

# Building a Better Pipeline Map: GPS Reinvents the “Wheel”

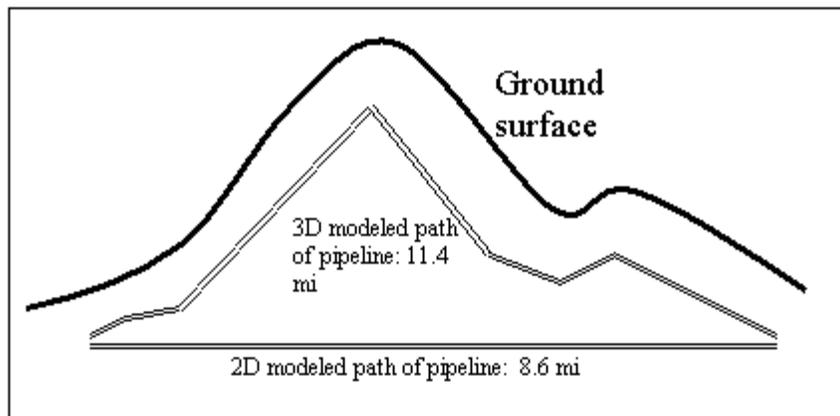
By Adena Schutzberg

Pipeline maps are not as glamorous as maps of forests or new subdivisions. The individual maps are thin strips that link together to form a long chain covering densely populated and remote areas. Along with the route of the pipeline the surveyor keeps a keen eye out for significant features along the corridor to mark on the map: roads and rivers, valves and pump stations. At the same time, he or she is collecting another virtually “invisible” piece of information for the pipeline engineers: the actual length of the pipe from start to end.

Before the development and widespread use of GPS, all of these data were routinely collected using a wheel, tape and sketchbook. A team of three surveyors, one to handle each task, would have to walk the path, record measurements and make sketches along the way. Alternatively, they might use a theodolite or transit to maintain a straight line and turn angles at points of interest, a chain or tape to measure distances, and sketchbook and pencil to note topographic features and station measurements. Today, tapes and theodolites have given way to total stations and data collectors. The wheel has not disappeared. It holds a special place because it accurately measures the true distance along the pipe making possible a measurement system called slope stationing.

## What is Slope Stationing?

Maps of pipelines have to include the pipe itself and many of the features that cross or surround it. The relative locations of those features, called stations, are measured and recorded as a distance from the start of the pipe or a pipe segment. That measurement can take one of two forms: horizontal stationing, which assumes an imaginary “flat earth” along which the pipe runs or slope stationing which measures the true 3D distance of the feature (including “Z”) along the pipe.



**Figure 1: Schematic of differences between measurement performed using (2D) horizontal stationing and (3D) slope stationing.**

The true pipe distance, which follows a path up mountains and down valleys, can be significantly different from a distance based on an imaginary horizontal. One example from Montana cites a discrepancy of 138 ft over a 5400 ft segment. That translates into 138 ft “more” oil or gas in the line, 138 ft “more” pipe materials being used during construction and 138 ft “more” labor to perform the initial installation. For those trying to accurately cost a pipeline construction project, estimate friction due to the length of pipe, or even calculate the time required for the oil or gas to move through the pipe, the true distance is critical. Further, engineers who design and maintain pipelines need true distance information for hydraulic calculations, drainups, line purges and other day-to-day tasks.

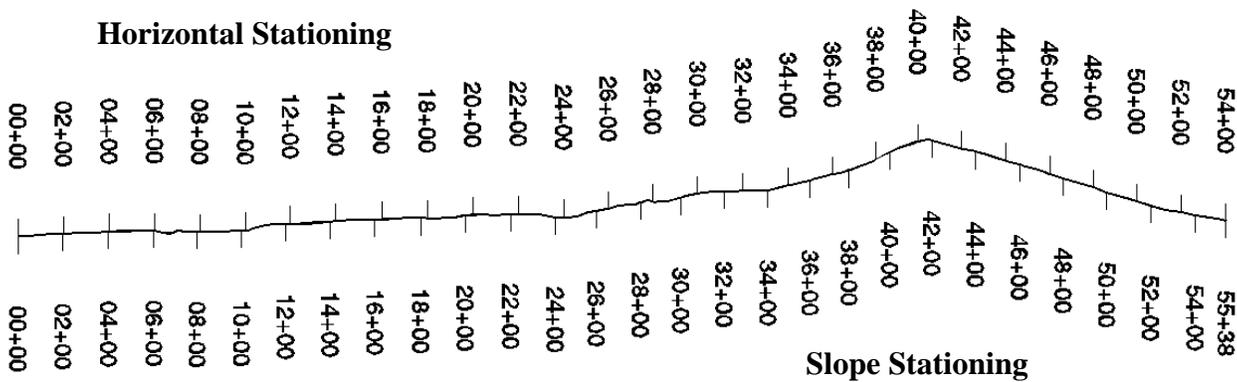


Figure 2: Comparison of station locations using horizontal stationing and slope stationing.

### Why are true lengths so important?

“The bottom line,” says Terry Moore, a Registered Land Surveyor and Senior Mapping Designer with Conoco, Inc. “is that I need to know the true length of the pipelines.” It was Terry’s training as a surveyor and the demands made on him under contract to Conoco, in Ponca City Oklahoma, that lead to a new software solution for slope stationing.

Engineers use the true distance of pipelines in many of their design calculations. For example, pumps are required to “push” material up hills. Engineer must ask: How much material do I have to move and how far it is moving? The answers to both questions require knowing the true length of the pipe. With those questions answered the engineers can determine the appropriate type and size of pump.

Another example of the importance of true distance comes from the related industry of fiber optic cable. Just as oil slows down due to friction as it moves through a pipe, light loses intensity while traveling through a fiber optic cable. And, continuing the analogy, just as a pump helps keep the oil moving, a regeneration station boosts the light’s intensity. The ups and downs of the landscape have no impact on locating regeneration stations since light is not affected significantly by gravity. The distance the light travels is the major factor that affects intensity and therefore distance determines the location of the regeneration stations. Horizontal stationing typically locates stations too far apart since it ignores the “extra distance” covered as the cable travels up and down.

True length information is one of many factors used in determining a pipeline’s operating pressure. The amount of pressure on material in a pipe at the bottom of a valley is higher than that at the top of a hill because there is more “pipe length” (which translates to product volume) pushing down on the pipe. If the pressure is too high at a low point in the landscape or too low at the top of a rise, dangerous situations can result. Other factors that are involved in this complex equation to calculate operating pressure include the output pressure of the pump(s) used to move the liquid in the pipeline, the weight of the liquid, difference in elevation, pipe wall thickness and pipe strength.

In many safety/environmental situations such as leaks and spills, it is important to know how much material is in the pipeline. Any figures based on “shorter” length segments assumed by horizontal stationing will yield underestimates and therefore potentially incomplete spill preparedness.

### Slope Stationing with GPS Data

Moore knew he needed slope stationing for his work as GPS gained widespread use at Conoco in 1994. In February 1995 Conoco decided to bring data collected by GPS into AutoCAD® for map production. Moore’s first challenge was to arrange the 10-12 pieces of data attached to each point in AutoCAD to produce a readable

map. This task, he quickly learned, required significant time per sheet and he was not convinced that he had the best tools for the task. A five mile segment of pipeline may contain 4 or more individual map sheets and each sheet may have 20 or more features translating into 200-400 significant attributes. That meant several hundred attributes to be hand located for each map!

Moore contacted Tom Inloes of TCI Software and explained the problem. Inloes responded with tools to manage the attributes and speed the process. Pleased with what he received, Moore asked the tough question: Is there a way to derive true distances for his pipelines from his GPS data in AutoCAD? The answer was "YES" and after two years of development and the addition of dozens of tools, the resulting custom software, ConoMap™, is now used daily at Conoco.

Inloes has since expanded ConoMap into CoriMap™ to provide a more generalized tool set for those involved in mapping any type of “corridor” feature: pipelines, fiberoptic cables, electrical cables, etc. ConoMap and CoriMap can automatically produce user customized strips maps. The format used by Conoco is a complex presentation including imagery and raster information.

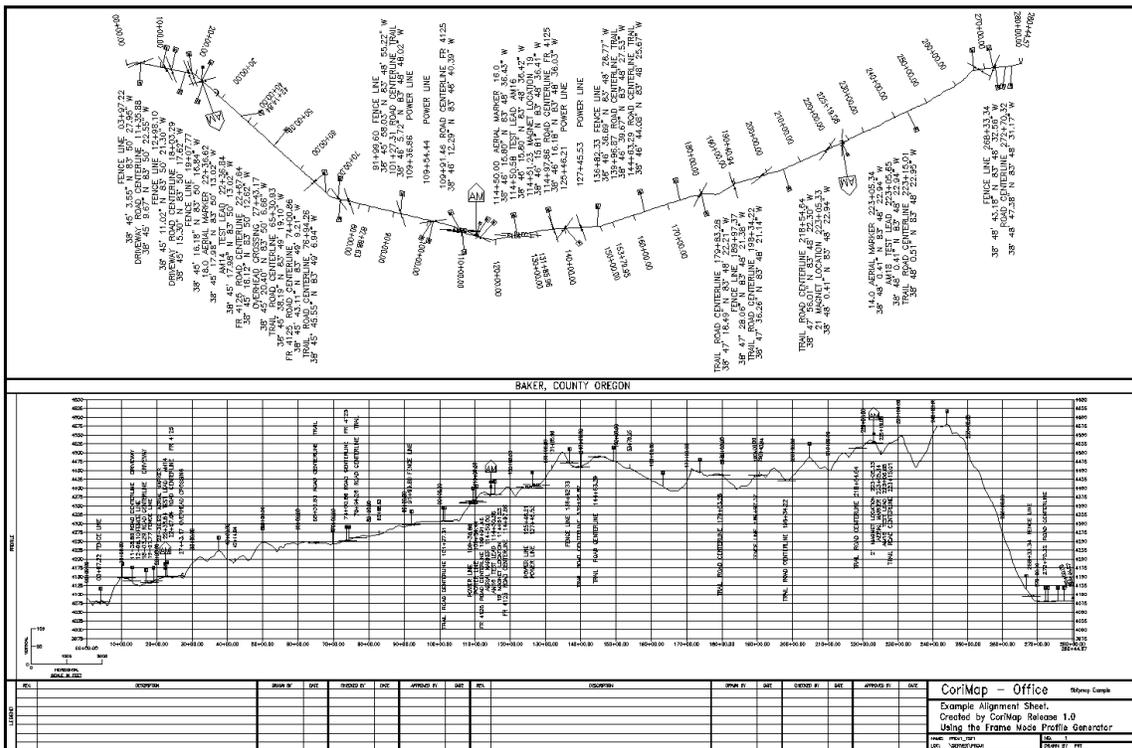


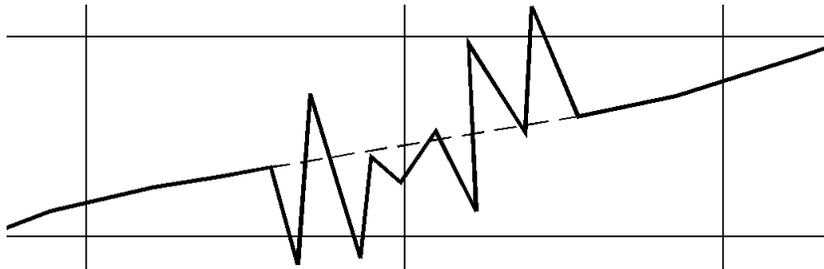
Figure 3: CoriMap includes the automated production of “strip maps” detailing linear features.

Unlike other plan and profiling tools, CoriMap uses the XY and Z values from the GPS, which means that the process of creating a station map and corresponding profile involves some new steps. Work begins in the field where 3D GPS readings are taken of both the pipeline’s path and the features of interest. Linear features can be traced on foot with readings being collected every few seconds, while point features such as valves are located by averaging several readings over a few seconds at a single location. Attributes about the features, such as the type of road or the ID number of a utility pole are captured at the same time.

GPS software, such as Trimble’s® GPS Pathfinder Office™, can output data points as AutoCAD blocks, which can include 3D locations, associated attributes and 3D linework. From there, the data is turned over to CoriMap. The blocks created by the GPS software are first replaced with a standard set of blocks to be used for mapping while 3D linework collected in the field is drawn using 3D polylines. Conoco uses a single set of symbols for all of its maps to meet their internal mapping standards. Other users have libraries of blocks to produce unique plan and profile sheets for different clients.

With the blocks in place, and the 3D linework drawn the corridor baseline is slope stationing to create a starting point for a Quality Control (QC) profile. The QC profile provides the surveyor, ideally in the field, the chance to look over the data in 3D to identify any obvious errors. Although GPS readings are quite reliable using “mapping level” equipment (roughly 1M accuracy) if a satellite is obstructed or there is some other error, elevations may be distorted. These distortions come in two common forms: “buzzsaws” and “shifts.” Buzzsaws are jagged up and down patterns and shifts are short-term elevation jumps or drops.

**Figure 4: Example of "buzzsawing" in a QC profile. The dashed line is the suggested correction.**



Reviewing the QC profile using what Inloes calls, “the computer between your ears,” helps identify these for semi-automatic correction. The user is presented with a preview of the revised profile before committing to making the changes. The original 3D polyline is then updated to reflect the elevations corrections.

To make the map easier to read, additional linear features like fences or roads, which cross or parallel the pipeline can be created from a series of commonly named blocks. For example, CoriMap will basically “connect the dots” moving from one “fence” block to the closest identical block, to draw the fence on the map. In order to limit the amount of information on a single sheet to a manageable amount, the user determines the total distance to be covered on each map sheet. CoriMap automatically determines where “matchlines” should be inserted and places blocks that will label the output with information about which mapsheet lies on either side of the current one.

With some of the map symbology assigned, and new features added, the user now “re-stations” in order to reflect the new distances caused by the elevation corrections and stations the new features. In this process the corridor can receive “mile posts” along its length at specified intervals while other features, roads and signs for example, receive distance assignments, too. All of these reflect the true 3D distance along the pipe. For example, a station of 27+45.34 assigned to a utility pole means that the pole lies 2745.34 ft along the pipeline.

### **Making Effective Maps**

Correctly stationing features is only half of the battle in pipeline mapping. Without a clear map, the data is virtually useless. The next challenge involves producing a meaningful, standard plan and profile sheet. There are two challenges in producing these sheets. First, each organization stations linear features a bit differently. The measurements may start at 0 at one end of a pipeline and simply increase across its length for 50, 500 or several thousand miles. Another measurement scheme might begin at 0 with each highway milepost. There are perhaps as many ways to station a linear feature as there are companies building and maintaining them. CoriMap is designed with considerable flexibility to meet all of these demands.

Stationing in CoriMap has many options including distance increments and units. Further, separate tools are available to station features that lie on the baseline or are at some distance from it. Thus, a driveway that crosses the pipeline can be stationed, as well as a sign 50 ft off the pipeline.

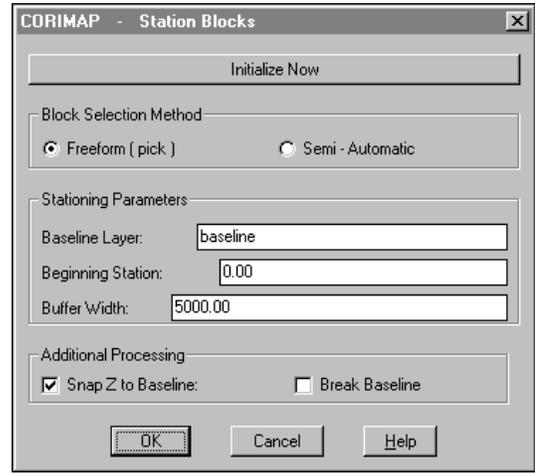
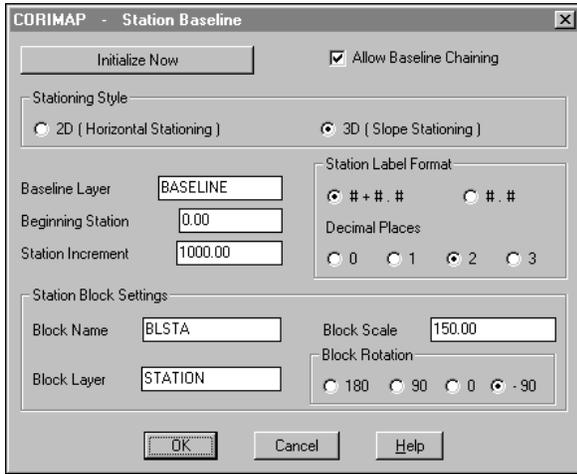


Figure 5: Some of the stationing parameters in CoriMap for the pipeline itself (left) and feature blocks that lie nearby (right).

The second challenge involves the amount of information that users want on strip maps, including details about the pipeline and nearby features. The task of making that much information available, and easy to find and read, takes experienced mapmakers long hours. The maps typically have far more data to present than space on the page, so the mapmaker will spend considerable time rearranging information to avoid clutter and overposting, where one piece of text obscures another. CoriMap stores the text associated with blocks using AutoCAD attributes.

This typically includes items such as identification numbers on signs, whether roads are dirt or paved, the names of streets and other descriptive information. Conoco also adds another attribute that stores the latitude and longitude of the mapped features, using tools from Mentor software’s Hawkeye. The coordinate information is calculated based on the projection and coordinate system, and presented in Conoco’s preferred format called a “picture”: 37° 34' 15.34" N and 94° 15' 34.34" W. Moore points out that this “picture” is just one of many possible presentations that can be defined in Hawkeye.

In general, moving an AutoCAD attribute repositions the map symbol, which is not acceptable in mapping. CoriMap introduces a host of tools to arrange the attributes intelligently: they can be stacked, placed on the right or left side of the pipeline, compressed into a small area and more. Any movement of the attributes however will not move them out of station order, nor move the symbol from its correct place along or off of the pipeline. Rules can be set up to arrange different features attributes in different ways. For example, the rules for arranging attributes may be different if they are on the right or left side of the pipeline.

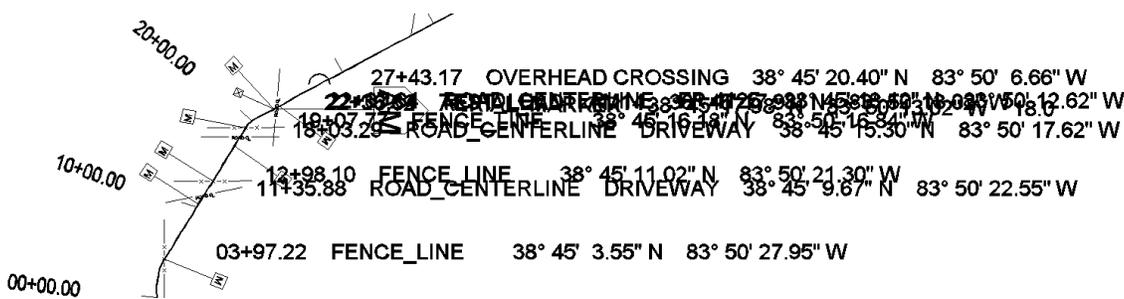


Figure 6: Blocks and attributes before applying CoriMap attribute arrangement tools.

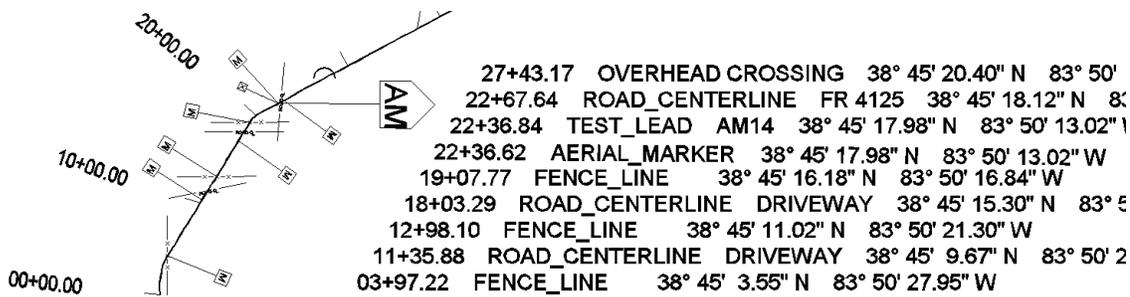


Figure 7: Attributes rearranged for legibility, still in station order.

The final step inserts the border and each sheet is stored in a separate AutoCAD drawing file for printing. Moore appreciates that much of this process can be automated. The batch tools mean he can set rules for nearly every part of the mapping process and run an entire section, covering many miles, unattended. In some cases, Moore forgoes the QC check and moves straight to final map production using this batch process. The only map production task done by hand is attribute arrangement, which is done interactively one map at a time. Moore notes that simpler maps, with fewer attributes can be labeled using batch attribute placement allowing the entire process to run unattended. The decision to automate the labeling depends in large part on the complexity of the map.

Moore reviews the final maps, and corrects them as needed. Only rarely must an area be remapped using GPS. Moore reports that his team of two is able to GPS about 5 miles per day depending upon the terrain. Moore then spends one to two hours to review, QC and fix the data to prepare it for map production.

### Better Maps Mean Better Decisions

As Moore puts it, “The ability to batch process my GPS data efficiently AND create true 3D distances has changed how we work. We get more maps, with more information out more quickly.” That, Moore suggests, means that Conoco can do work relating to its pipelines more efficiently.

Moore and Inloes like to point out one of their favorite tests of the technology. In work done under contract to David Evans, a single person in the field with GPS teamed with Moore in the office using GPS Pathfinder Office and Inloes in a different office using CoriMap, mapped 20 miles of a planned fiber optic route in four weeks. A team of three field workers surveyed the same route using a wheel and tape. When the computed distances and offsets were measured using two techniques, there was virtually no difference in the results.

3D data about pipelines is no longer a luxury requiring huge investments in field crews. The accuracy and speed of GPS, combined with the tools of CAD and the power of a computer to automate the process, mean pipeline maps can be better and more complete than ever before.

For More Information contact:

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