Virtual Boundary
Desk Guide

November 06, 2020

Introduction

Cutting unit boundaries define where timber harvest or other resource management activities will take place. It is important for the locations of these boundaries to be clearly identified to ensure these activities only occur in the designated areas and do not spill over onto private lands or ecologically sensitive areas. Typically, all timber sale contract cutting unit boundaries are designated with special paint, augmented with paper or plastic signs. Painting boundaries is one of the more costly practices associated with timber sale preparation. This sale preparation cost can be reduced by using virtual boundary designation methods including "discernable" and GeoFence methods.

Virtual boundaries

Virtual boundaries are considered to be clearly identified cutting unit boundaries that are unpainted or otherwise unmarked on the ground. There are two types of virtual boundaries:

Discernable: A natural or constructive feature so conspicuous it can be identified from a sale area map and using that feature will not cause mistakes to be made when trees are cut. Examples of discernable boundaries are roads (Fig 1), distinct breaks in vegetation, and rock outcrops.

Geo-fence: A virtual perimeter for a real-world geographic area. A geo-fence can be dynamically generated, as in a radius around a point location, or a geo-fence can be a predefined set of boundaries. The geo-fence is paired with a hardware/software application that responds to the boundary in some fashion as dictated by the parameters of the program.

Figure 1. Forest Service road.

Benefits

The benefits to using virtual boundaries over painted boundaries include:

Lower paint costs.

Lower crew costs, especially if the boundaries can be digitized from remote sensing data.

Decreased timeframe needed in sale preparation schedules to conduct field work associated with some, or all, of the boundary designation process.

Increased flexibility as to time of year some phases of sale preparation can be completed.

Lack of visible marks if used in areas with visual quality objectives.

Keeping crews out of or reducing crew time in potentially dangerous areas.

Negates the need for additional leave trees in close proximity to the road.

Costs

There are several costs associated with using virtual boundaries

Geo-Fences may require more expensive global navigation satellite system (GNSS) receivers.

Administering Geo-Fences may require additional training, take more time to administer, and increase sale administration costs.

More risk of not treating up to or treating areas over the designated boundary line.

Increased risk of disputes over boundary locations and possible claims.

Requires purchasers/contractors to invest in GNSS receivers and appropriate software, and provide training to employees and non-traditional oversight of logging operations.

Increased time and costs to purchasers/contractors in locating boundary lines which can result in reduced stumpage values or no-bid sales.

Sale Prep Planning

Painted boundary designations offer little risk of unintentional resource damage beyond the designation unit boundaries when done appropriately with inter-visible painted trees (Fig 2). For this reason, boundaries must be marked when the risk of unintentional resource damage will effect non-Forest Service land, impact the economic concerns of other partners, or impact sensitive or protected areas. Boundaries must therefore be marked with Forest Service tracer paint when:

Figure 2. Boundary marked with tracer paint and unit tag.

- Units from different sales or project areas have a common boundary.
- Units abut non-National Forest System lands or wilderness, designated natural, or roadless area boundaries.
- Units are adjacent to heritage resource sites or other resources that require protection as defined in site-specific NEPA decision and contract provisions.
- Where NEPA is not in place, such as beyond the sale or contract area boundary.

Except as described above, the District Ranger may authorize cutting unit boundaries be designated without paint marks using discernable features or geo-fences providing these boundary designations will meet the objectives of the resource management plan. Restrict geo-fences to scaled sales to reduce risk to purchasers.

Risk Assessment – the potential for resource damage or trespass if a virtual boundary is used.

A risk assessment should be completed for each boundary that is to be designated with a geo-fence to evaluate risk factors like high timber values and resource protection. The risk assessment should describe the boundary line location, resource risks, and any other considerations that may need to be taken into account (see Table 1). Doing the risk assessment will help to identify boundaries that have a discernable feature, boundaries that will need to be painted, and boundaries where a geo-fence is applicable.

Because a geo-fence will affect more than just sale preparation, collaboration between the sale prep team, sale administration, law enforcement, silviculturist, and other resource specialists during the risk assessment phase is important. Engaging the local purchasing and contracting community about the use of virtual boundaries, GNSS receivers, accuracy errors, and receiver costs should be part of the risk analysis process. The local purchasing and contracting community need to be fully aware of how all boundaries will be identified. Potential bidders unaccustomed to the use of geo-fences may decrease the rate they are willing to pay for the stumpage or decide not to submit a bid.

Table 1: Example of Risk Assessment Table

Boundary Location	Considerations	GEO-fence	Discernible
Land Ownership Boundaries (e.g. private and other public organizations)	Avoid trespass onto non-Forest Service lands.	NO – Current direction requires painted boundaries (FSH 2409.12 Chap 71).	NO – Current direction requires painted boundaries (FSH 2409.12 Chap 71).
Separation between different awarded contracts	Ensure compliance with timber sale or stewardship contracts such as differing timber rates or removal of another purchaser's volume. Minimize opportunities for claim.	NO	YES
External cutting unit borders FS land but does not have adjoining approved NEPA	Ensure environmental compliance.	NO	YES
External cutting unit borders FS land and NEPA coverage extends beyond the cutting unit boundary.	Avoid trespass and resource damage.	YES	YES
Cultural sites or other resources that require protection (e.g. specific soils)	Avoid damage or unintended impact to important resources that could be outside the effects of a biological opinion or other legal requirement.	NO	NO
Shared cutting unit boundaries within the sale area	Change in prescriptions, logging method, or timber types across boundary line. Unintended resource impact minimized.	YES	YES
GNSS observation conditions are poor (HDOP > 6), non-existent, or influenced by errors such as blockage or multi-pathing	Operator cannot implement and FS can't administer a Geo-Fence	NO	YES

Establishing Virtual Boundaries

The techniques used to survey the boundary lines will not change from using a painted boundary to using a virtual boundary. Area determination errors will still need to be met, so appropriate equipment and techniques will still need to be used (FSH 2409.12 chap 50). There are some specific issues to be aware of when establishing the different virtual boundaries however.

Discernable Boundaries:

When surveying a discernable boundary, whether by GPS or digitizing off of a geo-referenced map or photo, make sure the boundary is placed along the edge of the unit and not in the middle of the discernable feature. For example, if a road is being used as the discernable feature, the boundary line will need to be surveyed along the edge of the road closest to the unit and not down the middle of the road. You can take GPS measurements along the center of the road, but side shots to the unit boundary will need to be taken or an off-set will need to be applied to position the boundary correctly. Failure to do so will add additional area to the unit acreage that is not part of the unit description which will impact volume estimates if plot based cruising is used in the unit.

Geo-Fences:

Because GPS and geo-referenced maps and photos contain some level of accuracy error, the boundary locations will also have some level of error associate with them (FSH 2409.12 chap 51). For painted and discernable boundaries, these accuracy errors are mitigated by visual cues on ground, either from paint or from the discernable feature. For a geo-fence, there may or may not be any visual cues.

Figure 3. Example of a smooth boundary.

Care should be taken to establish the best possible boundary line when establishing a geo-fence. GPS receivers that have low accuracy errors for the type of canopy closure that occurs along the boundary line will provide the best results. The estimated accuracy for different GPS receivers can be determined by using the Missoula Technology and Development Center (MTDC) Accuracy Matrix. Geo-fences placed along smooth boundaries (Fig 3) will be easier to implement than boundaries with many sharp angles to create small corridors or fingers (Fig 4).

Make sure any map or photo errors are within an acceptable tolerance before using them to digitize a geo-fence boundary. If digitizing a geo-fence boundary from a photo or map, make sure you are digitizing across an area that has an acceptable GPS signal strength. Avoid placing geo-fences down steep slopes, in draws, or under heavy canopy where a GPS signal maybe weak, blocked, or be affected by multi-pathing. Digitized boundaries should have GPS signals verified in the field if there is any doubt about the quality of the signal strength. If the operator cannot establish a good GPS signal, those boundaries will need to be resurveyed and painted before the area can be treated.

Figure 4. Example of a boundary with many sharp angles.

Once a geo-fence has been established, the coordinates defining that boundary will be considered the exact boundary line for the purposes of the timber sale, stewardship contract, or service contract. In addition to locating these boundaries on the sale area map, an official digital vector/shape file will need to be developed that shows the formal designation of all geo-fence locations for the sale or project. This digital vector/shape file can be imported into GIS and survey applications to be used as an overlay on either a sale map or other remote sensed data.
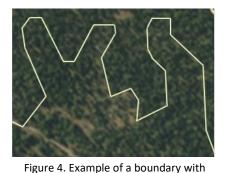
Timber Marking and Cruising

Any crew going into units with a geo-fence will need to have a reliable GNSS receiver and software that can relocate the boundary with at least the same accuracy as it was established. Marking crews will need to check the digital vector/shape file repeatedly as they approach a geo-fence, which will slow the crew down and add additional time to complete marking (Fig 5). Trees will need to be marked up to and not past the geo-fence boundary shown on the digital vector file/shapefile.

Figure 3. Cruiser using GPS in forest setting.

In general, cruising in a unit with a geo-fence will not be different than cruising in any other stand except more care will need to be taken to ensure all samples are within the unit boundary. When plot cruising, plot locations that occur near a geo-fence, where a portion of the plot may fall outside of the cutting unit boundary, will need be handled using the half-plot or quarter plot method instead of using mirage plots or the walk through method (FSH 2409.12 chap 34.23).

Data Management for Contract Administration

The official digital vector/shape file showing the formal designation of all geo-fence locations for the sale or project will need to be kept in a secure location (in a restricted folder on Pinyon for example) and will be the official file of record for sale or project geo-fence boundaries. The name and date of the file will need to be specified in the contact. The official file of record should contain the contract name in the file name. Copies of this file will need to be provided to the marking crews, timber cruisers, and sale administrator. Copies of the file will be provided at sale advertisement for prospective bidders to accurately assess the sale. The purchaser/contractor awarded the sale will need to be provided with a copy of this file to locate all geo-fence boundaries.

Discernable Boundaries

Discernable boundaries by definition are easily located on the ground and should have little risk from unintentional resource damage outside of the cutting unit boundary. Written descriptions of features used as discernable boundaries should be in the sale file and/or in a written logging plan document, and clearly shown on the Sale/Contract Area Map.

Geo-Fence

Although a geo-fence is a distinct line that describes the cutting unit boundary in a precise location, relocating that boundary is not exact. All GNSS receivers contain some level of accuracy error. The level of acceptable accuracy error needs to be determined based on the risk the CO or the NEPA Deciding Officer is willing to accept around any geo-fence boundary and needs take into account the accuracy levels of readily available GNSS receivers. This acceptable accuracy error is the Allowable Contract Tolerance.

Figure 4. Example of GNSS receiver used in forest setting.

The Allowable Contract Tolerance defines the level of accuracy error permitted in the contract and in the General Section of the timber sale prospectus. The operator will be required to select GNSS receivers that meet the level of accuracy error selected. Although the Missoula Technology and Development Center (MTDC) Accuracy Matrix can assist operators in determining appropriate receivers, the Accuracy Matrix should not be considered a list of approved receivers or devices. The operator will be required to cut trees up to and not past the geo-fence boundary shown on the digital vector file/shapefile using a GNSS receiver that meets the Allowable Contract Tolerance.

Area of Risk or Uncertainty

We use the term "risk" to mean there is the possibility the location showing on the GNSS device is not the true location on the earth. "Error" is a measure of risk, as is "accuracy" and "precision". We measure error in terms of "uncertainty." The GNSS recorder on the feller-buncher is expected to keep the cutting within the area risk. The Sale Administrator (SA) is expected to validate the feller-buncher stayed within the area of risk.

The level of Allowable Contract Tolerance defines the Area of Risk. Even though the GPS position might show as being on the geo-fence line, the real world position could be anywhere with the circle defined by the GPS accuracy error. By defining the maximum acceptable GPS accuracy error, the Area of Risk is also defined (Fig 7). Within this area of risk, the resource treatment may be applied inconsistently, sometimes not reaching the geo-fence line while sometimes going over the geo-fence line, even though the contractor, according to the GPS readings, is cutting up to and not over the geo-fence line.
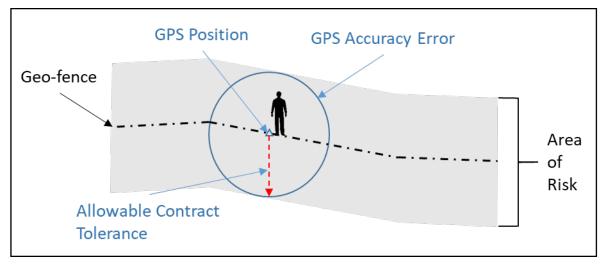

Figure 5. Area of Risk Defined by Allowable Contract Tolerance

However, there is an additional source of error needing consideration. When the geo-fence is checked by the SA, the GNSS receiver used by the SA will have an accuracy error associated with the device as well. Because the SA is checking to see if the operator stayed with the Allowable Contract Tolerance, the SA will need to check the work against the area of risk and not just the geo-fence boundary. The accuracy error of the GNSS receiver used by the SA will therefore be additive to the Allowable Contract Tolerance.

When the SA locates the geo-fence line, the GPS accuracy error creates an area of uncertainty around the SA's position. Because the real world position of the SA can be anywhere within the area defined by the GPS accuracy error, the maximum GPS accuracy error, or worst-case scenario, will need to be added to the Allowable Contract Tolerance to determine if the operator is in compliance (Fig 8). Otherwise, the SA could call stumps or trees outside of compliance when they were actually in compliance due to the SA GPS accuracy error.
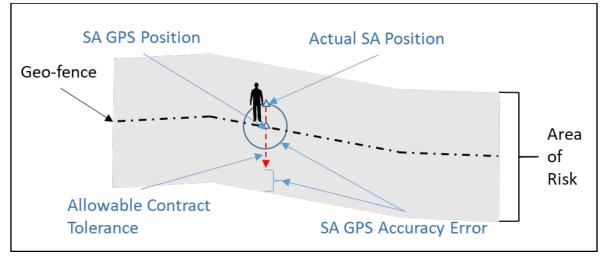
Figure 8. Worst-case SA GPS Accuracy Error combines with Allowable Contract Tolerance.

If the worst-case scenario happens in the direction closest to the Allowable Contract Tolerance boundary checked, the additional area of risk is double the SA GPS accuracy error. The definition of the Actual Area of Risk is the Allowable Contract Tolerance plus twice the GPS accuracy error from the receiver used by the Sale Administrator (Fig 9).
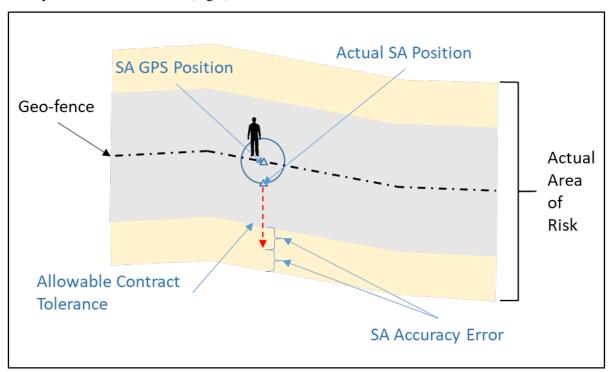

Figure 9. Actual Area of Risk includes twice SA GPS Accuracy Error Assuming Worst-Case Scenario.

To minimize this actual area of risk, the GNSS receiver used by the Sale Administrator should have low accuracy errors.

Sale Administration and Contract Compliance

To check the boundary for compliance, the SA will need:

- The final geo-fence vector file/shapefile (named in the contract provision for virtual boundary designation).

- An appropriate device (tablet/cell phone/mobile device) connected to a GNSS receiver with a known accuracy error.
- Appropriate software (e.g. Two-Trails or Arc Collector) displaying the geo-fence as a vector line (as opposed to a raster line) and able to collect and store waypoints as a way of documenting stump locations.

As noted above, the compliance check will use the Allowable Contract Tolerance plus the GPS accuracy error from the SA's receiver to determine if the resource treatment stayed with the geo-fence boundary. A two phase procedure is recommended for this check; a quick check and a compliance check.

Quick Check

The quick check is a procedure for the SA to make a quick estimate of the stump (or uncut tree) distance from the geo-fence to determine compliance. The SA will use the GPS receiver to locate the geo-fence perpendicular to the stump being checked. Once the SA is reasonably sure they are on the geo-fence line, the horizontal distance between the stump and the geo-fence line is measured (Fig. 10). A rangefinder laser device will be the most efficient way to determine horizontal distance to the stump. If the stump is within the tolerance (Allowable Contract Tolerance plus the SA GNSS accuracy error), the SA can move to the next stump to be checked. If the stump is out of tolerance or borderline out of tolerance, move to the compliance check.
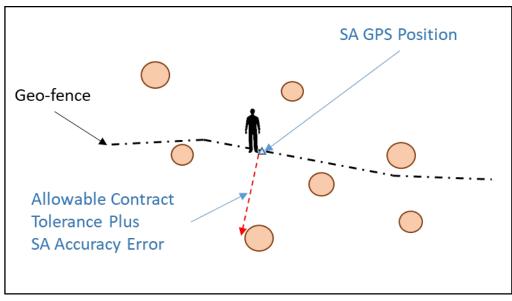

Figure 10. Quick Check Procedure.

Compliance Check

The compliance check will be the legal check for any stump or standing tree that may be out of compliance. Because it is difficult for the SA to determine where the exact geo-fence line is on the ground, the compliance check reverses the process. The SA will record the GPS position of the stump using the average of 60 positions. The SA will need to place the GPS receiver directly over the center of the stump when determining the location (Fig 11).

Record the GPS locations of possible noncompliance stumps on the digital shapefile/vector file and the distance to the geo-fence is determined. If the stump location is outside of the tolerance, the stump is in non-compliance. This can be determined in the field if the software used by the SA has the capability to do this calculation. Otherwise, the calculation will have to be done in the office. The SA will have a record of the stump location (so it can be easily relocated) and its proximity to the legal geo-fence line.
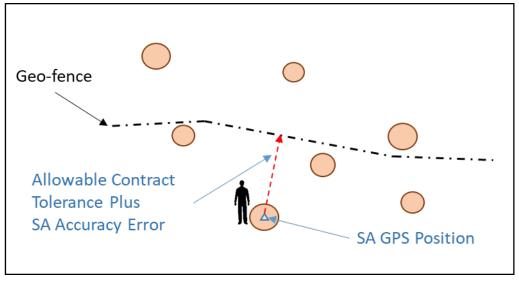
Figure 11. Collect Stump Position and Compare to Geo-Fence Line for Compliance Check.

For standing trees, a GPS location (using the average of 60 positions) taken close to the tree under open sky with a side-shot to the tree will give the best possible location. Use a side shot to the face of the tree that is perpendicular or in-line to the geo-fence boundary (Fig 12). This will remove possible Azimuth error. Half the tree DBH will need to be added to the side shot distance to determine a distance from the center of the tree to the geo-fence line. As with stumps, record the GPS locations of possible noncompliance standing trees on the digital shapefile/vector file and the distance to the geo-fence is determined.
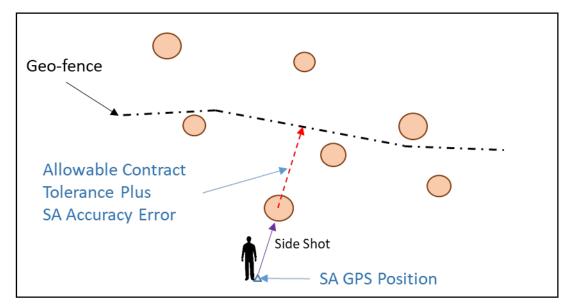

Figure 12. Collect standing tree position with an in-line side shot for compliance check.

Conclusion

The technology and hardware for implementing virtual boundaries already exist and are in use by the Forest Service. Discernable boundaries are permitted under current Forest Service regulations and their use is encouraged. Forest Service policy and contract language concerning geo-fence implementation are currently under development. Education for both Forest Service personnel and contractors will be necessary to successfully incorporate geo-fences into resource management projects.

For More Information, Contact
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