDP, smooth, and load into C_STATIC. Recalculate N_DATUM based on C_STATIC, F_DATUM, and the replacement velocity.

  If **mean static** is selected, C_STATIC for a CDP is derived from the mean of all S_STATIC and R_STATIC contributing to that CDP. These means are then smoothed over a number of CDPs. This result is multiplied by two to give the two-way static, C_STATIC. As mentioned above, each trace contributing to a CDP will get the same two-way C_STATIC. Since C_STATIC is the two-way time difference between the final datum and the floating datum, it can be used to calculate N_DATUM. The product of C_STATIC and the replacement velocity is divided by 2000 to get the
difference between the final datum and the floating datum in the correct units of measure. This difference, in feet or meters, plus the final datum elevation yields N_DATUM.

**Partition Statics**

In the case of varying topography, processing is typically referenced to a floating datum to avoid distortion of the hyperbolic shape of reflection events. Data processed relative to a floating datum are not shifted to the final datum until **CDP/Ensemble Stack, Stack DMO**, or **Stack DMO 3D** is executed in a flow. The ProMAX® processing system allows prestack processing to reference to either a floating datum plane or a final datum plane. We do this by partitioning the statics into two parts: the Pre NMO and Post NMO terms relative to the floating datum.

**Partitioned Trace Headers**

After the database attributes are established in the stat_math files, the static correction processes use these OPF attributes to compute the following trace header entries:

- **NMO_STAT** is the static shifting the trace data to a floating datum, N_DATUM. This is a pre NMO term.

  \[ \text{NMO_STAT} = S_{STATIC} + R_{STATIC} + C_{STATIC} \]

  S_STATIC and R_STATIC are statics to the final datum, and C_STATIC shifts the trace from final to N_DATUM. This static shift is applied to all traces when you execute a ProMAX® statics correction process.

- **FNL_STAT** is the two-way static that shifts each trace from N_DATUM to F_DATUM. This is a post NMO term.

  \[ \text{FNL_STAT} = 0 - C_{STATIC} \]

  This static shift is applied to traces during **CDP/Ensemble Stack, Stack DMO**, or **Stack DMO 3D**.

**Applying Elevation Statics**

When you execute one of the elevation static correction processes, the appropriate static shift is applied to trace data. In traditional processing systems, statics are usually applied immediately to traces, often resulting in several interpolations of traces prior to final stack. In addition to
adding significantly to total processing CPU time, these multiple interpolations can result in a loss of fidelity in the final stacked traces. This problem may be especially acute when the sample rate for processing is coarse relative to the maximum coherent frequency. In order to avoid these problems, static shifts in the ProMAX® processing system are normally made to the nearest sample. However, no accuracy is actually lost in the processing since NA_STAT is incorporated into the NMO correction interpolation. NA_STAT is also used by all programs that require corrected traces, including all residual statics and velocity analysis processes.

Whenever a static is actually applied, the following sequence occurs:

- \( \text{TOT_STAT} = \text{TOT_STAT} + \text{new static} \)
- \( \text{NA_STAT} = \text{NA_STAT} + \text{new static} \)
- \( \text{ISHIFT} = \text{NINT} \left( \frac{\text{NA_STAT}}{\text{SAMPRATz}} \right) \) where: \( \text{ISHIFT} = \) Nearest sample shift, \( \text{NINT} = \) Nearest Integer, and \( \text{SAMPRATz} = \) Sample Rate.

A static of ISHIFT samples is then applied to the trace. The value of NA_STAT is reset to the remaining fraction of a sample.

- \( \text{NA_STAT} = \text{NA_STAT} - \text{ISHIFT} \times \text{SAMPRATz} \)

**Initializing TOT_STAT and NA_STAT**

Two processes initialize trace header static words. These are **Tape Input** and **Disk Data Input**. In most cases NA_STAT, TOT_STAT, and SKEWSTAT are set to zero. If the NA_STAT is present, it is loaded into TOT_STAT and NA_STAT. The SKEWSTAT value is zeroed or set to the value from the input data. If the NA_STAT is not present, and a SKEWSTAT is present, the SKEWSTAT, TOT_STAT, and NA_STAT are set to the SKEWSTAT value. If NA_STAT is zero, all three header words are set to zero. No other header static words are initialized at this time.

When the ProMAX® processing system computes elevation or refraction statics, two key header words are created: NMO_STAT and FNL_STAT. NMO_STAT is a high-frequency static, intended to remove the short period statics within a CDP that cause misalignment during stacking. FNL_STAT is a low-frequency or long period static which is automatically
applied during CDP stacking. FNL_STAT moves the trace to the final datum. It has the same value for all traces in a CDP.

The NMO_STAT is typically applied by **Apply Elevation Statics, Apply User Statics, or Apply Refraction Statics**. These tools do not apply the FNL_STAT statics, because NMO correction velocities should be measured from a floating datum.