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July/August 2006

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Transform for Windows is currently the only tool specifically designed to provide land surveyors with a means of analyzing the measurements of a prior survey and analyzing the points found that mark it on-the-ground. This is a tool that can significantly reduce the time spent analyzing prior surveys while at the same time significantly improving the defensibility of work products. If you regularly perform retracement surveys, extend older control networks, or need to authenticate the locations of construction site structures, this is a tool you should not be without.

At the heart of Transform is an extremely efficient number crunching engine that best-fits a prior survey to the evidence found marking it on-the-ground. It performs these best-fit coordinate transformations by utilizing a least-squares mathematical modeling process. Unlike its competitors, Transform does not require the user to set up anything before producing each new solution; instead the user simply sets or clears a checkbox linking points that have been identified as common to the surveys being compared. Each time the user changes the link state of a point pair, a new solution is produced on-the-fly. It is this interactive nature of the program and the speed at which it can

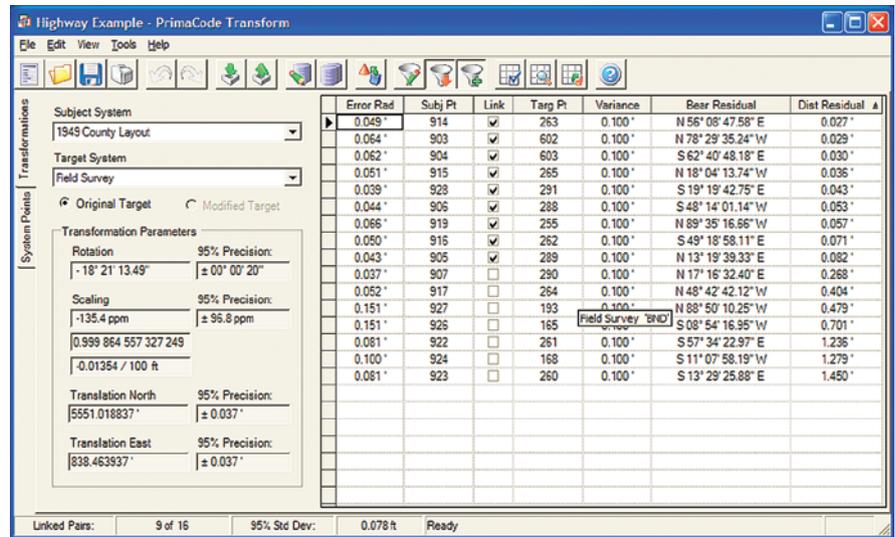


Figure 1

Transform for Windows

>> By Mary Ann Corcoran, LS

develop each new solution that makes it an analytical tool as well as a best-fit transformation tool.

As a result, this is an excellent tool when it comes to determining whether or not the points found on-the-ground marking a prior survey are in their original and undisturbed locations. The analysis process yields: (1) the most probable (or theoretical) locations of any missing or damaged points marking the prior survey, (2) the difference in unit length of measurements used to describe both surveys, (3) the amount by which the prior survey's meridian differs from the field survey's meridian (4) the

reliability (error radii) of the theoretical or most-probable point locations, (5) the reliability (precision) of the scaling and (6) the reliability (precision) of the rotation angle.

With little experience using this program, the surveyor can import coordinates for two surveys, filter both surveys, identify point pairings, remove pairs with excessive error (the analysis), rotate the field survey's meridian and export new coordinates for both surveys, *all in less than five minutes*, start to finish. When complete (as seen in **Figure 1**), the process can be repeated for any number of other surveys associated with

the same field work without the need to start a new session.

Analysis starts by first linking all probable pairs. Then the transformation table is re-sorted by double clicking the header for the distance residual column. Next, the linked pair with the largest residual is compared to the solution's overall standard deviation. If this residual is larger than the solution's overall standard deviation, the check box linking the pair is cleared. When the link is cleared, Transform instantly produces a new best-fit solution and updates all its display values.

Because changing just one linked pair results in all new paired point residuals as well as a new standard deviation for the solution, it is not possible to guess in advance if other linked pairs will also need to be removed from the solution, since removing a single linked pair can produce in a new solution where all the remaining linked pairs residuals may now conform to the solution's overall standard deviation. By repeating this simple process, iteratively, until no linked pair has a residual that is larger (or substantially larger) than the solution's overall standard deviation, it is possible to analyze the measurements of a prior survey and the monuments found marking it on the ground in a matter of minutes.

Prior to having access to such a tool, the analysis process typically involved inverting between found points and comparing those inverses to the measurements used to describe those points. However, this method of analyzing the points does not compensate for differences in unit length between the measurements used to describe both surveys and therefore can often lead to incorrect conclusions. Because the program corrects for such differences, it is not uncommon to discover that the points that seemed to be problematic (based upon un-scaled inverses) actually are not.

I recently ran into this phenomenon first hand while trying to reproduce a survey from the 1970s. I discovered that I was able to hold the majority of the iron pipes found marking the 70s' survey even though the un-scaled inverses varied from the record measurements by as much as two-tenths of a foot. Using Transform, it was obvious that the errors were due to a difference in unit length between the two different measuring devices (one a steel tape survey, the other an EDM survey) rather than a problem with the iron pipes. Interestingly, the survey was challenged in

a court of law and the judge agreed with my finding because I was able to satisfy him that the majority of the monuments found actually fit the record plan.

An analysis of a prior survey using Transform allows you to draw some very objective conclusions about the prior surveyor's work. By looking at the magnitude of the residuals for the remaining linked pairs or by looking at the solution's scaling along with its associated precision, it is easy to estimate the accuracy of the prior surveyor's work.

very important function when testing the validity of points set by other surveyors. If, for instance, you are asked to check a point set by another surveyor and that point falls within the error radius of your best-fit transformation's theoretical location, then the point, in theory, is just as defensible as the one you would set using Transform.

The program also provides a means of performing weighted solutions via variances. A variance is an estimate of a point pair's accuracy, or the amount by which

Every land surveyor who performs a retracement survey wants that survey to be as defensible as humanly possible.

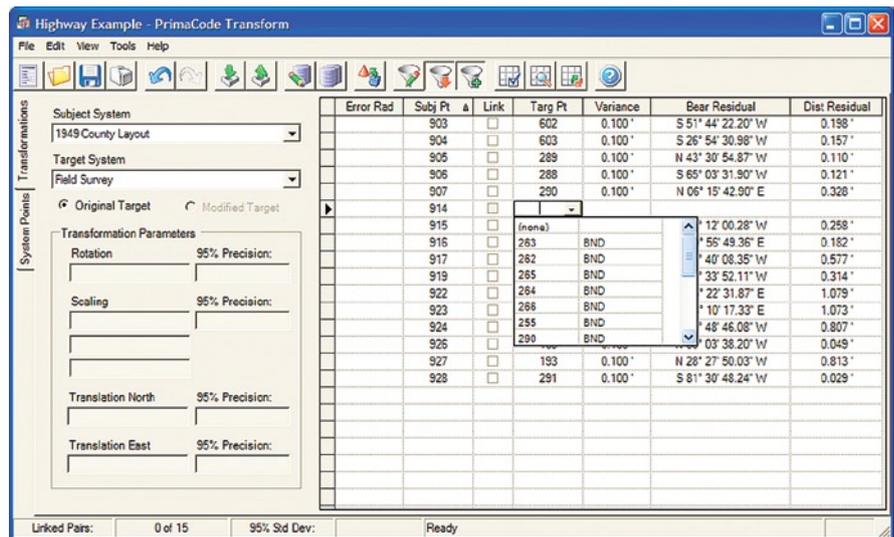


Figure 2

More often than not, it is desirable (if not necessary) to tie into another surveyor's meridian. The difference in meridians produced by Transform provides an extremely reliable or defensible means of reproducing another surveyor's meridian, since it is based upon a statistical treatment of all the available evidence. Furthermore, it provides a measure of by how much that rotation angle could vary from the truth (rotation precision).

The error radii produced provide a measure of each theoretical point's uncertainty. Since they are a measure of positional uncertainty, they serve a

the found point might vary from the measurement evidence used to describe it. The smaller a linked pair's variance, the greater weight it will be given. Therefore, it is possible to hold a single point, hold two points or to favor some points over others simply by assigning appropriate variances. Of course, when all variances are equal, an un-weighted solution is performed.

You can roll back scaling to one (no scaling) when deemed appropriate. When you choose to do so, you are informed that the resulting transformation will no longer be a best-fit solution, especially

if the scaling is statistically significant (*i.e.*, scaling is greater than its associated precision).

Points from more than one survey can be targeted by using something called a cloned point. It creates a cloned point by copying the transformed coordinates of its parent point into the fixed system it targets. Then a second survey that targets that same fixed system can also use that point as a target. A unique characteristic of cloned points is that you cannot edit its coordinate values and when the relationship between the clone's parent system and the target system is changed (a new transformation), Transform will transparently update the cloned point's coordinates for you.

The spreadsheet style format is very user configurable. Many of its columns and rows can be shown or hidden by selecting options on its view menu or by applying system filters. For instance, the columns can be switched between showing direction-distance residuals to northing-easting residuals. Other columns, such as the error radii and variances, can be selectively hidden. Two other columns that show the descrip-

tions for each system's points can be selectively shown. And the numbers of significant digits for most values are user configurable.

The rows of the transformation table can be switched between showing only those points that fit a certain filter criteria, to showing all points contained in the

those points contained in the subject system and a column for those points contained in the target system. The subject point column will show only those points that meet the system's filter criteria, while the target point column will initially be empty and is used to show only those points in the target system that have a

Transform is an invaluable tool for anyone that regularly ties into prior surveys.

system with a single click of a toolbar button. Coordinate points can be filtered by multiple point ranges, by multiple description masks (including single or multiple character wild cards) or by a built in filter that shows only paired points.

After selecting a subject system and target system, a column will display for

corresponding point in the subject system.

Target points are selected by clicking in the cell to the right of a subject point, which opens a dropdown list displaying those points in the target system that meet the system's current filter criteria. The most probable points for a match are placed at the top of the list as shown below. Notice also that the dropdown

USER GUIDE ADVANCED TOPICS

Transform's on-line user's guide contains a special section titled "Advanced Topics" devoted to addressing the use of the program in harmony with the "Law of Evidence" as well as the theory of using it to identifying monuments that are no longer in their original and undisturbed locations, the pros and cons of scaling, the unmonumented original survey, and the pros and cons of breaking the record.

Probably the most important of these issues is the use of Transform in harmony with the "Law of Evidence." Every land surveyor who performs a retracement survey wants that survey to be as defensible as humanly possible. Likewise, every surveyor knows that defensibility is predicated upon evidence and proper application of the rules of evidence.

This is one of those products that can actually help the land surveyor identify evidence, analyze that evidence and to use that evidence in a manner that is far more consistent with the rules of evidence than would otherwise be possible.

Quoting from Brown, Robillard and Wilson's *Evidence and Procedures for Boundary Location*, 5th edition, and *Brown's Boundary Control and Legal Principles*, 5th edition:

- "No one corner or monument recited in a description has any greater dignity than any other corner or monument recited in the same description."
- "All original corners have equal weight in location of the parcel. No single one is controlling, and they must be considered as evidence of that survey."
- "When a monument is called for in a written description, that monument, if it is undisturbed, is controlling over all other elements in the description."
- "A monument set by the original surveyor and called for by the conveyance has no error of position. It is legally correct, in that only the description may be in error."
- "Measurements may be used to prove the validity of corners and monuments.

Such monuments, to be acceptable, should be within reasonable proximity of the record measurements."

- "Corners cannot be proven from evidence of lines found. But lines are determined from the corners found."
- "Every measurement of distance or angle is subject to errors, either known or unknown. There is no perfect measurement."
- "When modern measurements are related to original measurements, the analysis must be in terms of the original creating units of measurement and not in terms of the more modern units of measurements."
- "For any conveyance or description of real property, the length of the unit of measurement is that measurement that was used and recited as of the date of the deed or survey."
- "Words and their meanings and distances recited in a description are to be interpreted as of the date of the description, not as of the time of the retracement."

list shows only those points with bound point descriptions (due to the system filter criteria) to help the user zero-in on just those points most likely to be a suitable match.

When the user selects a point in the target system dropdown list (**Figure 2**), he or she tells Transform that the coordinate for that target point should be considered a probable match for the associated subject point. Pairing points in this manner does not tell the program to use those points as part of a best-fit solution, but rather tells that it should report an error (residual) for that pairing. As shown in the next graphic, even before linking paired points, simulated residuals for all the pairs will display. These simulated residuals are designed as another aid for deciding which points are suitable for pairing prior to actually producing a solution with linked pairs.

System filters are used to speed up processing of transformations and to enhance the program's ability to accurately detect all possible pairings between any two surveys. Provided one point pair has already been selected and the

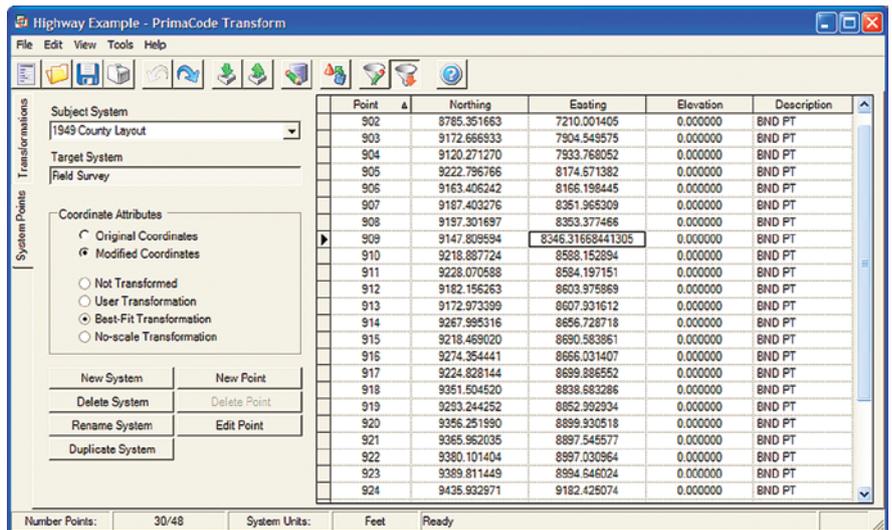


Figure 3

currently defined search radius is as large or larger than the largest possible residual, the user can instruct the program to “detect paired points” for them instead of selecting the pairs manually. Furthermore, this process can be used iteratively and with any number of pairs already chosen to refine the pairings following a change

to the search radius, scale factor or after revising a coordinate value.

A second view can be accessed by clicking the system points tab. This view shows the contents of each defined system. One project can contain any number of different coordinate systems, each representing a different survey. This makes it possible

When Transform is used as a reconnaissance tool to find original monuments that would otherwise go undiscovered, the resulting retracement survey is more defensible since it is based upon a better representation of the available physical evidence and because it is clear from the rules of evidence that original monuments carry more weight than do the measurements that describe them, *i.e.* a survey that locates boundaries based upon original monuments will be more defensible than one that locates boundaries from measurement evidence.

When used to determine which original monuments are still in their original and undisturbed locations, that analysis will be more defensible since it is based upon a treatment of those monuments that does not favor some monuments over others per the rules of evidence. An analysis with Transform is also more defensible because it is based upon a statistically most-probable unit of measurement and a statistically most-probable meridian that

do not favor some monuments over others and because the analysis is based upon a unit of measurement that is, as nearly as possible, consistent with the original creating units of measurement per the rules of evidence. Lastly, this type of analysis is far less subjective than other more traditional methods.

When used to reproduce lost or missing corners based upon the best-fit transformation's statistically most-probable positions, those positions are more defensible than positions based upon more subjective methods, since the most-probable positions are computed in a manner that does not favor some original monuments over others and because the most-probable positions are based upon a unit of measurement that is, as nearly as possible, consistent with the original creating units of measurement per the rules of evidence.

When used to reproduce a prior survey's meridian, the use of that meridian will be more defensible since it is

based upon a statistically most-probable rotation angle computed from a best-fit transformation that gives equal weight to all the original and undisturbed monuments per the rules of evidence. It is not insignificant that this type of solution is computed using all the available evidence combined into one unified solution instead of a subjective selection of certain pieces of evidence.

When used to equate the modern survey's unit of measurement to that of the original survey's unit of measurement, as required by the rules of evidence, the corrected distances will be more defensible since they have the highest probability of being consistent with the original creating units of measurement. Here again, the computation of the statistically most-probable scaling used to equate the distance measurements for the two surveys is based upon a best-fit transformation that gives equal weight to all the original and undisturbed monuments per the rules of evidence.

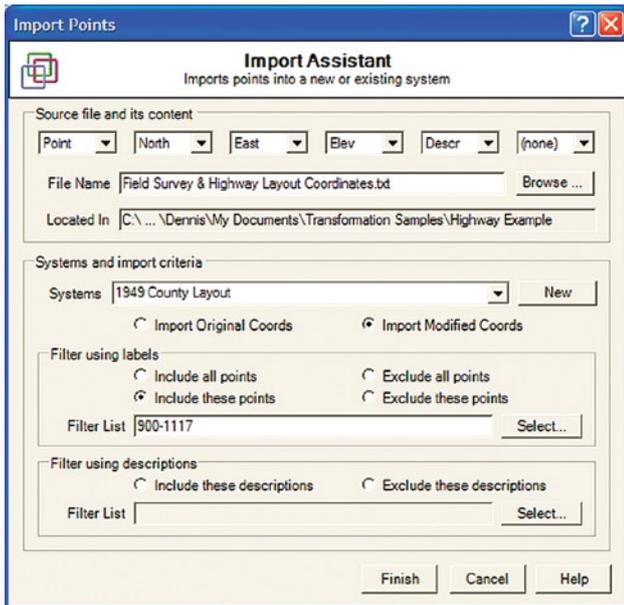


Figure 4

| Point | Northing | Easting | Elevation | Description |
|-------|-------------|-------------|-----------|-------------|
| 291 | 9155.918656 | 8289.207102 | 0.000000 | BND |
| 602 | 9172.672777 | 7904.520866 | 0.000000 | BND |
| 603 | 9120.257339 | 7933.795019 | 0.000000 | BND |
| 900 | 5014.089418 | 5053.600824 | 0.000000 | BND PT |
| 902 | 5076.780014 | 5029.665669 | 0.000000 | BND PT |
| 903 | 5663.173544 | 5566.996341 | 0.000000 | BND PT |
| 904 | 5622.638131 | 5611.232981 | 0.000000 | BND PT |
| 905 | 5795.828013 | 5807.624754 | 0.000000 | BND PT |
| 906 | 5736.782674 | 5818.285337 | 0.000000 | BND PT |
| 907 | 5818.064816 | 5987.068941 | 0.000000 | BND PT |
| 908 | 5827.905706 | 5985.292177 | 0.000000 | BND PT |
| 909 | 5778.701257 | 5994.175996 | 0.000000 | BND PT |
| 910 | 5922.333228 | 6201.356894 | 0.000000 | BND PT |
| 911 | 5929.804381 | 6194.709950 | 0.000000 | BND PT |
| 912 | 5892.448615 | 6227.944673 | 0.000000 | BND PT |
| 913 | 5884.977462 | 6234.591617 | 0.000000 | BND PT |
| 914 | 5990.545338 | 6250.987880 | 0.000000 | BND PT |
| 915 | 5954.193902 | 6298.722281 | 0.000000 | BND PT |
| 916 | 5999.511450 | 6257.815891 | 0.000000 | BND PT |
| 917 | 5963.160014 | 6305.550293 | 0.000000 | BND PT |
| 918 | 6127.119358 | 6397.410722 | 0.000000 | BND PT |
| 919 | 6076.321743 | 6429.341935 | 0.000000 | BND PT |

Figure 5

for any number of subject systems to target the same system (e.g., a field survey) without needing to run multiple projects or instances of Transform.

The system points view also allows the user to verify coordinate values and to

perform common tasks, such as editing point values, deleting points, defining new points, defining new systems, copying systems, etc. The coordinate values entered or edited in this view can be either the original coordinates or

the modified (transformed) coordinates, which is especially useful once your CAD drawing has been transformed.

While either view can be configured to show differing numbers of significant digits, regardless of the display option

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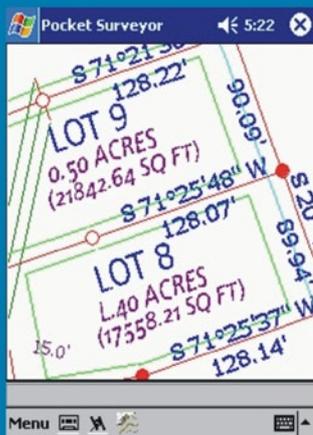
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chosen, the full internal precision of each value can also be accessed by simply clicking the value (as shown in **Figure 3** for point 909's easting value) which changes the display mode from normal to edit (full precision) mode. In edit mode, values can be copied to the Windows clipboard and its full precision value can then be pasted into any other Windows program.

To protect against coordinate drift due to internal round-off errors, the original imported coordinates will not be modified. Instead, the program will apply the four transformation parameters to the original coordinate values in order to display or export modified coordinates. These four transformation parameters are automatically updated with each new solution, which means a system's modified coordinates will also be automatically updated.

All of the information entered, including all the user's preferences, can be saved to disk as a single project. The project can then be re-opened at a later date to review previous work or to add new work, as would be the case when a follow-up field reconnaissance trip yields new locations based upon an interim best-fit solution. The contents of either view can also be printed in the form of a report for transmission to others or for filing of a hard copy.

While Transform allows the user to enter and edit coordinate values manually, it also provides a means of editing or adding new points using the program's import assistant. The import assistant is a very robust and flexible tool that utilizes standard ASCII text files for the interchange of data with other programs and data collectors. The only caveat is that the files must be comma delimited, since spaces are allowed in the description field. The import file can contain any number of significant digits and the import assistant will capture as many digits as are available, regardless of the number of significant digits currently displayed.

Using the import assistant (**Figure 4**), any number of coordinate systems can be populated from a single import session and the import assistant can be re-run any number of times after leaving it. The filter criterion for a system is saved and a new system is defined from within the import assistant by simply supplying the name for the new system. Because each coordinate system is treated as a discrete survey, each system

can contain a point number 345, for instance, without it conflicting with any other system's point number 345. Additionally, point labels are not restricted to just numerals, they can also contain alphabet characters.

The import assistant provides a convenient means of visually selecting ranges of points (or descriptions) from within a window that opens when either of the import assistant's "select" buttons

is clicked (**Figure 5**). The new window shows the entire contents of the import file. You can then visually select which points will be imported by dragging or selecting point labels and descriptions. When the OK button is clicked, the import assistant captures your selections and enters them in the appropriate "filter list" box and then selects the "include these points" option. The import assistant will even inspect your

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description selections for similarities and condense the list by adding wildcard characters for you.

The import assistant is also designed to automate the process of updating coordinate systems. If a system is already populated with points, the import assistant will ignore any point information in the import file that duplicates information Transform already has. If the import assistant encounters point information that is

new or has been updated, the user is prompted to skip or overwrite that instance or all such instances. With this approach, the user never needs to edit import files to contain only new or updated information.

The export assistant works very much the same way as the import assistant does, allowing the user to easily transfer information to other sources. A special window can be opened for copying and pasting

full-precision values directly into CAD drawings, thereby enabling the user to merge CAD drawings along with all their line and point attributes, but without the risk of making keyboard input errors and entering values that have been rounded off.

A comprehensive online user's guide is organized into chapters. One of the chapters contains two tutorials that step the user through a transformation using some sample data supplied with the program. The remaining chapters address details associated with each feature and an advanced topics section that provides an in-depth look at subjects such as tweaking transformations, scaling and the law, Transform and the law, and reproducing prior surveys that do not reference monuments (see the Advanced Topics sidebar). Some of these sections contain direct references to subjects in *Evidence and Procedures for Boundary Location* by Brown, Robillard and Wilson to provide further substantiation of the concepts being discussed. The user's guide also contains a handy glossary of terms.

Extensive context-sensitive help is available when the mouse is hovered over an item, and error reporting occurs when the user attempts to use the program in an unsupported manner. Additionally, the options dialog, import assistant, and export assistant make extensive use of another type of help that is available by clicking the question mark in the upper right corner of the dialog and then clicking the item on which you need help.

Transform is an invaluable tool for anyone that regularly ties into prior surveys, whether or not they are retrace-ment surveys, construction layout surveys or control surveys. For more information, visit www.primacode.com. *A*

Mary Ann Corcoran is licensed as a Professional Land Surveyor in Massachusetts, Vermont, and Connecticut, and is the Chief Land Surveyor at Hill Engineers, Architects Planners in Dalton, Massachusetts. She has been involved in all aspects of surveying for the past 21 years, has been a participating member of the Massachusetts Association of Land Surveyors and Civil Engineers and most recently was a member of the committee that rewrote the 2006 Massachusetts Land Court Manual of Instructions.

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