

# Early Detection of Invasive Exotic Plants in the Northern Colorado Plateau Network

## Standard Operating Procedure (SOP) 3: Monitoring Route Methods

**Version 1.01 (April 2009)**

### Revision History Log:

| Prev. Version # | Revision Date | Author     | Changes Made                                                                 | Reason for Change                                               | New Version # |
|-----------------|---------------|------------|------------------------------------------------------------------------------|-----------------------------------------------------------------|---------------|
| 1.00            | 04/09         | D. Perkins | Streamlined plot set up, removed macroplot – plots are now done on transects | Make protocol more efficient while still covering the same area | 1.01          |
|                 |               |            |                                                                              |                                                                 |               |
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This SOP gives step by step methods for the collection of field data for invasive plants monitoring routes. Methods for extra area surveys and monitoring “lite” are found in SOPs 4 and 5, respectively. The methods outlined in this SOP essentially follow the methods outlined by Utah State University (Anderson and Dewey 1997). In several cases large portions of the text have been lifted directly from their handbook. We are grateful for their efforts on the Colorado Plateau and their expertise in this area.

### I. Monitoring Routes

Monitoring routes will follow the roads, trails, and riparian areas in a park. As monitoring routes are traversed, locations of all target species are documented using mapping grade global positioning system (GPS) units with better than 5-meter accuracy.

Field locations are recorded by GPS as UTM coordinates, and are later differentially corrected in the production of final digital products. The crews record invasive plant occurrence data on hard-copy (USGS 7.5-minute topographical maps) in any situation where GPS satellite reception is not possible (such as in narrow canyons) or in cases of GPS equipment malfunction. All data from field maps are converted to digital format.

### II. Determine Settings

*A. Determine the Park Priority Invasive List.* At each park NCPN staff will work with park staff and other local cooperators to develop a target species list of 20-30 invasive plant species that the NCPN crews will be responsible for during the monitoring routes and while surveying the monitoring routes. This targeted list will allow training prior to park visits. Since these surveys are designed to be rapid, they will be much more effective if the crews can have a focused search image, rather than every possible invasive plant species. The list will be updated annually to ensure that any species that are new to the area are added (SOP #11).

B. *Determine the Minimum Detection Target Size (MDTS)*. Field technicians cannot be expected to find every single plant of every targeted weed species when conducting monitoring routes. While searching for single mature plants of some species such as Russian olive (*Elaeagnus angustifolia*) and saltcedar (*Tamarix ramosissima*) might be possible due to their large size, single plants of other species such as field bindweed (*Convolvulus arvensis*) or sulfur cinquefoil (*Potentilla recta*) might prove impossible under certain field conditions. The Minimum Detection Target Size (MDTS) represents the patch size that is large enough to be detected with a high level of confidence (typically at least 90 percent of the total number of patches of that size and larger in the monitoring area) under actual field conditions; but small enough so that any missed patches smaller than the MDTS could still feasibly be eradicated if not found until the next scheduled monitoring visit. NCPN monitoring will have a minimum detection target size of 0.01 acres (approximately 40<sup>2</sup>m or 20 x 20 ft) for all invasive species, unless otherwise noted.

C. *Determine Effective Detection Distance (EDD)*. The EDD is the maximum distance from which a searcher can consistently detect (see and recognize) the MDTS of the least visible targeted species with at least 90 percent detection efficiency (Figure 3.1). Crew members calibrate themselves by walking away from a targeted patch size of the least visible species and determining the maximum distance from which they can consistently see and recognize the patch with complete confidence. The distance is measured either by pacing or using a laser rangefinder. The width of an EDD is determined and adjusted as needed by each surveyor based on variations in terrain, walking speed, associated vegetation, and target species. Heavy cover and/or difficult-to-see species may require slowly walking detection swath widths as narrow as 5-7 meters. In very open terrain with little vegetation, effective swath widths may be 50 m or greater for an EDD of 1 meter<sup>2</sup>.

D. *Determine Effective Detection Swath Width (EDSW)*. EDSW is defined as the maximum width (meters) of a linear search swath (band transect) in which a walking observer is confident of visually detecting 90% of all target species of the minimum specified infestation size (Figure 3.1). NCPN sets the maximum width of their search pattern swaths based on the goal of detecting at least 90 percent of all target weed patches 0.01 acres or larger in size. The effective detection swath width (EDSW) is equal to 2 times the EDD, because the surveyor is able to effectively detect weeds 1 EDD on either side of his/her search route. Determine the EDSW and enter into the GPS per monitoring route. It is not necessary to adjust the setting for small or temporary changes (going through a small patch of dense shrubs) in the EDSW, but actual search patterns should always be modified as needed to compensate for any temporary changes in visibility.

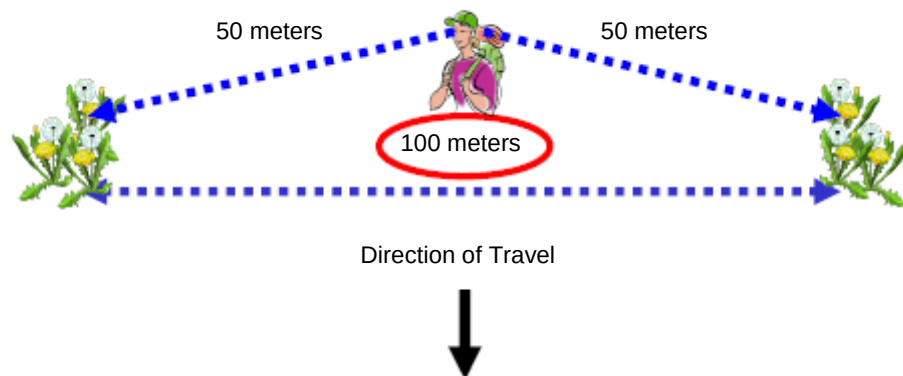


Figure 3.1. If the maximum Effective Detection Distance (EDD) for this MDTS is 50 meters, the actual Effective Detection Swath Width would be 100 meters.

E. *Determine Patch Separation Resolution (PSR)*: The PSR is defined as the minimum distance between plants that must be considered members of separate patches or infestations. Individuals or clusters of a target species separated by the PSR distance or more must be recorded as separate patches. Plants separated by less than the PSR are usually considered a single patch or infestation. The PSR set at 50 meters, unless otherwise noted. The basis for selecting this value is the assumption that most plants or groups of plants less than 50 meters apart will typically be considered as one infestation when planning and implementing normal weed control operations.

F. *Set the Between Feature Position (BFP) Setting*. BFPs allow electronic tracking of the user's route. In the case of some Trimble units (GeoExplorer III, XM, and XT models) this option is called "Between-Feature" tracking. The GPS unit automatically generates these positions at a set distance or time interval. Use the distance setting for these positions. Use the EDSW as the setting for the BFP. The "Between-Feature" positions can be depicted on end-product maps to represent the coverage and identify any gaps. Each time a surveyor walks the equivalent of "one effective detection swath width", the Trimble GPS unit "beeps" and creates a point. So, at the beginning of each day, and whenever moving to significantly different terrain or vegetative cover, each surveyor must adjust the GPS Between-Feature Position (BFP) distance setting to correspond to the average EDSW for that new area.

### **III. Conducting a Monitoring Route**

A. *Set the Between Feature Position*: The same distance as the EDSW.

B. *Initiate Monitoring Route*: A monitoring route is one continuous road, stream, or trail, for example the park entrance road. In some cases where the road/stream/trail is extremely long it may be broken up into smaller routes, for example the north park entrance road and south park entrance road.

Monitoring will take place one EDD from the road or riparian corridor. For roads and riparian corridors, technicians will walk out on one side of the monitoring route (road/waterway), then return to the starting point walking back on the other side. For single track trails the route will generally only be walked in one direction and the technician will walk on the trail itself. While walking, the surveyor searches for species on the Park Priority Invasive List by visually scanning (side to side) all of the land within the imagined borders of the swath. While searchers may be able to visually scan the landscape for target species as they walk, it is usually necessary to glance frequently at the ground to ensure safe foot placement, especially on highly uneven or steep terrain. If a high percent of the time spent walking through a search area must be devoted to looking down at one's feet, there is increased likelihood that weed infestations will be missed. In order to compensate, searchers are encouraged to stop on a regular basis and visually scan the area in all directions around them if they are unable to adequately inspect the area while walking. In such situations it is recommended that, at the very least, searchers stop and conduct a stationary 360-radius visual scan each time the equivalent of 1 EDSW has been traveled.

C. *Recording Invasive Plants*: Once a weed patch/infestation of a plant on the Park Priority Invasive List has been discovered, a mapping crew must record: 1) the monitoring route (4 letter code) and whether it is a road (R), trail (T), or riparian or hydrologic feature (H) (this information is usually pre-set in the GPS unit, 2) the sequential number of an invasion per monitoring route (this information is usually automatically generated by the GPS), 3) Point (with size estimate), 4) estimate canopy cover, and 5) note if the plant was pulled. For example on the park entrance road (four letter code of PAEN) monitoring route, the second detection of an invasive plant would be identified as "PAEN\_R\_2". It is important to note that not all non-native species that are found will be mapped. Widespread species, such as cheatgrass, may not be recorded during monitoring routes at some parks.

1. Verify that the pre-recorded information on the monitoring route and whether it is a road, trail, or riparian/hydrologic area is correct.

2. Record the location as a point. NCPN crews will map all invasive plant infestations as points. In the case of large infestations the observer can record multiple points 50 m apart. If several species are present with similar distributions, a point must be recorded for each individual species with its own sequential identification number. Invasions more than 50 m (55 yards) apart are considered separate invasions and must be marked as a separate point.

a. Point features reflect a distinct location described as a single position coordinate (Figure 3.2). Included with each point feature should be a buffer to estimate the infestation size and density. Point Dimensions - The size of each infestation is recorded as a point feature that is estimated visually (using a laser rangefinder) and placed in the size category most closely matched to its actual area: 1) 1 to a few plants, 2) few plants to 40 meters<sup>2</sup> (48 yards<sup>2</sup> or 0.01 acres), 3) 40 square meters to 400 square meters (48 yards<sup>2</sup> to 478 yards<sup>2</sup> or 0.01 to 0.10 acres), 4) 400 meters<sup>2</sup> to 1000 meters<sup>2</sup> (0.1 acre to 0.25 acre), 5) or 1000 m<sup>2</sup> to 2000 m<sup>2</sup> (0.25 acre to 0.5 acre) (see table 3.1). "1 to few plants" is used for isolated single plants or very small patches (2 meters x 2 meters) or less.

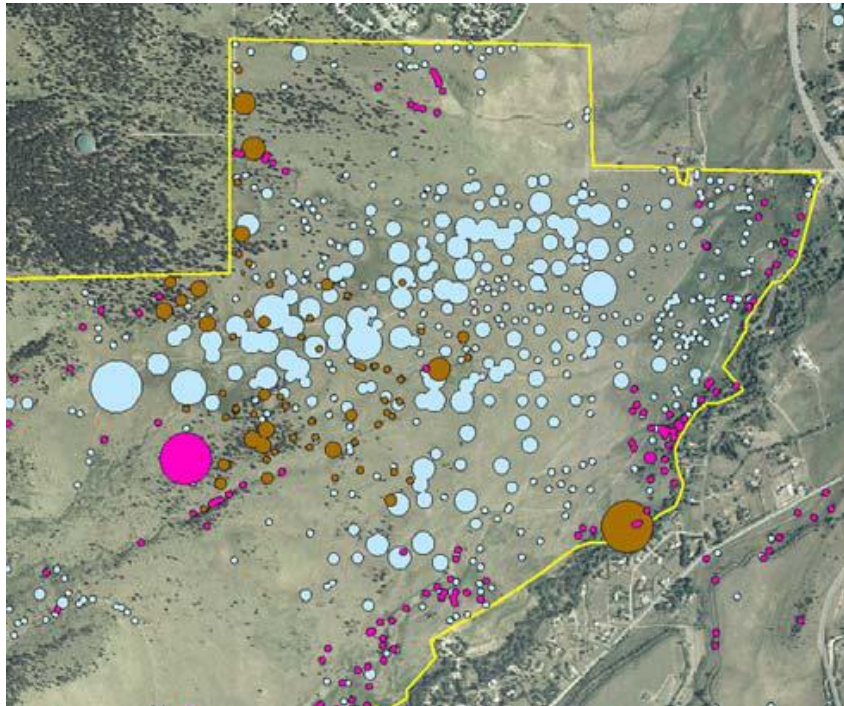


Figure 3.2. Areas mapped using buffered points to reflect the true scale of each infestation recorded by surveyors.

Table 3.1. Reference table for metric and English measurements.

| Meters <sup>2</sup> | Acres | Square Yards | Radius (m) | Radius (Yards) | Diameter (m) | Diameter (Yards) |
|---------------------|-------|--------------|------------|----------------|--------------|------------------|
| 40                  | 0.01  | 48           | 3.6        | 3.9            | 7.2          | 7.8              |
| 400                 | 0.1   | 478          | 11.3       | 12.3           | 22.6         | 24.6             |
| 1000                | 0.25  | 1,120        | 17.9       | 18.9           | 35.7         | 37.8             |
| 2000                | 0.5   | 2,420        | 25.3       | 27.8           | 50.1         | 55.5             |

- To estimate the size of a point infestation, the surveyor should envision the patch as a circle, oval, square, or rectangle (Zamora and Petroff 1985), whichever most closely represents its actual shape. These shapes enable the surveyor to take some basic measurements to calculate an area. If considered circular, the

surveyor determines a patch's average radius by visual estimate, pacing, or laser rangefinder (Figure 3.3). The radius should be an average of 2 readings - the measured distances to the furthest and closest edges of the patch as the surveyor stands in the approximate center. For rectangular or square patches, determine the average length and width, then multiply to obtain the total area (square meters).

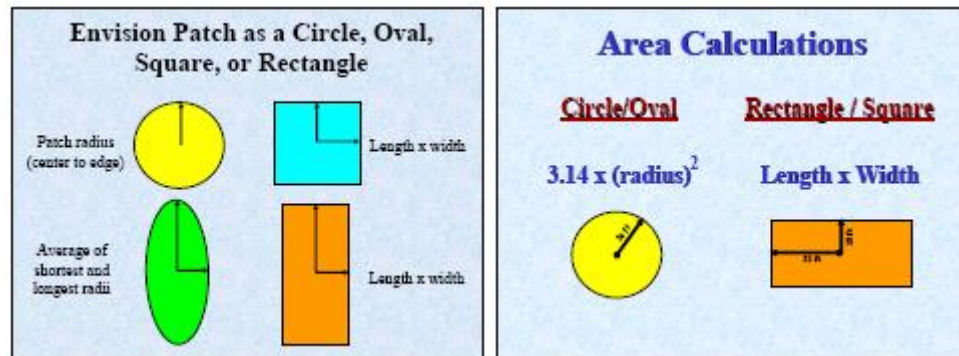


Figure 3.3. Standard shapes for estimating patch size with the necessary measurements required to determine area (left). Calculations used to find the area of an infestation (right).

3. Percent cover must be used in conjunction with PSR to describe weed infestations in such a way that the information will be of maximum value to control personnel. For example, based on a 50-m PSR, 20 yellow hawkweed plants all growing within a single dense circular patch would be considered a 0.001-hectare infestation (Figure 3.4). The infestation's density or canopy cover designation would be very high. However, if 20 plants of the same size were spread over a larger area, so that each plant was approximately 40 m away from its nearest neighbor, all of the plants would still be considered part of the same infestation. The total area infested would be 4 hectares, with a very low density or canopy cover designation (Figure 3.4).

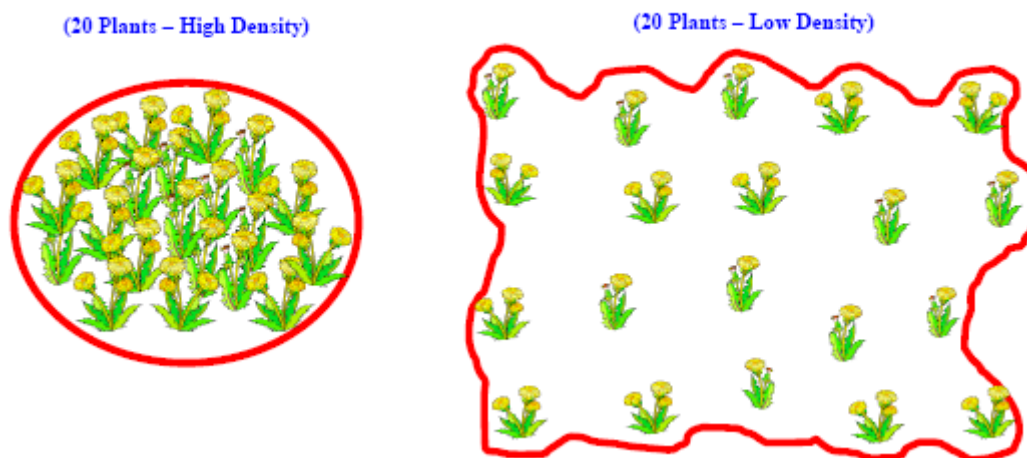


Figure 3.4. On the left, twenty plants are crowded into a 0.001-hectare area. Individual plants are separated from one another by much less than the PSR, and so are considered a single high density infestation of 0.001 hectare in size. On the right, twenty plants spread over a 4-hectare area. Individual plants are separated from one another by only slightly less than the PSR, and are still considered a single infestation. However, this patch is very low in density and is 4 hectares in size.

The term "canopy cover" refers to a visual estimate of the amount or "percentage" of ground covered by the vertical projection of plant matter as visualized from a bird's-eye view of the vegetation (Elzinga et al. 1998). In other words, the estimated percentage of ground obscured by the vegetation of a single weed species (as if viewed from above) is the canopy cover (or aerial cover) of that species. It includes both the living and dead standing material of the

vegetation of a single plant species. It is possible that the individual canopy cover values for 2 or more species growing in the same patch may total more than 100 percent.

Canopy cover of a patch is expressed as a range of canopy cover classes: 1) trace = less than 1 percent, 2) low = 1 to 5 percent, 3) moderate = 6 to 25 percent, 4) high = 26 to 50, or majority = 51 to 100 percent. A surveyor first envisions a perimeter defined by the outermost plants of an infestation (Figure 3.5). To estimate canopy cover the surveyor first considers the midpoint value between 0 and 100 percent, and asks the question "Is the percent cover greater or less than 50 percent?" If the answer is less, the surveyor selects the midpoint value between 0 and 50, and then asks the question "Is the percent cover greater or less than 25 percent?" If the answer is less, then the next question becomes "Is the percent cover between 25 and 12.5 percent or between 12.5 and 0 percent?" This continues until the surveyor cannot confidently make a distinction between values above and below the next midpoint. The closest canopy cover class is then chosen and selected from the GPS menu. The same process applies, whether estimating the canopy cover of a 0.5-acre infestation or a single plant. For the smallest size class cover is estimated by envisioning a 2 x 2 m plot centered on invasion.



Figure 3.5. The percent canopy cover is estimated from within the perimeter of the actual infested area.

4. Qualified surveyors may remove small isolated populations of invasive plants. Surveyors will need to use judgment on when to pull plants. If they are at a head of a canyon far from a road and they are in a weed free area then a single specimen or a group of a small invasion should be removed. If there are several small invasions then that should be left for park control personnel to control. In the vast majority of cases invasions will require response commitments from parks and EPMTs. Note whether the species was pulled.

5. Record the following ancillary information with every infestation: slope and aspect, topography (hillside, distance to road, wetland, or stream, etc.), the growth stage of trees, evidence of prior treatment, and any disturbance features (e.g., recent fire, flood, small mammal disturbance).

#### **IV. Conducting a Monitoring Transect**

In order to collect data to make trend estimates over time, transects with plots are needed in addition to the more spatially extensive monitoring routes. Plots are more statistically sound, and increase the power of the data collected by allowing for greater inference across unsampled areas. The methods for the monitoring plots are based on the Beyond NAWMA standards by Stohlgren et al. (found at <http://www.nawma.org/documents/Mapping%20Standards/BEYOND%20NAWMA%20STANDARD%20DS.pdf>) This method makes the samples comparable to other monitoring standards (e.g. Forest

Health Monitoring, Forest Inventory and Analysis, USGS Modified- Whittaker technique and others). These plots provide an estimate of actual cover, a method to calibrate ocular and other cover estimates, models the patches of missed and less sampled non-native species, and a method for understanding which habitats and sites are being invaded. Plots are kept to a minimum so that maximum spatial extent can be achieved with monitoring crews.

A transect with 3 vegetation quadrats is established every 500 m along each monitoring route.

#### A. Establishing the Transect and Vegetation Quadrats

1. For single-track trails where the observer is walking on the trail itself, a transect shall be established perpendicular from the monitoring route (road, trail, stream/river channel) on alternating sides. For roads and riparian areas where the observer is walking one EDD from the road or riparian area the transect will be established perpendicular to the edge of the road or stream bed on the same side as the route is occurring. For routes such as roads or riparian areas where the observer is walking on one side on the way out and the opposite side on the way back, the transects only need to be established on the way out. Take a GPS location at the start of the transect.
2. Establish 3 vegetation quadrats along the transect at 3, 8, and 13 m from the monitoring route. If there are not 13-m between the monitoring route and a constrained area (cliff face, NPS boundary, etc.), space the 3 vegetation quadrats equidistant from each other.
3. Place a 1-m<sup>2</sup> sampling frame on the plot. The 1m<sup>2</sup> quadrat frame is placed on the right side of the transect line as the technician walks from the monitoring route. Level quadrat if necessary by propping up quadrat corners.

#### B. Measuring the Vegetation Quadrats

1. Vegetation diversity and cover measurements are taken within the 1-m<sup>2</sup> quadrat. On each quadrat, the following types of data are recorded: identify any plant species and life form from the Invasive Plant Priority List and its respective percent cover to the following classes: <1, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11-25, 26-50, >50. Unlike monitoring routes, in plots even widespread exotic plants (cheatgrass) will be recorded.
2. Identify dominant microhabitats and percent cover to the nearest 10% within the 1-m<sup>2</sup> quadrat. Cover is estimated for each ground variable listed in the Microhabitat Variables Table.

| Microhabitat Variables |                                                                                                                                                                           |
|------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Code                   | Definition                                                                                                                                                                |
| 1                      | Dead wood; log and slash (>10cm diameter), stump, branches and limbs                                                                                                      |
| 2                      | Dung                                                                                                                                                                      |
| 3                      | Fungus                                                                                                                                                                    |
| 4                      | Lichen                                                                                                                                                                    |
| 5                      | Litter / Duff; accumulation of organic matter over forest mineral soil.                                                                                                   |
| 6                      | Live root / bole; living roots at the base of trees or exposed at the surface of the forest floor or soil and cross-sectioned area of live tree boles at the ground line. |
| 7                      | Mineral soil / Sediment; physically weathered soil parent material that may or may not also be chemically and biologically altered.                                       |
| 8                      | Moss                                                                                                                                                                      |
| 9                      | Cryptogram                                                                                                                                                                |
| 10                     | Road                                                                                                                                                                      |
| 11                     | Rock; a large rock or boulder or accumulations of pebbles or cobbles.                                                                                                     |
| 12                     | Standing water / flooded; ponding or flowing water that is not contained within banks.                                                                                    |
| 13                     | Stream; body of flowing water contained within banks.                                                                                                                     |

Each 1-m<sup>2</sup> quadrat frame is calibrated (painted in 10 cm sections) to make cover estimates easier. Only estimate cover on plants or portion of plant that falls inside the quadrat frame. Visually group species together into a percent cover. Fine tune that estimate by subtracting out any spaces or gaps. Familiarize yourself with what certain cover estimates (e.g., 10%, 50%, 80%, etc.) look like and use them as reference sizes. For example, if you know that 10% cover is about the same size as your fist, use your fist as a reference. There will often be overlap of plant species. Therefore, your total cover for a quadrat may exceed 100%.

## V. Field Data Processing

At the end of each day, field crews will mark and date all monitored areas on USGS 7.5' topographic maps to assist in determining project progress and thoroughness of coverage. The GPS between-feature positions that are recorded each day are used for reference when marking the topographic maps. Each crew member will keep a daily log of where they searched, what species they encountered, disturbances noted, thoroughness of coverage, and any additional information that they felt might be of importance to the project. Edits (such as eliminating any duplicate features) were made to the data, and any additional information (such as infestations drawn by hand on field maps or other data not recorded with a GPS unit) were added at this time. Four sub-folders are established within the main project folder on the computer hard drive. These are for: 1) unedited raw GPS rover files, 2) edited GPS rover files, 3) differentially corrected edited GPS rover files, and 4) GIS shapefiles created from the differentially corrected rover files (for export and use in ArcView). Separate disks were used for raw and edited rover files.

Raw data consists of rover files that are transferred directly from GPS units to the computer, and stored without any editing or modification. They are named using a 6-digit code (month-day-hour) preceded by a single letter (corresponding to the first letter in the crew member's last name), and ending in ".ssf." For example, "A051913.ssf" would be the file name for raw GPS data collected by Kim Andersen beginning in the thirteenth hour (24-hr local time) on May 19.

Edited data files are created from raw files that are viewed in Pathfinder Office and checked for accuracy. Features were added or deleted in the process of editing to eliminate any duplicate reporting (two crew members finding the same infestation), and to add locations drawn on field maps (as when satellite signals could not be obtained). Any locations that are added in the editing process are noted as "hand mapped" in the notes section and are denoted as "Non-GPS" under the differential correction section. Notes are sometimes expanded during the editing process to include more detailed information about the surrounding habitat. Gross area features are added during this process. File names are changed after editing to avoid confusion with the raw files. Edited files are named as a 3-letter month and 2-digit day abbreviation, followed by a dash and the first letter of the crew member's last name. If a crew member collected more than one file for that day, a number would follow the crew identification letter. For example, the edited version of the second file of GPS data collected by Kim Andersen on May 19 would be May19-A2.ssf.

The data from edited GPS rover files are then differentially corrected. Features that were added or deleted in the editing process were not differentially corrected; nor were points for which corresponding base station data were not available. Generally, the closest base station to the monitoring area was used. However, if use of a slightly more distant base station resulted in a higher percentage of successfully corrected points, it was used in preference to a closer station. Corrected files retained the same name as their edited counterparts, but used the file extension "cor" rather than "ssf". Example: May19-A2.cor.

Shapefiles are created from exported data by exporting the differentially corrected files from Pathfinder Office into ArcView. The shapefiles are created from the various categories in the data dictionary such as point-weed shapefile, line-weed shapefile, area-weed shapefile, photopoint

shapefile, and between-feature point shapefile. Three kinds of files are created from each “.cor” file. These are “.shp”, “.shx”, and “.dbf.” Example: pt-weed.shp, pt-weed.shx, ptweed.dbf.

NCPN Invasive Plant Monitoring Entered by: Proofed by:

Proofed by:

Observer \_\_\_\_\_

| Microhabitat                | % cover to nearest 10% |    |    | Cover Classes |       |
|-----------------------------|------------------------|----|----|---------------|-------|
|                             | Q1                     | Q2 | Q3 |               |       |
| Dead wood (>10 cm diameter) |                        |    |    | <1            | 11-25 |
| Dung                        |                        |    |    | 1             | 26-50 |
| Fungus                      |                        |    |    | 2             | >50   |
| Lichen                      |                        |    |    | 3             |       |
| Litter/Duff                 |                        |    |    | 4             |       |
| Live root/Bole              |                        |    |    | 5             |       |
| Mineral soil/Sediment       |                        |    |    | 6             |       |
| Moss                        |                        |    |    | 7             |       |
| Cryptogram                  |                        |    |    | 8             |       |
| Road                        |                        |    |    | 9             |       |
| Rock                        |                        |    |    | 10            |       |
| Standing water/flooded      |                        |    |    |               |       |
| Stream                      |                        |    |    |               |       |
| Trash/junk                  |                        |    |    |               |       |

**REMEMBER:**

**A transect w/3 quadrats are established every 200m along each segment.**

**Resulting in 5 transects per monitoring segment.**

**For single-track trails=transects are perpendicular from route on alternating sides.**

**For roads=transects are established only on the way out.**

**Establish 3 quadrats along transect at 3,8,13m from monitoring route.**

**If there are not 13m btwn route and obstacle, space quads equidistant.**

**1m<sup>2</sup> quadrat frame placed on the right side of transect line away from route.**

**Only estimate cover on plants that fall inside quadrat frame.**

[illegible]

# Early Detection of Invasive Exotic Plants in the Northern Colorado Plateau Network

## Standard Operating Procedure (SOP) 4: Extra-Area Search Methods

**Version 1.00 (May 2008)**

### Revision History Log:

| Prev. Version # | Revision Date | Author | Changes Made | Reason for Change | New Version # |
|-----------------|---------------|--------|--------------|-------------------|---------------|
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This SOP gives step by step methods for the collection of field data for invasive plants extra-area searches. Each year up to 25% of NCPN survey effort within a park can be directed towards extra-areas. Extra-areas are somewhere where park personnel think an invasive plant survey is of utmost importance. Examples could be a new burn, change in land management within a park or adjacent to a park, or an anecdotal report of a threatening new invasive plant. In some years there may not be any extra areas conducted, in others multiple surveys may be needed. The methods outlined in this SOP essentially follow the methods outlined by Utah State University (Anderson and Dewey 1997). In several cases large portions of the text have been lifted directly from their handbook. We are grateful for the efforts on the Colorado Plateau and their expertise in this area.

### I. Determine the Species and Area to Be Searched and Method of Search

The first task is to determine the size of the area and the method to accomplish the search. Transects are an effective way to ensure that an area is covered thoroughly, and are the preferred method in large areas of relatively featureless flat terrain. However, this method is generally impractical in steep terrain or along winding river corridors or canyon bottoms.

*A. Determine the Park Priority Invasive List.* At each park NCPN staff will work with park staff and other local cooperators to develop a target species list of 20-30 invasive plant species that the NCPN crews will be responsible for during the monitoring routes and while surveying the monitoring routes. This targeted list will allow training prior to park visits. Since these surveys are designed to be rapid, they will be much more effective if the crews can have a focused search image, rather than every possible invasive plant species. The list will be updated annually to ensure that any species that are new to the area are added (SOP #11).

*B. Transect Searches:* A transect pattern consists of searching along straight parallel lines, usually by following a UTM northing/easting (preferred) or a compass bearing. The surveyor walks to a starting position on the edge of the intended search area corresponding to a convenient UTM value (perhaps ending in one, two, or three zeros). Using a compass, the surveyor takes a declination corrected bearing from that point and aims for a landmark on the distant horizon in the direction of desired travel (grid-north, grid-south, grid-east, or grid-west). It

is important to remember that UTM northings and eastings are based on grid north, rather than true\ north or magnetic north. When using UTM northings or eastings as search transects mapping crews should generally keep the GPS's north reference set to "magnetic". This helps reduce confusion if wanting to use the GPS bearing reference for navigation (and have it be the same as the compass bearing). Note from the appropriate topographic map the correct declination for the area being surveyed.

While glancing occasionally at the horizon landmark and UTM location displayed on the GPS screen to stay on course, the surveyor walks along searching on either side of the transect center. When a weed patch is found, the surveyor leaves the transect, stands in the center of the patch, enters the necessary data, and then uses the GPS to return to the same place on the transect. A quick check of the horizon (or compass) indicates the desired direction of travel.

*C. Contouring (Topographic) Searches:* This is the method preferred for hilly country. Searchers using a contouring search pattern walk as perpendicular as possible to the direction of the slope, essentially paralleling the elevation lines of a topographic map. Having completed a full "pass" across a slope, the surveyor then moves up or down slope one effective search swath width and repeats the process in the opposite direction. This creates a series of parallel contiguous search swaths, which allows surveyors to sample all micro-habitats associated with the terrain – ridges, draws, and side slopes - over the full range of aspects, elevations, and plant communities. Equally important, it minimizes the physical exertion required to search hilly terrain.

The main challenge of the contour method is staying relatively level. A clinometer can help to alleviate some of this frustration. In open hilly terrain, a surveyor uses the clinometer to identify a landmark a few hundred meters ahead at the same elevation. The surveyor walks toward that landmark without climbing or going downhill any more than necessary. The surveyor re-checks the landmark from time to time with the clinometer to be sure he/she is staying at the desired elevation. In timbered hilly terrain, if visibility is limited so that the use of distant visual landmarks is not feasible, use the elevation reading of the GPS unit to stay at approximately the same level.

## **II. Initiating the Search**

*A. Determine the Minimum Detection Target Size (MDTS).* Field technicians cannot be expected to find every single plant of every targeted weed species when conducting monitoring routes. While searching for single mature plants of some species such as Russian olives (*Elaeagnus angustifolia*) and saltcedar (*Tamarix ramosissima*) might be possible due to their large size, single plants of other species such as field bindweed (*Convolvulus arvensis*) or sulfur cinquefoil (*Potentilla recta*) might prove impossible under certain field conditions. The Minimum Detection Target Size (MDTS) represents the patch size that is large enough to be detected with a high level of confidence (typically at least 90 percent of the total number of patches of that size and larger in the inventory area) under actual field conditions; but small enough so that any missed patches smaller than the MDTS could still feasibly be eradicated if not found until the next scheduled monitoring visit. NCPN surveys will have a minimum detection target size of 1 meter<sup>2</sup> (approximately 20 x 20 ft) for all invasive species, unless otherwise noted.

*B. Determine Effective Detection Distance (EDD).* The EDD is the maximum distance from which a searcher can consistently detect (see and recognize) the MDTS of the least visible targeted species with at least 90 percent detection efficiency (Figure 4.1). Crew members calibrate themselves by walking away from a targeted patch size of the least visible species and determining the maximum distance from which they can consistently see and recognize the patch with complete confidence. The distance is measured either by pacing or using a laser rangefinder. The width of an EDD is determined and adjusted as needed by each surveyor based on variations in terrain, walking speed, associated vegetation, and target species. Heavy cover and/or difficult-to-see species may require slowly walking detection swath widths as narrow as 5-7 meters. In very open terrain with little vegetation, effective swath widths may be 50 m or greater for an EDD of 1 meter<sup>2</sup>.

C. *Determine Effective Detection Swath Width (EDSW)*. EDSW is defined as the maximum width (meters) of a linear search swath (band transect) in which a walking observer is confident of visually detecting 90% of all target species of the minimum specified infestation size (Figure 4.1). NCPN sets the maximum width of their search pattern swaths based on the goal of detecting at least 90 percent of all target weed patches 1 meter<sup>2</sup> or larger in size. The effective detection swath width (EDSW) is equal to 2 times the EDD, because the surveyor is able to effectively detect weeds 1 EDD on either side of his/her search route. Determine the EDSW and enter into the GPS. It is not necessary to adjust the setting for small or temporary changes in the EDSW, but actual search patterns should always be modified as needed to compensate for any temporary changes in visibility (typically, crews don't change settings more than a maximum of once or twice per monitoring route).

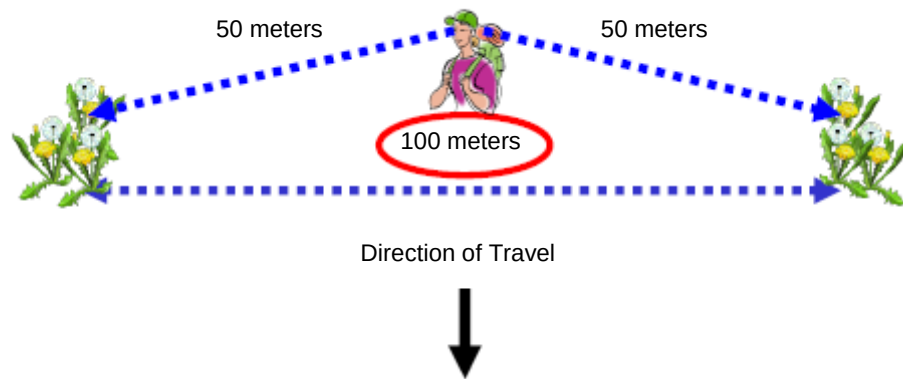


Figure 4.1. If the maximum Effective Detection Distance (EDD) for this MDTs is 50 meters, the actual Effective Detection Swath Width would be 100 meters.

D. *Determine the Patch Separation Resolution (PSR)*. The PSR is defined as the minimum distance between plants that must be considered members of separate patches or infestations. Individuals or clusters of a target species separated by the PSR distance or more must be recorded as separate patches. Plants separated by less than the PSR are usually considered a single patch or infestation. The PSR set at 50 meters, unless otherwise noted. This is the same whether an infestation is mapped as a point or polygon. The basis for selecting this value is the assumption that most plants or groups of plants less than 50 meters apart will typically be considered as one infestation when planning and implementing normal weed control operations.

E. *Set the Between Feature Position (BFP) Setting*. BFPs allow electronic tracking of the user's route. In the case of some Trimble units (GeoExplorer III, XM, and XT models) this option is called "Between-Feature" tracking. The GPS unit automatically generates these positions at a set distance or time interval. Use the distance setting for these positions. Use the EDSW as the setting for the BFP. The "Between-Feature" positions can be depicted on end-product maps to represent the coverage and identify any gaps. Each time a surveyor walks the equivalent of "one effective detection swath width", the Trimble GPS unit "beeps" and creates a point. So, at the beginning of each day, and whenever moving to significantly different terrain or vegetative cover, each surveyor must adjust the GPS Between-Feature Position (BFP) distance setting to correspond to the average EDSW for that new area.

F. *Initiate Survey Route*: While walking the surveyor searches for target weeds by visually scanning (side to side) all of the land within the imagined borders of the swath. While searchers may be able to visually scan the landscape for target species as they walk, it is usually necessary to glance frequently at the ground to ensure safe foot placement, especially on highly uneven or steep terrain. If a high percent of the time spent walking through a search area must be devoted

to looking down at one's feet, there is increased likelihood that weed infestations will be missed. In order to compensate, searchers are encouraged to stop on a regular basis and visually scan the area in all directions around them if they are unable to adequately inspect the area while walking. In such situations it is recommended that, at the very least, searchers stop and conduct a stationary 360-radius visual scan each time the equivalent of 1 EDSW has been traveled.

*G. Determine the Spacing of Survey Routes:* In most cases the areas will be surveyed comprehensively. In this case transects will be placed on EDSW apart so that the entire extra area is covered. In some cases, park staff may only want a quick look to determine if additional surveys should be completed. In this case the spacing of transects would be determined in cooperation with the pertinent park staff.

### III. Recording Invasive Plants

Once a weed patch/infestation from the Invasive Plant Priority list has been discovered, a mapping crew must record : 1) the survey unit, 2) the number of the invasion per survey unit, 3) dimension of a point record the dimensions, and 4) estimate canopy cover. It is important to note that not all non-native species that are found will be mapped as points. For example cheatgrass that is dominant across a park or a portion of the park might not be individually mapped. These large infestations can be marked as gross areas (see below).

*A. Record the extra area location.*

*B. Record the number of the infestation in sequential order.*

*C. Decide to record the location as a point, polygon, or gross area.* NCPN crews will map all invasive plant infestations 0.25 hectares or less (0.6 acres or 55 yards by 55 yards or half the size of a football field) in size as individual point features. Infestations larger than 0.25 hectares can be recorded as polygons or gross areas if the polygon is extremely large or contains habitat that is difficult to traverse. If several species are present with similar distributions, a polygon or point must be recorded for each individual species. Invasions more than 50 m apart are considered separate invasions and must be marked as either a point or polygon.

1. Polygon features are created by delineating the boundaries of existing weed infestations by walking the actual boundary with the GPS.

2. Point features reflect a distinct location described as a single position coordinate. Point features will be buffered with circles to reflect the recorded patch size (Figure 4.2). The size of each infestation is recorded as a point feature that is estimated visually (using a laser rangefinder) and placed in the size category most closely matched to its actual area: 1) 1 to a few plants, 2) few plants to 40 meters<sup>2</sup> (48 yards<sup>2</sup>), 3) 40 square meters to 400 square meters (48 yards<sup>2</sup> to 478 yards<sup>2</sup>), 4) 400 meters<sup>2</sup> to 1000 meters<sup>2</sup> (0.1 acre to 0.25 acre), 5) or 1000 m<sup>2</sup> to 2000 m<sup>2</sup> (0.25 acre to 0.5 acre) (see table 4.1). "1 to few plants" is used for isolated single plants or very small patches (2 meters x 2 meters) or less. "1 to few plants" is used for isolated single plants or very small patches (2 meters x 2 meters) or less.

Table 4.1. Reference table for metric and English measurements.

| Meters <sup>2</sup> | Acres | Square Yards | Radius (m) | Radius (Yards) | Diameter (m) | Diameter (Yards) |
|---------------------|-------|--------------|------------|----------------|--------------|------------------|
| 40                  | 0.01  | 48           | 3.6        | 3.9            | 7.2          | 7.8              |
| 400                 | 0.1   | 478          | 11.3       | 12.3           | 22.6         | 24.6             |
| 1000                | 0.25  | 1,120        | 17.9       | 18.9           | 35.7         | 37.8             |
| 2000                | 0.5   | 2,420        | 25.3       | 27.8           | 50.1         | 55.5             |

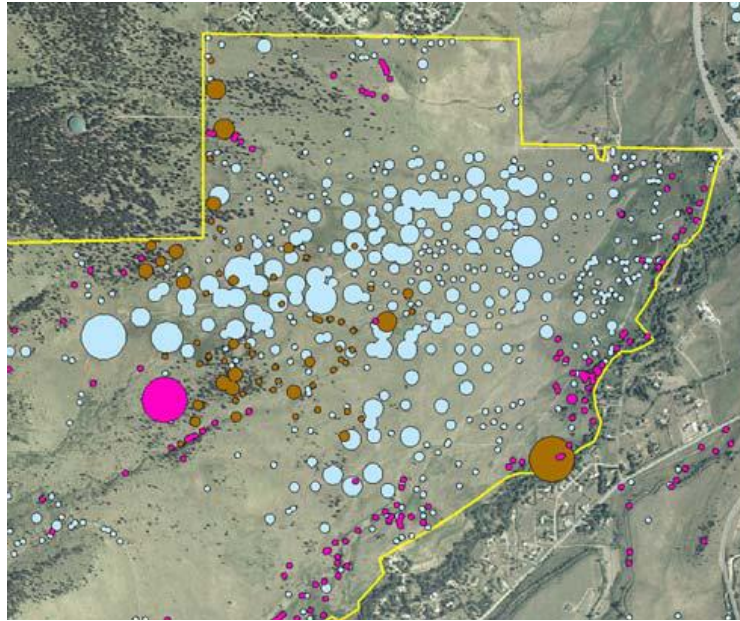


Figure 4.2. Areas mapped using buffered points to reflect the true scale of each infestation recorded by surveyors.

- To estimate the size of a point infestation, the surveyor should envision the patch as a circle, oval, square, or rectangle (Zamora and Petroff 1985), whichever most closely represents its actual shape. These shapes enable the surveyor to take some basic measurements to calculate an area. If considered circular, the surveyor determines a patch's average radius by visual estimate, pacing, or laser rangefinder (Figure 4.3). The radius should be an average of 2 readings - the measured distances to the furthest and closest edges of the patch as the surveyor stands in the approximate center. For rectangular or square patches, determine the average length and width, then multiply to obtain the total area (square meters).

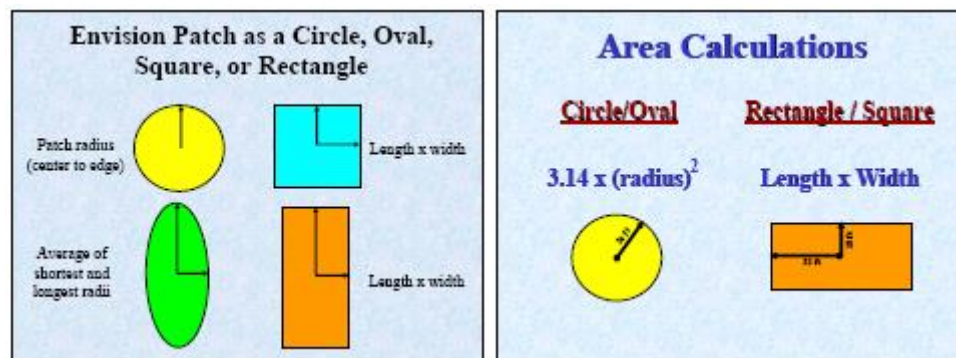


Figure 4.3. Standard shapes for estimating patch size with the necessary measurements required to determine area (left). Calculations used to find the area of an infestation (right).

3. Gross Area is typically used to describe a very large infestation, or a conglomerate of many smaller infestations or individual plants distributed widely over a very large area, if mapping each as a separate polygon or point is not feasible. It is very time consuming to plot the actual perimeter of extremely large or discontinuous infestations of an abundant species spread over broad landscapes, and the increased accuracy of plotting individual plants or patches is not valuable enough to compensate for the associated increase in cost or manpower when conducting extra-area searches. In such cases, a gross estimate of the total land area infested is sufficient to meet the survey requirements (USDA-FS 2002).

Gross areas are based on crude approximations and mathematical calculations rather than measured values. Whenever a Gross Area is designated, an accompanying value must be provided estimating the percentage of the Gross Area that is likely infested by the target weed species. This "percent infested" value will be used to calculate the total estimated acreage of all weed patches/infestations within the *Gross Area*. In addition to an estimate of the total infested area, an estimated average canopy cover within the infested areas is also required. It is important to remember that this value is not to be based on all of the land within the Gross Area boundary, but only for those portions considered "infested".

D. *Percent Cover*: These measurements must be used in conjunction with PSR to describe weed infestations in such a way that the information will be of maximum value to control personnel. For example, based on a 50-m PSR, 20 yellow hawkweed plants all growing within a single dense circular patch would be considered a 0.001-hectare infestation (Figure 4.4). The infestation's density or canopy cover designation would be very high. However, if 20 plants of the same size were spread over a larger area, so that each plant was approximately 40 m away from its nearest neighbor, all of the plants would still be considered part of the same infestation. The total area infested would be 4 hectares, with a very low density or canopy cover designation (Figure 4.4).

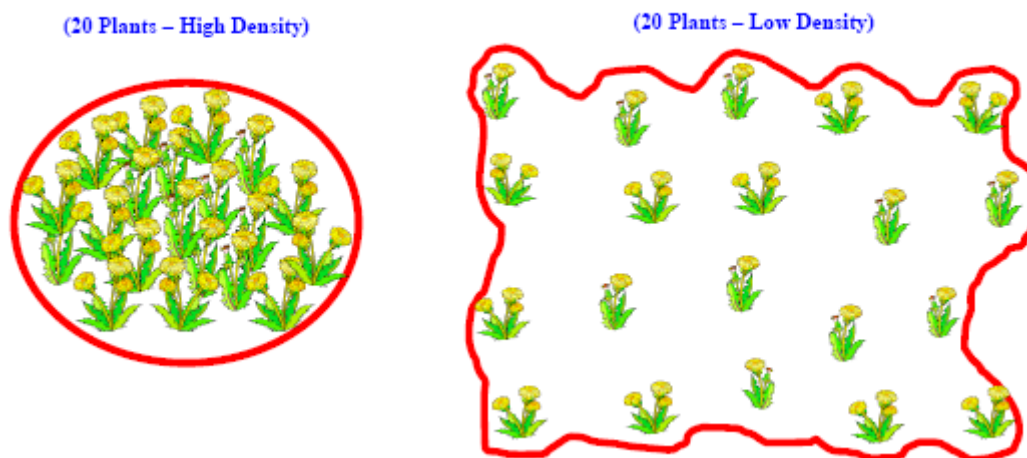


Figure 4.4. On the left, twenty plants are crowded into a 0.001-hectare area. Individual plants are separated from one another by much less than the PSR, and so are considered a single high density infestation of 0.001 hectare in size. On the right, twenty plants spread over a 4-hectare area. Individual plants are separated from one another by only slightly less than the PSR, and are still considered a single infestation. However, this patch is very low in density and is 4 hectares in size.

The term "canopy cover" refers to a visual estimate of the amount or "percentage" of ground covered by the vertical projection of plant matter as visualized from a bird's-eye view of the vegetation (Elzinga et al. 1998). In other words, the estimated percentage of ground obscured by the vegetation of a single weed species (as if viewed from above) is the canopy cover (or aerial cover) of that species. It includes both the living and dead standing material of the vegetation of a single plant species. It is possible that the individual canopy cover values for 2 or more species growing in the same patch may total more than 100 percent.

Canopy cover of a patch is expressed as a range of canopy cover classes: 1) trace = less than 1 percent, 2) low = 1 to 5 percent, 3) moderate = 6 to 25 percent, 4) high = 26 to 50, or majority = 51 to 100 percent. A surveyor first envisions a perimeter defined by the outermost plants of an infestation (Figure 4.5). To estimate canopy cover the surveyor first considers the midpoint value between 0 and 100 percent, and asks the question "Is the percent cover greater or less than 50 percent?" If the answer is less, the surveyor selects the midpoint value between 0 and 50, and then asks the question "Is the percent cover greater or less than 25 percent?" If the answer is less, then the next question becomes "Is the percent cover between 25 and 12.5 percent or between 12.5 and 0 percent?" This continues until the surveyor cannot confidently make a distinction between values above and below the next midpoint. The closest canopy

cover class is then chosen and selected from the GPS menu. The same process applies, whether estimating the canopy cover of a 0.5-acre infestation or a single plant.



Figure 4.5. The percent canopy cover is estimated from within the perimeter of the actual infested area.

**E. Note Whether the Species was Pulled:** Qualified surveyors may remove small populations. Surveyors will need to use judgment on when to pull plants. If they are at a head of a canyon far from a road and they are in a weed free area then a single specimen or a group of a small invasion should be removed. If there are several small invasions then that should be left for park control personnel to control. In the vast majority of cases invasions will require response commitments from parks and EPMTs. Note whether the species was pulled.

**F. Ancillary Information:** Record the following with every infestation: slope and aspect, topography (hillside, distance to road, wetland, or stream, etc.), and any disturbance features (e.g., recent fire, flood, small mammal disturbance)

### III. Additional Situations

**A. Invasion on Inaccessible Land:** If mapping in terrain where reaching a visible weed infestation is difficult or impossible, it is still possible to accurately record that location as a point feature using an "offset" command in Trimble GPS models, the "projecting" option in certain Garmin GPS units, or similar functions in other brands and models of GPS units. Offsetting or projecting allows the surveyor to safely map those identifiable infestations found on steep terrain, across canyons, and across rivers without actually having to stand on that site (Figure 4.6). It allows the observer to maintain better accuracy than might be achieved by drawing the infestation by hand on a paper map or a touch-screen GPS unit.



Figure 4.6. Offsetting to a weed patch on a steep hillside across an impassable river.

Offsetting or projecting requires a determination of the compass bearing and the horizontal distance between the observer and the target. If an accurate elevation value is required, the vertical distance between the observer and the patch also is needed. Equipment needed for offsetting/projecting distant weed infestations includes a basic field compass, a laser rangefinder, a simple clinometer, and a calculator capable of computing basic trigonometry equations.

1. Bearing: A compass is used to determine the bearing to the center of the targeted weed infestation. It is easiest if the GPS is configured to magnetic north rather than true north. Otherwise, you will have to adjust the compass reading to compensate for declination. It is also important to hold the compass as far away as possible from your body, metal, electronic equipment (such as the GPS unit), or other objects that could influence the compass needle.

2. Horizontal Distance: The horizontal distance is easiest to determine, if the targeted infestation is at the same elevation as the observer. In this situation, simply use the laser rangefinder to determine the exact distance from your location to the center of the targeted weed patch. However, if the infestation is significantly above or below your present location, the distance determined by the rangefinder will be greater than the true horizontal distance. This distance determined by the laser rangefinder is referred to as the visual distance or slope distance (hypotenuse of a right triangle, Figure 4.7). If the visual distance rather than the true distance is used in the offsetting function, the weed point's placement on a map will be incorrect (placed further away from the observer than was actually the case).

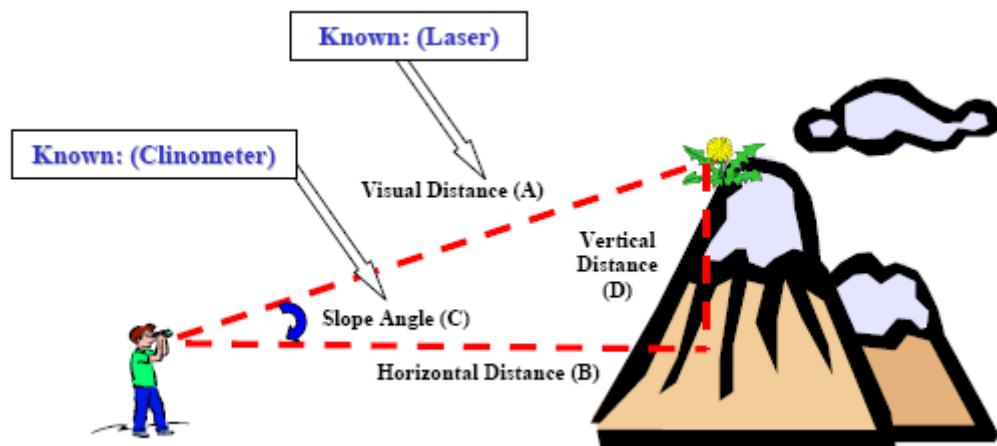


Figure 4.7. The visual distance between the observer and the weed (A) as measured by a laser rangefinder is greater than the true horizontal distance (B). Simple trigonometry can be used to calculate the horizontal distance and the vertical distance (D).

To determine the true horizontal distance requires use of a little basic trigonometry as per the following equation (based on the letters indicated in Figure 4.7):

$(\text{Cosine of } C) \times A = B$ . In other words, the cosine of the slope angle (C), multiplied by the visual distance (A), equals the horizontal distance (B).

The vertical angle can be determined by one of several methods. A clinometer is the most accurate tool, and some models can be relatively inexpensive. The field compasses can come equipped with a built-in clinometer.

3. Vertical Distance: The vertical distance is the difference in elevation between the observer and the targeted infestation (Figure 4.7). Vertical distance is calculated using the following equation (see Figure 4.7):

(Sine of C) x A = D In other words, the sine of the slope angle (C), multiplied by the visual distance (A) equals the vertical distance (D).

B. *Estimating Infestation Size From a Distance:* One of the challenges associated with offsetting is visually estimating the size of a distant weed infestation. The size of a remote weed patch can be estimated with surprising accuracy by using essentially the same measurements and calculations described above for offsetting. Two compass bearings are used to estimate the width of the patch (in degrees), and the degrees are converted to a distance using a slight variation of the trigonometric equation described earlier for vertical distance.

1. Circular Patches: To approximate the size of a distant weed infestation that is roughly round or square, you will need to determine distance between the surveyor and the center of the patch, as well as the radius or width of the patch.

a) The first step is to determine the distance to the approximate center of the patch (B) by using a laser rangefinder (Figure 4.8). The width of the patch is measured by determining the compass bearings of the right and left edges. The difference in degrees between the two edges is considered the width angle (Figure 4.9).

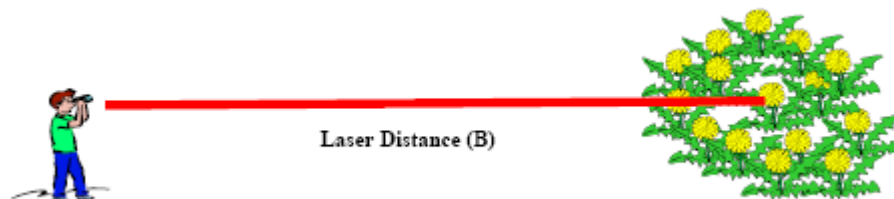


Figure 4.8. Side view of the surveyor determining the laser distance (B) to the center of a remote weed patch.

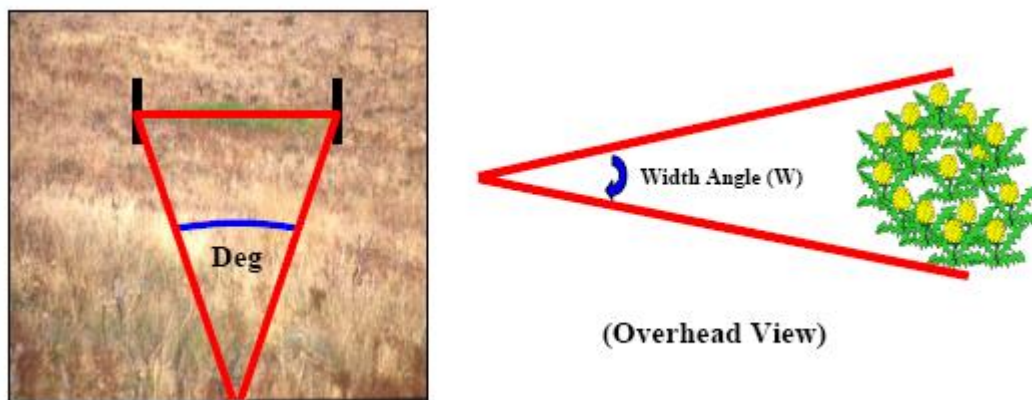


Figure 4.9. To determine the width angle, the surveyor must find the compass bearings of the left and right edges of the patch. The difference between the two bearings is the width angle (W). For example, if the left edge bearing is 88 degrees and the right edge bearing is 100 degrees, the width angle (W) is 12 degrees.

b) The next step is to determine the patch radius. To do this requires the radius angle (C), which is simply one half of the width angle described above. In Figure 4.10 the radius angle is identified by the letter "C" and the patch radius is designated as "D".

c) Patch radius is calculated using the following equation (see Figure 4.10): **(Tangent of C) x B = D**

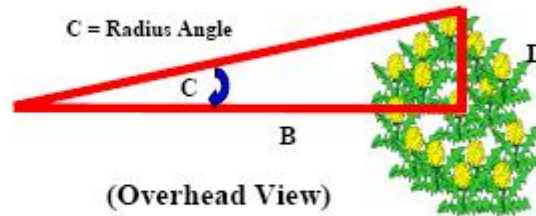
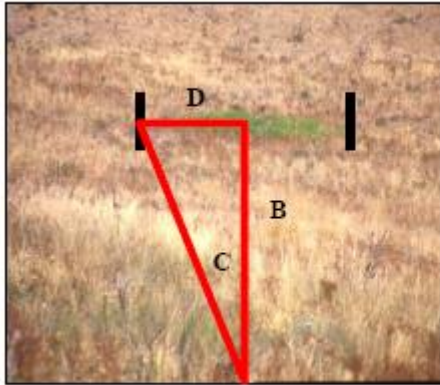


Figure 4.10. The radius angle (C) is equal to one half of the width angle (W in Figure 4.9). If the width angle of this leafy spurge patch was determined to be 12 degrees, the radius angle would be 6 degrees.

The area of a circular patch is calculated by using the following equation: **Area = 3.14 x (radius<sup>2</sup>)**

2. Square Patches: The same procedure could be followed up to the point of having determined the value corresponding to "D" (patch radius). But instead of using that value in the formula for determining the area of a circle, the calculated radius value would be considered half of the width of the square patch.

3. Other Shaped Patches: In situations where the shape of a remote patch is not circular or square, the observer is encouraged to envision it as a rectangle. The objective then becomes to estimate its length and width, then multiply the two together to determine the total area. The simplest approach is to first determine its width or length using the tangent equation described above. If a length is determined, the width value is estimated visually based on the ratio (percentage) of the width's dimension to the "measured" length value. The length of the patch is calculated using the same trigonometric equation described for determining the radius of a circular patch. However, the value resulting from this calculation (158 meters) is equal to only half of the total patch length, and so must be multiplied by 2 (Figure 4.11). **(Tangent of 37 degrees) x 210 meters = 158 meters.**

The width of the patch is estimated using the calculated length value as a standard of measure. In other words, the surveyor estimates the ratio between the length and width distances, and then multiplies the length by the corresponding percentage to determine the width. The surveyor estimates that the width of the saltcedar patch is approximately 20 percent of its length. By multiplication, the width is calculated to be an average of 63 meters (316 x 0.20) (Figure 4.11).



Figure 4.11. On the left, the length of the patch is equal to twice the value determined for "D" (see Figure 4.10). If "D" is 158 meters, the total patch length would be 316 meters. On the right, the width of the patch is estimated to average approximately 20 percent of the patch length. Thus, 20 percent of 316 meters is 63 meters.

#### IV. Field Data Processing

At the end of each day, field crews will mark and date all monitored areas on USGS 7.5' topographic maps to assist in determining project progress and thoroughness of coverage. The GPS between-feature positions that are recorded each day are used for reference when marking the topographic maps. Each crew member will keep a daily log of where they searched, what species they encountered, disturbances noted, thoroughness of coverage, and any additional information that they felt might be of importance to the project. Data are downloaded from GPS units onto a laptop computer each day using Pathfinder Office GIS software. Edits (such as eliminating any duplicate features) were made to the data, and any additional information (such as infestations drawn by hand on field maps or other data not recorded with a GPS unit) were added at this time. Four sub-folders are established within the main project folder on the computer hard drive. These are for: 1) unedited raw GPS rover files, 2) edited GPS rover files, 3) differentially corrected edited GPS rover files, and 4) GIS shapefiles created from the differentially corrected rover files (for export and use in ArcView). Separate disks were used for raw and edited rover files.

Raw data consists of rover files that are transferred directly from GPS units to the computer, and stored without any editing or modification. They are named using a 6-digit code (month-day-hour) preceded by a single letter (corresponding to the first letter in the crew member's last name), and ending in ".ssf." For example, "A051913.ssf" would be the file name for raw GPS data collected by Kim Andersen beginning in the thirteenth hour (24-hr local time) on May 19.

Edited data files are created from raw files that are viewed in Pathfinder Office and checked for accuracy. Features were added or deleted in the process of editing to eliminate any duplicate reporting (two crew members finding the same infestation), and to add locations drawn on field maps (as when satellite signals could not be obtained). Any locations that are added in the editing process are noted as "hand mapped" in the notes section and are denoted as "Non-GPS" under the differential correction section. Notes are sometimes expanded during the editing process to include more detailed information about the surrounding habitat. Gross area features are added during this process. File names are changed after editing to avoid confusion with the raw files. Edited files are named as a 3-letter month and 2-digit day abbreviation, followed by a dash and the first letter of the crew member's last name. If a crew member collected more than one file for that day, a number would follow the crew identification letter. For example, the edited version of the second file of GPS data collected by Kim Andersen on May 19 would be May19-A2.ssf.

The data from edited GPS rover files are then differentially corrected. Features that were added or deleted in the editing process were not differentially corrected; nor were points for which corresponding base station data were not available. Generally, the closest base station to the monitoring area was used. However, if use of a slightly more distant base station resulted in a higher percentage of successfully corrected points, it was used in preference to a closer station. Corrected files retained the same name as their edited counterparts, but used the file extension ".cor" rather than ".ssf". Example: May19-A2.cor.

Shapefiles are created from exported data by exporting the differentially corrected files from Pathfinder Office into ArcView. The shapefiles are created from the various categories in the data dictionary such as point-weed shapefile, line-weed shapefile, area-weed shapefile, photopoint shapefile, and between-feature point shapefile. Three kinds of files are created from each ".cor" file. These are ".shp", ".shx", and ".dbf." Example: pt-weed.shp, pt-weed.shx, ptweed.dbf.

# Early Detection of Invasive Exotic Plants in the Northern Colorado Plateau Network

## Standard Operating Procedure (SOP) 5: Monitoring Lite

**Version 1.00 (May 2008)**

### Revision History Log:

| Prev. Version # | Revision Date | Author | Changes Made | Reason for Change | New Version # |
|-----------------|---------------|--------|--------------|-------------------|---------------|
|                 |               |        |              |                   |               |
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This SOP gives step by step methods for the collection of field data for invasive plants along roads, trails, and other areas where park personnel might visit. This is a modification of SOP #3 Monitoring Route Methods to allow park staff, volunteers, or students that may not have extensive botanical information to still collect exotic plant information. Unlike SOP# 3 routes are conducted opportunistically as staff or volunteers conduct other park tasks. The methods outlined in this SOP essentially follow the methods outlined by Utah State University (Anderson and Dewey 1997). In several cases large portions of the text have been lifted directly from their handbook. We are grateful for the efforts on the Colorado Plateau and their expertise in this area.

### I. Monitoring Routes

Monitoring routes will follow the roads, trails, and riparian areas in a park. As monitoring routes are traversed, locations of all target species are documented using mapping grade global positioning system (GPS) units less than 5-meter accuracy.

Field locations are recorded by GPS as UTM coordinates, and are later differentially corrected in the production of final digital products. The crews record invasive plant occurrence data on hard-copy (USGS 7.5-minute topographical maps) in any situation where GPS satellite reception was not possible (such as in narrow canyons) or in cases of GPS equipment malfunction. All data from field maps are converted to digital format.

### II. Definitions

*A. Determine the Minimum Detection Target Size (MDTS).* Field technicians cannot be expected to find every single plant of every targeted weed species when conducting monitoring routes. While searching for single mature plants of some species such as Russian olive (*Elaeagnus angustifolia*) and saltcedar (*Tamarix ramosissima*) might be possible due to their large size, single plants of other species such as field bindweed (*Convolvulus arvensis*) or sulfur cinquefoil (*Potentilla recta*) might prove impossible under certain field conditions. The Minimum Detection Target Size (MDTS) represents the patch size that is large enough to be detected with a high level of confidence (typically at least 90 percent of the total number of patches of that size and larger in the monitoring area) under actual field conditions; but small enough so that any missed

patches smaller than the MDTs could still feasibly be eradicated if not found until the next scheduled monitoring visit. NCPN monitoring will have a minimum detection target size of 1 meter<sup>2</sup> (approximately 20 x 20 ft) for all invasive species, unless otherwise noted.

**B. Determine Effective Detection Distance (EDD).** The EDD is the maximum distance from which a searcher can consistently detect (see and recognize) the MDTs of the least visible targeted species with at least 90 percent detection efficiency (Figure 5.1). Crew members calibrate themselves by walking away from a targeted patch size of the least visible species and determining the maximum distance from which they can consistently see and recognize the patch with complete confidence. The distance is measured either by pacing or using a laser rangefinder. The width of an EDD is determined and adjusted as needed by each surveyor based on variations in terrain, walking speed, associated vegetation, and target species. Heavy cover and/or difficult-to-see species may require slowly walking detection swath widths as narrow as 5-7 meters. In very open terrain with little vegetation, effective swath widths may be 50 m or greater for an EDD of 1 meter<sup>2</sup>.

**C. Determine Effective Detection Swath Width (EDSW):** EDSW is defined as the maximum width (meters) of a linear search swath (band transect) in which a walking observer is confident of visually detecting 90% of all target species of the minimum specified infestation size (Figure 5.1). NCPN sets the maximum width of their search pattern swaths based on the goal of detecting at least 90 percent of all target weed patches 1 meter<sup>2</sup> or larger in size. The effective detection swath width (EDSW) is equal to 2 times the EDD, because the surveyor is able to effectively detect weeds 1 EDD on either side of his/her search route. Determine the EDSW and enter into the GPS per monitoring route. It is not necessary to adjust the setting for small or temporary changes in the EDSW, but actual search patterns should always be modified as needed to compensate for any temporary changes in visibility (typically, crews don't change settings more than a maximum of once or twice per monitoring route).

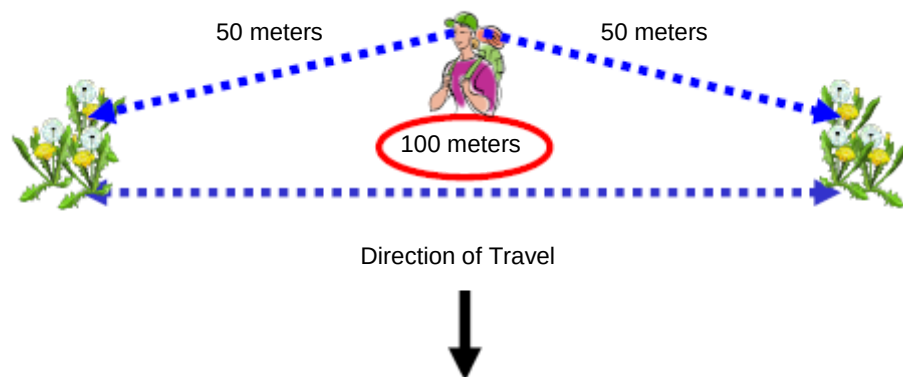


Figure 5.1. If the maximum Effective Detection Distance (EDD) for this MDTs is 50 meters, the actual Effective Detection Swath Width would be 100 meters.

**D. Determine Patch Separation Resolution (PSR):** The PSR is defined as the minimum distance between plants that must be considered members of separate patches or infestations. Individuals or clusters of a target species separated by the PSR distance or more must be recorded as separate patches. Plants separated by less than the PSR are usually considered a single patch or infestation. The PSR set at 50 meters, unless otherwise noted. This is the same whether an infestation is mapped as a point or polygon. The basis for selecting this value is the assumption that most plants or groups of plants less than 50 meters apart will typically be considered as one infestation when planning and implementing normal weed control operations.

E. *Set the Between Feature Position (BFP) Setting.* BFPs allow electronic tracking of the user's route. In the case of some Trimble units (GeoExplorer III, XM, and XT models) this option is called "Between-Feature" tracking. The GPS unit automatically generates these positions at a set distance or time interval. Use the distance setting for these positions. Use the EDSW as the setting for the BFP. The "Between-Feature" positions can be depicted on end-product maps to represent the coverage and identify any gaps. Each time a surveyor walks the equivalent of "one effective detection swath width", the Trimble GPS unit "beeps" and creates a point. So, at the beginning of each day, and whenever moving to significantly different terrain or vegetative cover, each surveyor must adjust the GPS Between-Feature Position (BFP) distance setting to correspond to the average EDSW for that new area.

### **III. Conducting a Monitoring Route**

A. *Set the Effective Detection Swath Width (EDSW):* Determine the EDSW and enter into the GPS. It is not necessary to adjust the setting for small or temporary changes in the EDSW, but actual search patterns should always be modified as needed to compensate for any temporary changes in visibility (typically, crews don't change settings more than a maximum of once or twice per monitoring route.)

B. *Set the Between Feature Position:* The same distance as the EDSW.

C. *List the Target Invasive Species that can be Detected by the Observer.* The observer enters in the species that they are targeting and can reliably detect and identify.

D. *Initiate Monitoring Route:* Monitoring will take place directly along the road, trail, riparian corridor, or other area that is being traversed. While walking, the surveyor searches for target weeds by visually scanning (side to side) all of the land within the imagined borders of the swath. While searchers may be able to visually scan the landscape for target species as they walk, it is usually necessary to glance frequently at the ground to ensure safe foot placement, especially on highly uneven or steep terrain. If a high percent of the time spent walking through a search area must be devoted to looking down at one's feet, there is increased likelihood that weed infestations will be missed. In order to compensate, searchers are encouraged to stop on a regular basis and visually scan the area in all directions around them if they are unable to adequately inspect the area while walking. In such situations it is recommended that, at the very least, searchers stop and conduct a stationary 360-radius visual scan each time the equivalent of 1 EDSW has been traveled.

E. *Recording Invasive Plants:* Once a weed patch/infestation has been discovered, a mapping crew must record: 1) the monitoring route, 2) Buffered point, and 3) estimate canopy cover. It is important to note that not all non-native species that are found will be mapped. For example cheatgrass that is dominant across a park or a portion of the park will not be individually mapped, however it will be recorded in the quantitative plots. These species are to be identified prior to the initiation of a monitoring route.

1. Record the monitoring route.

2. All invasions will be recorded as buffered points. If several species are present with similar distributions, a point must be recorded for each individual species. Invasions more than 50 m apart are considered separate invasions and must be marked separately. Point features reflect a distinct location described as a single position coordinate. Included with each point feature should be an estimate of infestation size and density. Point features should be buffered to reflect the recorded patch size. Buffered points can be displayed to scale as circular polygons representing the area of individual patches (Figure 5.2). In other words, an infestation deemed to be 0.5 hectares in size will appear on the map as a dot that is 0.5 hectares in size.

a. Size of point - To estimate the size of a point infestation, the surveyor should envision the patch as a circle, oval, square, or rectangle (Zamora and Petroff 1985) - whichever most closely represents its actual shape. These shapes enable the surveyor to take some basic measurements to calculate an area. If considered circular, the surveyor determines a patch's average radius by visual estimate, pacing, or laser rangefinder (Figure 5.3). The radius should be an average of 2 readings - the measured distances to the furthest and closest edges of the patch as the surveyor stands in the approximate center. For rectangular or square patches, determine the average length and width, then multiply to obtain the total area (square meters).

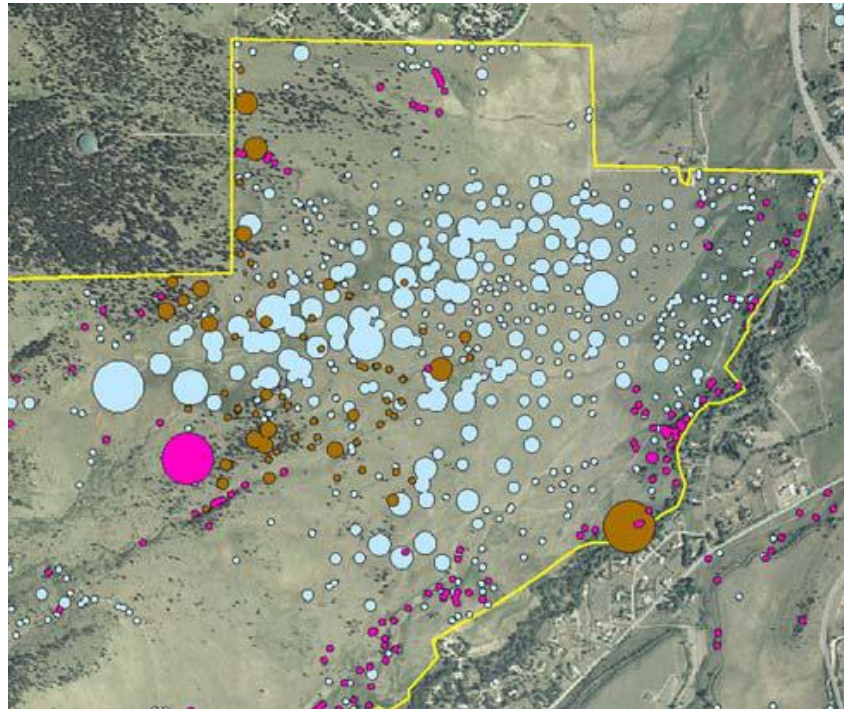


Figure 5.2. Areas mapped using buffered points to reflect the true scale of each infestation recorded by surveyors.

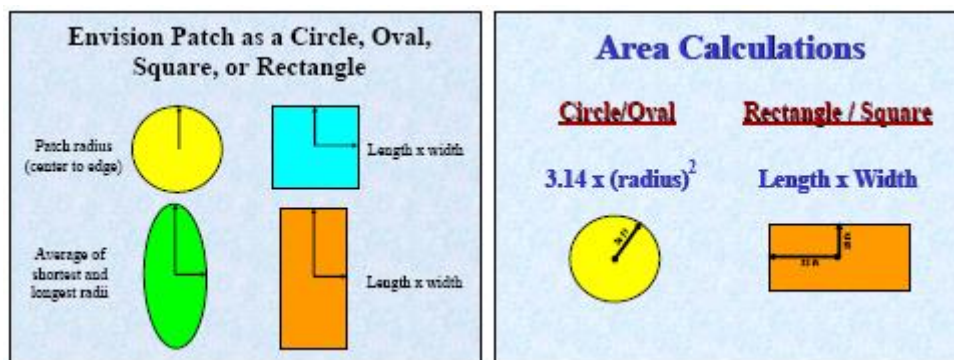


Figure 5.3. Standard shapes for estimating patch size with the necessary measurements required to determine area (left). Calculations used to find the area of an infestation (right).

b. Point Dimensions – Using the size recordings above enter the infestation as a point feature in the size category most closely matched to its actual area: 1) 1 to a few plants, 2) few plants to 40 meters<sup>2</sup> (48 yards<sup>2</sup>), 3) 40 square meters to 400 square meters (48 yards<sup>2</sup> to 478 yards<sup>2</sup>), 4) 400 meters<sup>2</sup> to 1000 meters<sup>2</sup> (0.1 acre to 0.25 acre), 5) or 1000 m<sup>2</sup> to 2000 m<sup>2</sup> (0.25 acre to 0.5 acre) (see table 5.1). “1 to a few plants” is used for isolated single plants or very small patches (2 meters x 2 meters) or less.

Table 5.1. Reference table for metric and English measurements.

| Meters <sup>2</sup> | Acres | Square Yards | Radius (m) | Radius (Yards) | Diameter (m) | Diameter (Yards) |
|---------------------|-------|--------------|------------|----------------|--------------|------------------|
| 40                  | 0.01  | 48           | 3.6        | 3.9            | 7.2          | 7.8              |
| 400                 | 0.1   | 478          | 11.3       | 12.3           | 22.6         | 24.6             |
| 1000                | 0.25  | 1,120        | 17.9       | 18.9           | 35.7         | 37.8             |
| 2000                | 0.5   | 2,420        | 25.3       | 27.8           | 50.1         | 55.5             |

c. Linear infestations as points - When an infestation follows a linear pattern such as along a road or waterway (Figure 5.4), it can be mapped as a point or series of points using the following procedure:

- Envision the infestation as a much-elongated rectangle.
- Estimate the average width and approximate length of the infestation.
- Determine area by multiplying length by width.
- Stand in the middle of the infestation to record the GPS location.

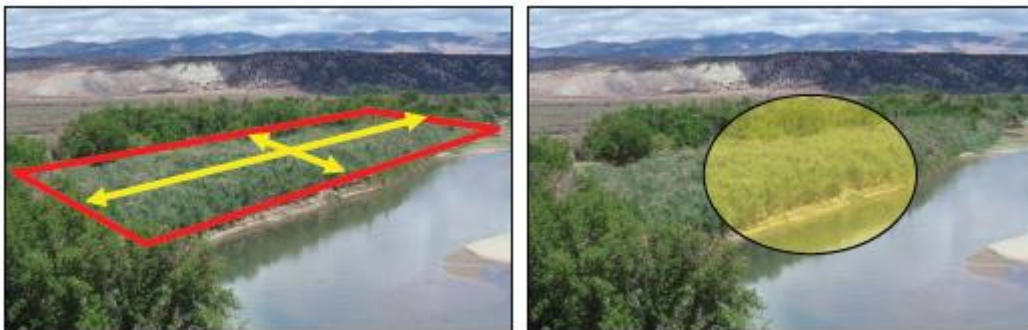


Figure 5.4. The infestation is envisioned as a long rectangle for which length and average width can be determined. The area of the rectangle is then represented as a single buffered point centered in the patch.

If the length or overall size of a linear infestation is considered too great to represent as a single point, it can be visually divided into 2 or more contiguous segments, with a separate point feature recorded for each segment (Figure 5.5). If the surveyor wishes to record a linear infestation as a series of points rather than a single point, use the following procedure:

- Determine the average width of the first infestation segment.
- Choose an appropriate point size category.
- Calculate the corresponding length required to equal that size.
- Walk half the calculated distance (so as to be in the center of the first segment).
- Record the location as a point feature.
- Walk the full calculated distance (to be in the center of the second segment).
- Record the second location.
- Repeat as long as the infestation continues, adjusting point size if patch segment width changes.

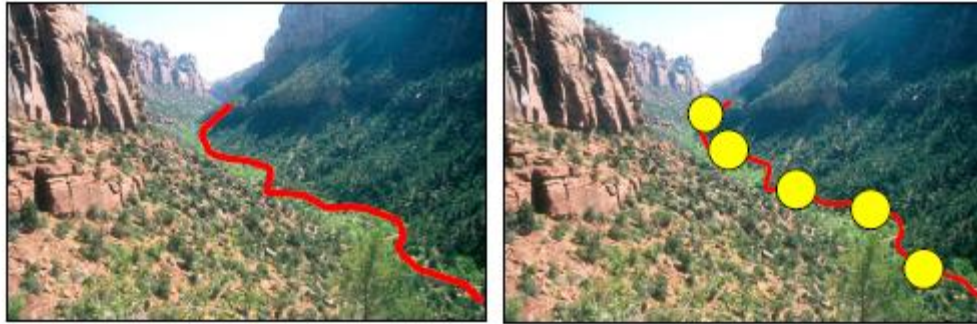


Figure 5.5. To map a linear infestation as a series of points, the surveyor begins by estimating the average width of the infestation, deciding upon the appropriate point size category, calculating the necessary patch segment length based upon that size category, and then placing a new point each time an infested area of that distance is walked.

If several species are present with similar distributions, the same procedure is followed for each individual species. The surveyor calculates the estimated width of each species, determines the appropriate size category, and then calculates the necessary segment length for each species (Figure 5.6). Each time the surveyor walks a determined patch segment length, points are recorded for each species present. This allows the surveyor to map multiple linear species without having to duplicate search efforts.

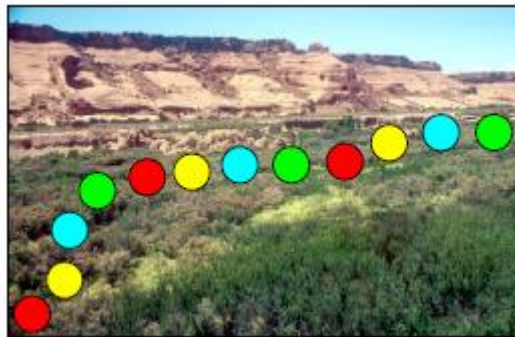


Figure 5.6. Continuous linear infestations of four intermixed weed species mapped as staggered point features. Each point of the same color represents a 0.1-hectare segment of a continuous line of that species.

3. Weed density or canopy cover must be used in conjunction with PSR to describe weed infestations in such a way that the information will be of maximum value to control personnel. For example, based on a 50-m PSR, 20 yellow hawkweed plants all growing within a single dense circular patch would be considered a 0.001-hectare infestation (Figure 5.7). The infestation's density or canopy cover designation would be very high. However, if 20 plants of the same size were spread over a larger area, so that each plant was approximately 40 m away from its nearest neighbor, all of the plants would still be considered part of the same infestation. The total area infested would be 4 hectares, with a very low density or canopy cover designation (Figure 5.7).

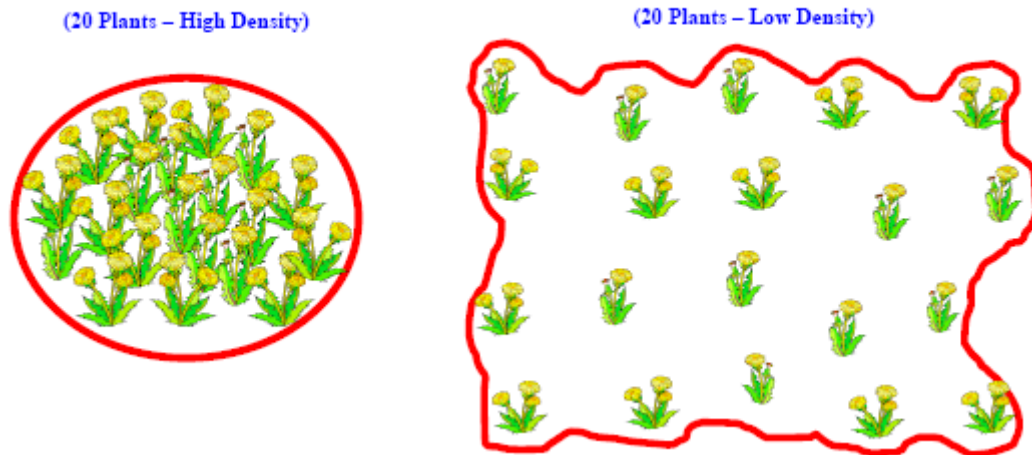


Figure 5.7. On the left, twenty plants are crowded into a 0.001-hectare area. Individual plants are separated from one another by much less than the PSR, and so are considered a single high density infestation of 0.001 hectare in size. On the right, twenty plants spread over a 4-hectare area. Individual plants are separated from one another by only slightly less than the PSR, and are still considered a single infestation. However, this patch is very low in density and is 4 hectares in size.

The term “canopy cover” refers to a visual estimate of the amount or “percentage” of ground covered by the vertical projection of plant matter as visualized from a bird’s-eye view of the vegetation (Elzinga et al. 1998). In other words, the estimated percentage of ground obscured by the vegetation of a single weed species (as if viewed from above) is the canopy cover (or aerial cover) of that species. It includes both the living and dead standing material of the vegetation of a single plant species. It is possible that the individual canopy cover values for 2 or more species growing in the same patch may total more than 100 percent.

Canopy cover of a patch is expressed as a range of canopy cover classes: 1) trace = less than 1 percent, 2) low = 1 to 5 percent, 3) moderate = 6 to 25 percent, 4) high = 26 to 50, or majority = 51 to 100 percent. A surveyor first envisions a perimeter defined by the outermost plants of an infestation (Figure 5.8). To estimate canopy cover the surveyor first considers the midpoint value between 0 and 100 percent, and asks the question “Is the percent cover greater or less than 50 percent?” If the answer is less, the surveyor selects the midpoint value between 0 and 50, and then asks the question “Is the percent cover greater or less than 25 percent?” If the answer is less, then the next question becomes “Is the percent cover between 25 and 12.5 percent or between 12.5 and 0 percent?” This continues until the surveyor cannot confidently make a distinction between values above and below the next midpoint. The closest canopy cover class is then chosen and selected from the GPS menu. The same process applies, whether estimating the canopy cover of a 0.5-hectare infestation or a single plant.



Figure 5.8. The percent canopy cover is estimated from within the perimeter of the actual infested area.

4. Qualified surveyors may remove small populations if under a threshold size (*i.e.*, it would take less time to remove the plants than it would to hike back out to remove them later), but larger populations require rapid response commitments from parks. Note whether the species was pulled.

5. (Optional) Record the following ancillary information with every infestation: slope and aspect, topography (hillside, distance to road, wetland, or stream, etc.), and any disturbance features (e.g., recent fire, flood, small mammal disturbance)

#### IV. Field Data Processing

At the end of each day, field crews will mark and date all monitored areas on USGS 7.5' topographic maps to assist in determining project progress and thoroughness of coverage. The GPS between-feature positions that are recorded each day are used for reference when marking the topographic maps. Each crew member will keep a daily log of where they searched, what species they encountered, disturbances noted, thoroughness of coverage, and any additional information that they felt might be of importance to the project. Data are downloaded from GPS units onto a laptop computer each day using Pathfinder Office GIS software. Edits (such as eliminating any duplicate features) were made to the data, and any additional information (such as infestations drawn by hand on field maps or other data not recorded with a GPS unit) were added at this time. Four sub-folders are established within the main project folder on the computer hard drive. These are for: 1) unedited raw GPS rover files, 2) edited GPS rover files, 3) differentially corrected edited GPS rover files, and 4) GIS shapefiles created from the differentially corrected rover files (for export and use in ArcView). Separate disks were used for raw and edited rover files.

Raw data consists of rover files that are transferred directly from GPS units to the computer, and stored without any editing or modification. They are named using a 6-digit code (month-day-hour) preceded by a single letter (corresponding to the first letter in the crew member's last name), and ending in ".ssf." For example, "A051913.ssf" would be the file name for raw GPS data collected by Kim Andersen beginning in the thirteenth hour (24-hr local time) on May 19.

Edited data files are created from raw files that are viewed in Pathfinder Office and checked for accuracy. Features were added or deleted in the process of editing to eliminate any duplicate reporting (two crew members finding the same infestation), and to add locations drawn on field maps (as when satellite signals could not be obtained). Any locations that are added in the editing process are noted as "hand mapped" in the notes section and are denoted as "Non-GPS" under the differential correction section. Notes are sometimes expanded during the editing process to

include more detailed information about the surrounding habitat. Gross area features are added during this process. File names are changed after editing to avoid confusion with the raw files. Edited files are named as a 3-letter month and 2-digit day abbreviation, followed by a dash and the first letter of the crew member's last name. If a crew member collected more than one file for that day, a number would follow the crew identification letter. For example, the edited version of the second file of GPS data collected by Kim Andersen on May 19 would be May19-A2.ssf.

The data from edited GPS rover files are then differentially corrected. Features that were added or deleted in the editing process were not differentially corrected; nor were points for which corresponding base station data were not available. Generally, the closest base station to the monitoring area was used. However, if use of a slightly more distant base station resulted in a higher percentage of successfully corrected points, it was used in preference to a closer station. Corrected files retained the same name as their edited counterparts, but used the file extension "cor" rather than "ssf". Example: May19-A2.cor.

Shapefiles are created from exported data by exporting the differentially corrected files from Pathfinder Office into ArcView. The shapefiles are created from the various categories in the data dictionary such as point-weed shapefile, line-weed shapefile, area-weed shapefile, photopoint shapefile, and between-feature point shapefile. Three kinds of files are created from each ".cor" file. These are ".shp", ".shx", and ".dbf." Example: pt-weed.shp, pt-weed.shx, ptweed.dbf.

## Appendix A: Invasive Monitoring ~ Lite GPS Instructions

### Point Weed and Area Weed Features

These point and area features are used to map invasive exotic plant infestations while traveling along a monitoring route.

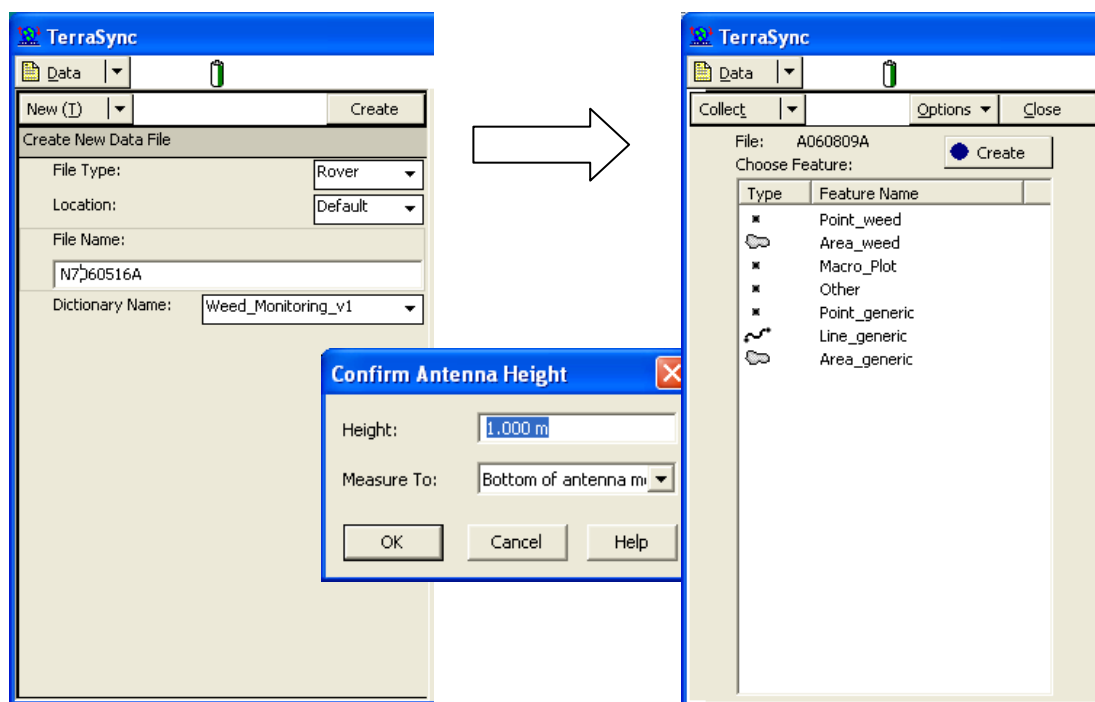
When multiple species are noted within one area (within the PSR, see SOP#5, section 2D) and you are mapping these locations as point features, collect the data for species #1, then walk a step or two, and collect the data for species #2 and continue until one point per species is collected. If mapping an infestation of multiple species as a polygon, attribute the polygon with the primary species, and note the remaining species in your field notebook along with the InfestationID of the polygon.

| Point_Weed or Area_Weed | Attribute Explanation                                                                                                                                                                                                                                                                                                                                             | Entry                              | Type    |
|-------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------|---------|
| InfestationID           | Unique ID. One unique letter per field crew member, numbers automatically generated by GPS unit                                                                                                                                                                                                                                                                   | Entry <b>required</b> in the field | Text    |
| SpeciesName             | Common name of invasive plant. This list will be updated for each park visited, based on input from park staff. "Other" will always be a choice.                                                                                                                                                                                                                  | Entry <b>required</b> in the field | Menu    |
| Size                    | Infestation size <ul style="list-style-type: none"> <li>1 to few plants</li> <li>few plants – 40m sq.</li> <li>40 – 400m sq.</li> <li>400 – 1000m sq.</li> <li>1000 -2000m sq.</li> </ul>                                                                                                                                                                         | Entry <b>required</b> in the field | Menu    |
| CanopyCover             | Percent Canopy Cover: <ul style="list-style-type: none"> <li>Trace (&lt;1%)</li> <li>Low (1 – 5%)</li> <li>Moderate (6 – 25%)</li> <li>High (26 – 50%)</li> <li>Majority (51 – 100%)</li> </ul>                                                                                                                                                                   | Entry <b>required</b> in the field | Menu    |
| Pulled                  | Note if plant(s) pulled by observer: <ul style="list-style-type: none"> <li>Yes (pulled)</li> <li>No (not pulled) -Default</li> </ul>                                                                                                                                                                                                                             | Entry permitted in the field       | Menu    |
| GrowthStage             | Growth stage of trees: <ul style="list-style-type: none"> <li>Seedling(s)</li> <li>Sapling(s)</li> <li>Mature Tree(s)</li> <li>Old Growth</li> </ul>                                                                                                                                                                                                              | Entry permitted in the field       | Menu    |
| Disturbance             | Disturbances noticed at the site: <ul style="list-style-type: none"> <li>Flooding</li> <li>Grazing Impact</li> <li>Hiking trails</li> <li>Human occupation</li> <li>Prehistoric occupati(on)</li> <li>Insect disturbance</li> <li>Livestock</li> <li>Recreation use</li> <li>Roads/OHV Trails</li> <li>Spring Source</li> <li>Windthrow</li> <li>Other</li> </ul> | Entry permitted in the field       | Menu    |
| Surveyor                | Name of person surveying the monitoring route                                                                                                                                                                                                                                                                                                                     | Entry permitted in the field       | Menu    |
| EDSW                    | Effective Detection Swath Width in meters (see SOP #5 section 2,C for further explanation)                                                                                                                                                                                                                                                                        | Entry <b>required</b> in the field | Numeric |
| PSR                     | Patch Separation Resolution – minimum distance between patches that constitutes separation of infestations (see SOP#5, sec 2,D)                                                                                                                                                                                                                                   | Entry permitted in the field       | Numeric |

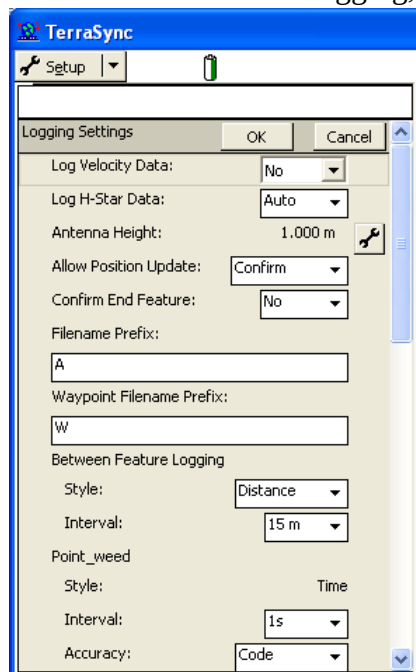
|       |                                                                       |                              |                 |
|-------|-----------------------------------------------------------------------|------------------------------|-----------------|
| Notes | Any comments regarding the site (can contain species name if “other”) | Entry permitted in the field | Text – Optional |
|-------|-----------------------------------------------------------------------|------------------------------|-----------------|

### **Beginning Invasive Exotic Plant GPSing**

Open TerraSync. From the opening satellite **Status** screen, choose **Data** from the dropdown menu. Choose New(T) (it should be the default). Leave File Type, Location and File Name alone, but be sure that *Weed\_Monitoring\_v2\_DINO* is chosen for the Dictionary Name. Tap Create. The Antenna Height window will pop open, tap OK. You should then see the **Data** screen with the features in the data dictionary displayed.

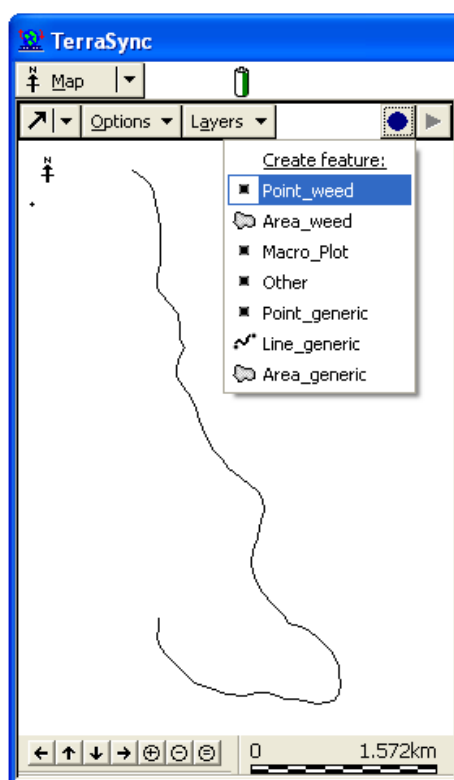
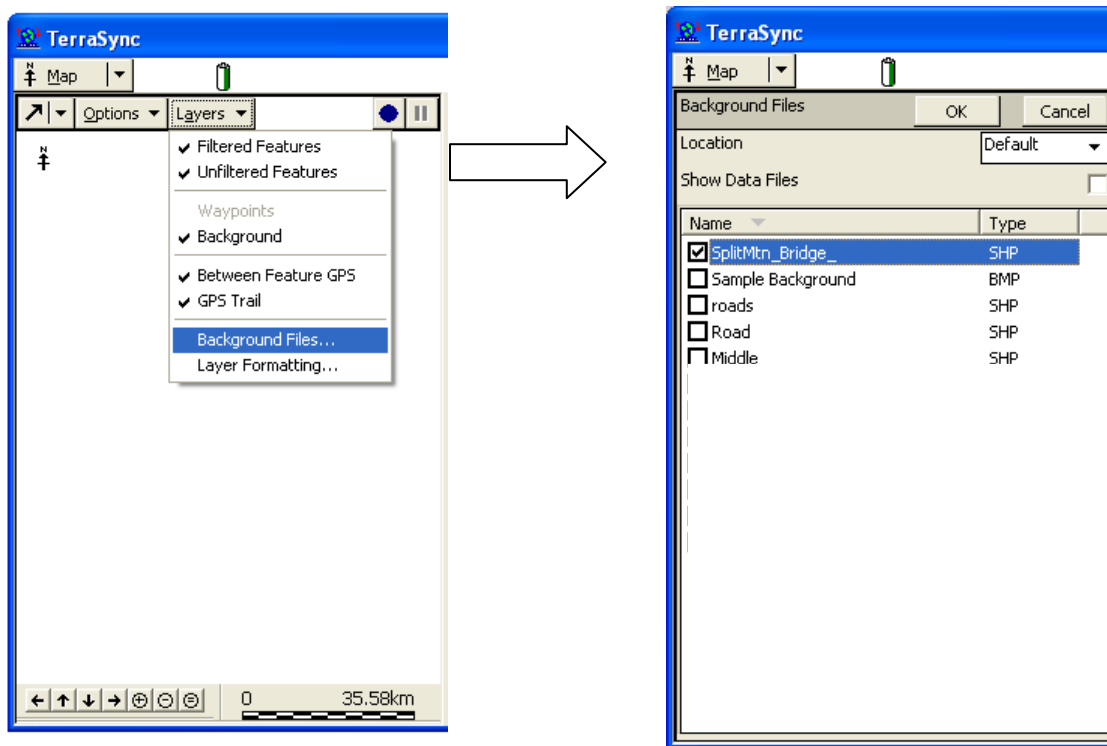


Once a file has been created, you’ll need to determine what the EDSW (Effective Detection Swath Width) and then set the Between Feature Logging to that distance. To set the Between Feature Logging, tap the down arrow next to **Data**, and select **Setup**.



On the **Setup** menu, choose Logging Settings. On the logging settings screen, scroll down until you see Between Feature Logging. For Style, choose Distance and for Interval, type in your EDSW. Tap OK. This sets the Between Feature distance for the file, so you won’t have to change it again, unless you feel that the EDSW changes for the monitoring route you are walking.

The monitoring routes are available to display on the **Map** Screen as a background file if you choose to use them. To add a background layer, choose **Map** from the dropdown menu on the upper left corner. Then tap the Layers button in the middle of the screen, and choose Background Files. The four monitoring routes are listed, choose the one you'll be following and tap OK.



As you begin walking the route, and you come across a species of weed which you need to log, tap the blue dot and your data dictionary will appear. The majority of the time, you'll be using the Point\_Weed feature.

Once you have reached the middle of a weedy infestation, select the Point\_Weed feature and the data dictionary items for that feature will be displayed.

The screenshot shows the TerraSync application interface. At the top, there's a blue header with the 'TerraSync' logo. Below it, a menu bar includes 'Data', 'Collect', 'Options', and 'Log'. The main form is titled '1 Point\_weed' and has 'OK' and 'Cancel' buttons. The form contains several fields: '\*InfestationID:' with a value of '1', '\*SpeciesName:', '\*CanopyCover:', '\*Size:', 'Pulled:' with a dropdown set to 'No (not pulled)', 'GrowthStage:', 'Disturbance:', 'Surveyor:' with a dropdown set to 'MesaState Students', '\*EDSW:' with a value of '1', 'PSR:' with a value of '50', and a 'Notes:' text area at the bottom.

Record the data for the weedy patch.

#### Multiple Species:

If there are more than one weed species, fill in the information for species #1, then take two steps, and log the information for species #2.

#### Required Fields:

The items in the Data Dictionary with a red asterisk (\*) are items that must be recorded, or Terra Sync will not let you close the feature.

#### Log / Pause:

In the upper right corner, there's a button that says Log. If you tap that button, it will temporarily pause the logging (the button is a toggle between Log and Pause). As you log the feature (GPS) and record data, there will be a little satellite icon on the top of the screen that will record the number of "hits" from the satellite. This number should be at least 10-20 hits. Each time the GPS receives a hit,

the GPS unit will beep (if the sound is turned on).

#### Cancel:

If you began to collect (log) a point and have decided not to, tap the Cancel button while in the data dictionary, and tap Yes to Abandon feature.

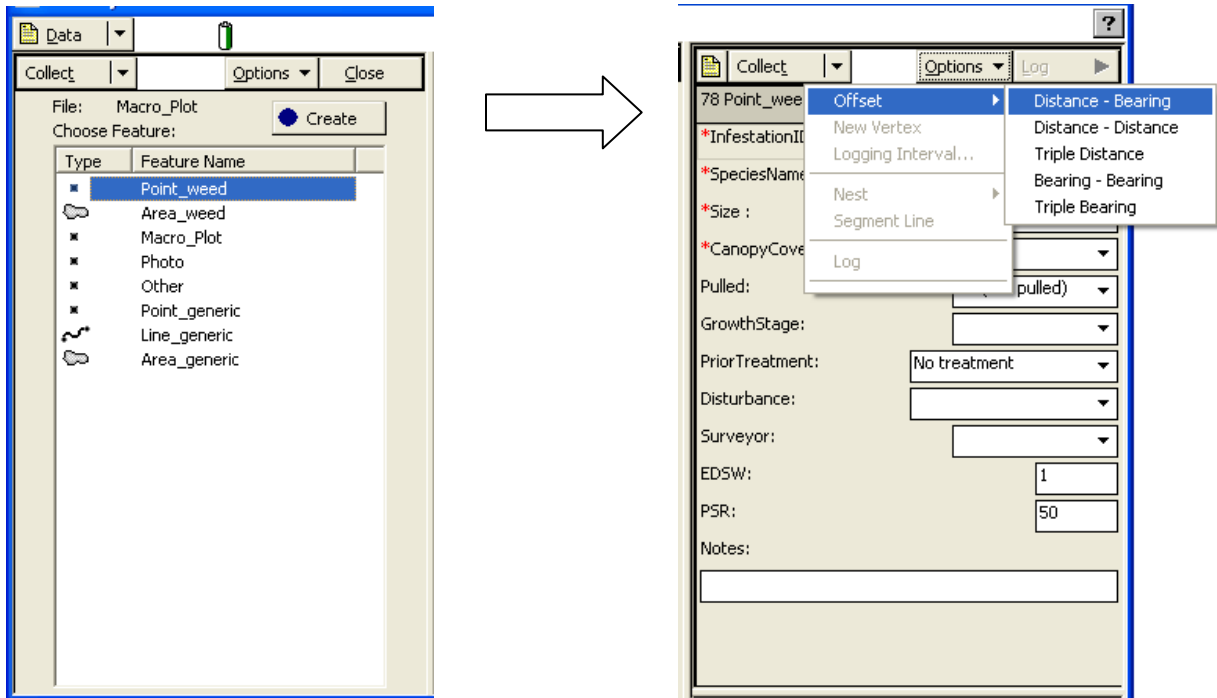
When you've finished recording the data, tap the OK button.

Once you've completed your monitoring route, close the file. Tap the menu choices in the upper left corner, choose Data. On the right side of the screen, tap Close. TerraSync will ask you if you are sure, tap Yes if you are sure. You can then create a new file or shut TerraSync down by tapping the X in the upper right corner.

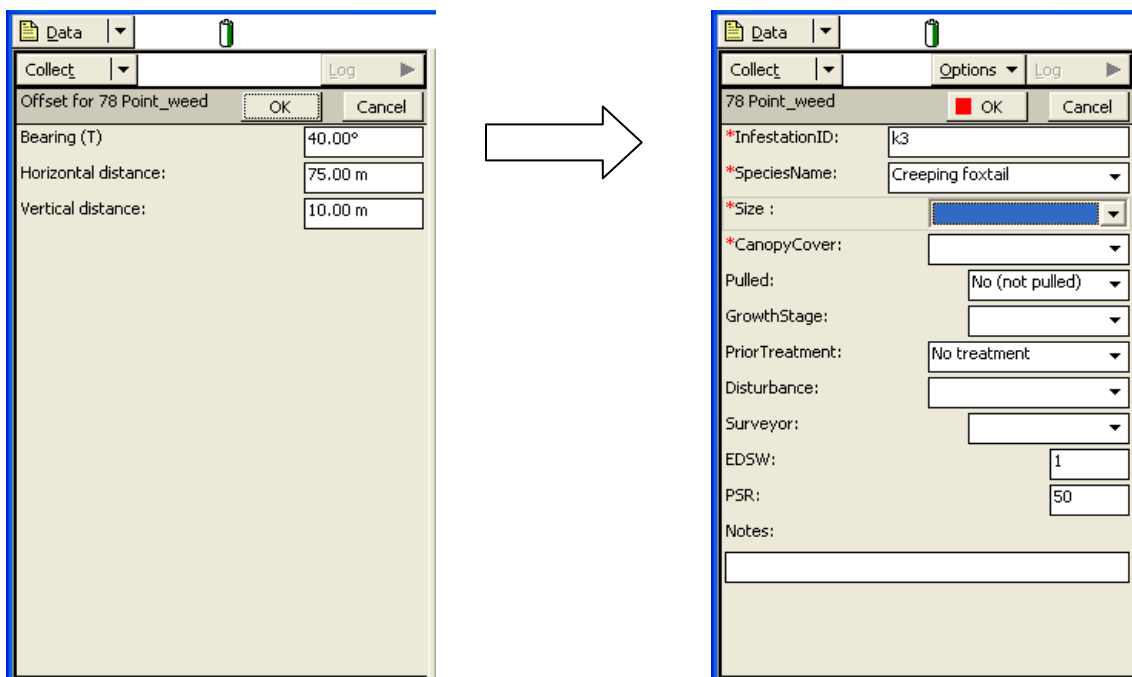
### **Point Offset**

If a weed population is noted in a difficult location (such as across a drainage/river), but you'd like to log the species you see there, you can do that with the Offset feature.

Create the Point\_Weed feature and tap the Options dropdown menu. Select Offset/Distance – Bearing.



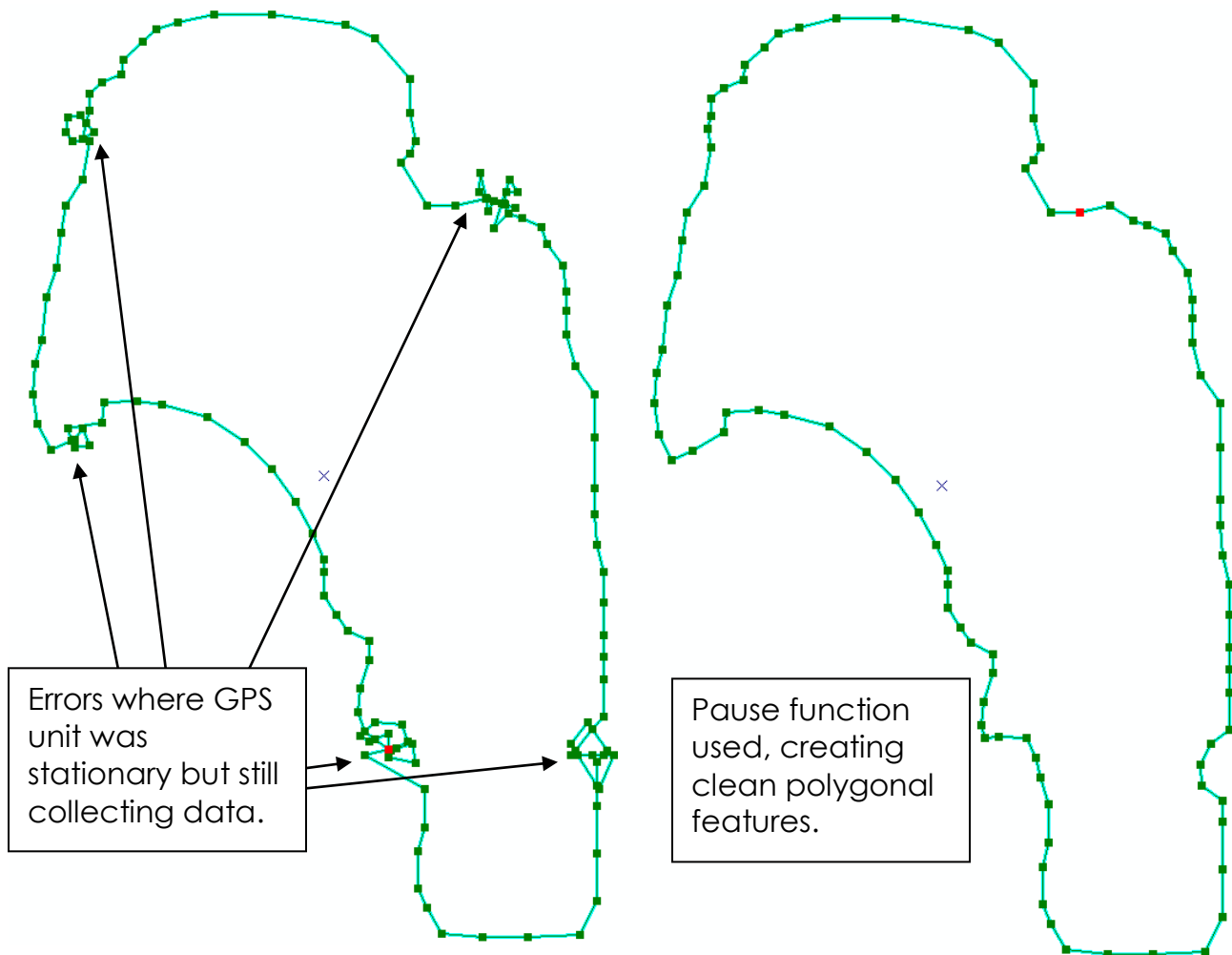
The Offset screen will appear. Fill in your bearing and horizontal distance (Vertical distance is optional) describing where the point is in relation to you, then tap OK. The data dictionary for that point feature will appear, allowing you to fill in the information necessary to collect the location.



There is one other point feature, Other, included in the Invasive Data Dictionary for your use. If you need to mark a location of something else in the field (the location of your vehicle, an archaeology site, etc.), use the Other feature point, and type in a comment regarding that location.

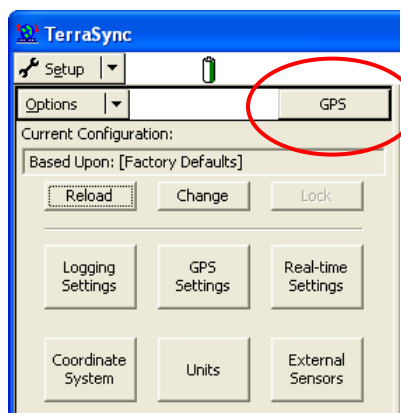
### **GPSing Areas**

If you choose to map an invasive exotic plant infestation as a polygon feature (Area\_Weed), the data dictionary items are the same as they are for Point\_Weed. When collecting an Area\_Weed feature, you will need to walk the perimeter of the infestation in its entirety while the GPS is mapping your progress. As you walk, it is important that you do not stop moving while the GPS is collecting locational data, or the polygon will have errors. If you need to navigate over difficult terrain or someone stops you to ask questions, etc., pause the logging of the polygon until you are ready to resume.



**Tips:**

- Log a point feature for a minimum of 10 “hits” (10 seconds).
- Holding the power button down for 30 seconds will soft re-boot the XM GPS. Holding the power button down for 60 seconds will hard re-boot the XM GPS. Neither of these re-boots will loose any data, but you should recheck the coordinate system.
- To re-boot the Junos, there is a little hole on the top left side (next to the expansion card). Push that with the tip of the stylus to re-boot the Juno.
- There is a sliding button near the power button, if it is slid down, this will “lock” the Juno off so it won’t turn on while bouncing around in a backpack or something while getting to the beginning of the monitoring route. Using this to turn the unit off (and on) seems to help conserve battery life (and seems to behave if TerraSync is left open).
- The NCPN has a copy of the TerraSync Guide, which goes into more detail about the many functions of TerraSync. Please contact the GIS technician if you would like to take a look at it.
- Label the back (or case) of your GPS unit with your name on a piece of masking tape so you’ll be able to use the same unit throughout a field stint.
- If the GPS gets disconnected, go to the Setup screen and tap the GPS button on the upper right side.



- Report any idiosyncrasies with the Trimble GPSes to the NCPN data management staff.

## **Invasive Exotic Plants Protocol for the Park Units in the Northern Colorado Plateau Network**

### **Standard Operating Procedure (SOP) # 6**

### **Using Global Positioning System (GPS) Units**

#### **Version 1.01 (July 2009)**

#### **Revision History Log:**

| Prev.<br>Version # | Revision<br>Date | Author | Changes Made          | Reason for Change   | New<br>Version # |
|--------------------|------------------|--------|-----------------------|---------------------|------------------|
| 1.00               | 7/8/09           | Wight  | Macroplot to transect | Methodology changed | 1.01             |
|                    |                  |        |                       |                     |                  |
|                    |                  |        |                       |                     |                  |
|                    |                  |        |                       |                     |                  |
|                    |                  |        |                       |                     |                  |

This Standard Operating Procedure (SOP) explains the procedures and considerations that all observers should follow when navigating to and/or collecting invasive exotic plant geospatial data.

This SOP assumes that each observer is familiar with the operation and function of the GPS unit to be used for this project. This SOP is intended to compliment, not replace, the operations manual accompanying the GPS unit. Each observer should be familiar with the use of their particular GPS unit before entering the field to collect data or navigating to monitoring routes.

#### **1 GPS Requirements**

The NCPN project lead, GIS tech as well as park personnel will establish monitoring routes and segments to locate invasive exotic species. The NCPN requires the use of a mapping grade GPS unit (requirements listed below) to record these invasive exotic infestation locations along the monitoring routes.

##### **1.1 Minimum GPS Receiver Requirements**

- Capable of uploading (pre-determined) monitoring routes and macroplot points
- Capable of utilizing data dictionary utilities (NCPN Exotics Data Dictionary, see section 1.3)
- Capable of utilizing park-specific background GIS data layers (points, lines and polygons)
- Capable of navigation
- Capable of maintaining 4 or more satellites
- Capable of maintaining horizontal errors of less than 5 meters (PDOP (or equivalent error reading) of less than 6), or recording error readings
- Capable of taking “Between Feature” points (breadcrumbs)
- Capable of offsetting point features

- Capable of post data collection correction (differential correction)
- Capable of storing date, time, elevation and coordinates of features collected (in addition to data dictionary items)
- Capable of exporting features collected to a GIS data format

## 1.2 GPS Unit Setup

The NCPN currently uses the Trimble line of mapping grade GPS units and TerraSync Professional software to capture the spatial data for Invasive Exotic Plant Monitoring. The requirements should be transferable to other mapping grade GPS receivers (such as Leica etc.).

Positional accuracy can be affected by several factors which mapping-grade GPS units can track and to some extent, compensate for. Table 1 lists these functions, their definitions, and the standard settings.

**Table 1 Minimum GPS Receiver Settings Standards**

| <b>Name</b>                                     | <b>Definition</b>                                                                                                                                                                | <b>Standard</b>                                                                                                                       |
|-------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------|
| Almanac                                         | GPS unit collects data containing estimated position of satellites, time corrections, and atmospheric delay parameters.                                                          | The unit will automatically collect the almanac. Acquire within 10 days prior to data collection or navigating, download to computer. |
| Altitude reference                              | Ellipsoid model                                                                                                                                                                  | Height Above Ellipsoid (HAE)                                                                                                          |
| Antenna heights                                 | GPS unit height above the ground (average).                                                                                                                                      | 1.0 – 1.5 meters                                                                                                                      |
| Between Feature positions                       | Positions automatically logged by the GPS at either a time or distance interval defined by the user.                                                                             | 15 meters                                                                                                                             |
| Coordinate System                               | A reference system consisting of a set of points, lines, and/or surfaces, and a set of rules, used to define the positions of points in space in either two or three dimensions. | Universal Transverse Mercator (UTM)                                                                                                   |
| Datum                                           | Geodetic model designed to fit a point on the earth's surface to the ellipsoid.                                                                                                  | NAD 1983 (Conus)                                                                                                                      |
| Elevation mask                                  | The minimum angle at which a GPS receiver will track satellite vehicles.                                                                                                         | 15 degrees                                                                                                                            |
| Logging intervals                               | Time interval between positions gathered.                                                                                                                                        | Point: 1 second<br>Line and Polygon: 3-5 seconds                                                                                      |
| Minimum number of positions for a point feature | Number of positions received then averaged to create a point feature.                                                                                                            | 10                                                                                                                                    |
| Mode                                            | 2-Dimensional or 3-Dimensional                                                                                                                                                   | 3-Dimensional (4 satellites)                                                                                                          |
| PDOP Mask                                       | Positional Dilution of Precision is a measurement of the geometry of the satellites.                                                                                             | 6.0 or less                                                                                                                           |

| <b>Name</b>        | <b>Definition</b>                                                                                        | <b>Standard</b>                                                   |
|--------------------|----------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------|
| Satellite vehicles | Number of satellites, currently a constellation of 28 DOD satellites.                                    | 4                                                                 |
| SNR Mask           | Signal-to-Noise Ratio is a measure of the strength of the satellite signal relative to background noise. | 4.0                                                               |
| Unit of Measure    | Units of measure.                                                                                        | Meters                                                            |
| Zone               | In UTM coordinate system, the globe is divided into 60 north-south zones.                                | Zone 12 North (N)*<br><br>*Black Canyon & Curecanti are Zone 13 N |

### 1.3 Data Dictionary

A data dictionary should be created to facilitate field data collection as well as assuring necessary data items are (correctly) collected. The minimum elements necessary for the invasive data dictionary features are shown below. All point features in the Invasive Data Dictionary should have the default feature settings of:

|                   |                         |
|-------------------|-------------------------|
| Logging Interval  | Time = 1 second         |
| Minimum Positions | 3                       |
| Accuracy          | Code                    |
| Label 1           | PlotID (for macroplots) |

Prior to data collection, a comprehensive list of invasive exotic species should be obtained from the park where invasive exotic monitoring will be occurring to update the data dictionary. Surveyor names may need to be updated as well.

The following digital data dictionary file on the next page (.ddf) can be obtained by contacting the NCPN Data Management staff.

### **Point Weed and Area Weed Features**

These point and area features are used to map invasive exotic plant infestations while traveling along a monitoring route. When multiple species are noted within one area (within the PSR, see SOP#3, section 2D) and you are mapping these locations as point features, collect the data for species #1, then walk a step or two, and collect the data for species #2 and continue until one point per species is collected. If mapping an infestation of multiple species as a polygon, attribute the polygon with the primary species, and note the remaining species in your field notebook along with the InfestationID of the polygon.

| <b>Point_Weed or Area_Weed</b> | <b>Attribute Explanation</b>                                                                                                                                                                                                                                                                                                                                      | <b>Entry</b>                       | <b>Type</b>     |
|--------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------|-----------------|
| InfestationID                  | Unique ID. One unique letter per field crew member, numbers automatically generated by GPS unit                                                                                                                                                                                                                                                                   | Entry <b>required</b> in the field | Text            |
| SpeciesName                    | Common name of invasive plant. This list will be updated for each park visited, based on input from park staff. "Other" will always be a choice.                                                                                                                                                                                                                  | Entry <b>required</b> in the field | Menu            |
| Size                           | Infestation size <ul style="list-style-type: none"> <li>1 to few plants</li> <li>few plants – 40m sq.</li> <li>40 – 400m sq.</li> <li>400 – 1000m sq.</li> <li>1000 -2000m sq.</li> </ul>                                                                                                                                                                         | Entry <b>required</b> in the field | Menu            |
| CanopyCover                    | Percent Canopy Cover: <ul style="list-style-type: none"> <li>Trace (&lt;1%)</li> <li>Low (1 – 5%)</li> <li>Moderate (6 – 25%)</li> <li>High (26 – 50%)</li> <li>Majority (51 – 100%)</li> </ul>                                                                                                                                                                   | Entry <b>required</b> in the field | Menu            |
| Pulled                         | Note if plant(s) pulled by observer: <ul style="list-style-type: none"> <li>Yes (pulled)</li> <li>No (not pulled) -Default</li> </ul>                                                                                                                                                                                                                             | Entry permitted in the field       | Menu            |
| GrowthStage                    | Growth stage of trees: <ul style="list-style-type: none"> <li>Seedling(s)</li> <li>Sapling(s)</li> <li>Mature Tree(s)</li> <li>Old Growth</li> </ul>                                                                                                                                                                                                              | Entry permitted in the field       | Menu            |
| PriorTreatment                 | Note if area looks like it was previously treated, by any means (stumps, piles of weeds etc., spraying obvious): <ul style="list-style-type: none"> <li>Yes, area treated</li> <li>No treatment -Default</li> </ul>                                                                                                                                               | Entry permitted in the field       | Menu            |
| Disturbance                    | Disturbances noticed at the site: <ul style="list-style-type: none"> <li>Flooding</li> <li>Grazing Impact</li> <li>Hiking trails</li> <li>Human occupation</li> <li>Prehistoric occupati(on)</li> <li>Insect disturbance</li> <li>Livestock</li> <li>Recreation use</li> <li>Roads/OHV Trails</li> <li>Spring Source</li> <li>Windthrow</li> <li>Other</li> </ul> | Entry permitted in the field       | Menu            |
| Surveyor                       | Name of person surveying the monitoring route                                                                                                                                                                                                                                                                                                                     | Entry permitted in the field       | Menu            |
| EDSW                           | Effective Detection Swath Width in meters (see SOP #3 section 2,C for further explanation)                                                                                                                                                                                                                                                                        | Entry <b>required</b> in the field | Numeric         |
| PSR                            | Patch Separation Resolution – minimum distance between patches that constitutes separation of infestations (see SOP#3, sec 2,D)                                                                                                                                                                                                                                   | Entry permitted in the field       | Numeric         |
| Notes                          | Any comments regarding the site (can contain species name if "other")                                                                                                                                                                                                                                                                                             | Entry permitted in the field       | Text – Optional |

### **Monitoring Transect Feature Point**

This feature point is used to map the transect (and quadrat) locations. These locations will be uploaded to the GPS unit, spaced at 500 meter intervals (intervals may change yearly and by park) along the monitoring route. The field personnel will need to move perpendicular (and on alternating sides) away from the monitoring route and the points along that monitoring route (see SOP#3, sec 4, A). When the transect location is established, the point on the GPS unit then needs to be updated (logged).

| <b>Transect_start</b> | <b>Attribute Explanation</b>                                                                         | <b>Entry</b>                            | <b>Type</b>     |
|-----------------------|------------------------------------------------------------------------------------------------------|-----------------------------------------|-----------------|
| PlotID                | Alpha- (auto) numeric code. PlotIDs will be generated in the office, no entry necessary in the field | Entry <b>not permitted</b> in the field | Text            |
| EDSW                  | Effective Detection Swath Width in meters (see SOP #3 section 2,C for further explanation)           | Entry permitted in the field            | Numeric         |
| Comments              | Any comments regarding the site                                                                      | Entry permitted in the field            | Text – Optional |

### **Other Point Feature - OPTIONAL**

This point feature is used for incidental observations the monitoring crews may encounter. For example, if you found lithic scatter or spring/hanging garden or wanted to mark the location of your vehicle or a photo you've taken, you may want to mark the location with this point feature, briefly commenting why you marked the location.

| <b>Other Attributes</b> | <b>Attribute Explanation</b>   | <b>Entry</b>                 | <b>Type</b>     |
|-------------------------|--------------------------------|------------------------------|-----------------|
| Comment                 | Incidental observation comment | Entry permitted in the field | Text – Optional |
| Comment2                | Incidental observation comment | Entry permitted in the field | Text – Optional |

#### 1.4 Uploading monitoring locations

Mapping grade GPS units have the ability to upload data points to be used in concert with the data dictionary. Invasive Exotic Transects will be taken at a given interval along established monitoring routes. These points will be generated in the office, then imported with the Invasive Data Dictionary and uploaded to the GPS unit(s) by the NCPN GIS technician. Importing points (uploading) to the GPS unit eliminates the need to type in unique identifiers in the field, as well as allowing the user to navigate more easily to the approximate location of the transect start point. Points will appear directly on the monitoring routes, the field personnel will need to position themselves in the appropriate direction (see SOP#3 section 4, A).

Also, background data layers can be used to assist with navigation. One layer necessary is the monitoring routes (line) file. This can be combined with the park boundary to assist in navigation. Either shapefiles or TerraSync background files can be used.

#### 1.5 Collecting data

Once you've discovered an invasive infestation, it's time to collect the GPS locations necessary (either points or a transect start point). Appendix A contains detailed instructions for use with the Invasive data dictionary and various files. Within TerraSync, open the existing file of transect start points. This will also open the data dictionary "Weed\_Monitoring\_v2.ddf." Open the background file containing the monitoring routes to assist in navigation. Once the Transect points and Invasive data dictionary are open, choose the appropriate feature type and begin logging the point and data required. Each point collected should be allowed to receive 10 positions before ending data collection and moving onto collecting another feature along the monitoring route(s). If you are mapping a polygon, open the Area\_Weed feature and walk around the infestation until you've closed your circle. Pause the GPS reception and enter the necessary data dictionary fields.

Each crew member will keep a daily log of where they traversed, what species they encountered, disturbances noted, thoroughness of coverage, and any additional information that they felt might be of importance to the project. This data will be used when QC-ing the data.

#### 1.6 Downloading:

When data collection is finished, the GPS data needs to be downloaded. The NCPN GIS technician will download the data from the GPS unit(s) after each field excursion, and then differentially correct the data, using the appropriate (closest) base station. The corrected GPS files are then exported to a GIS data format. Table 2 indicates the attributes to capture while exporting the corrected GPS data into a GIS data format ("turn on" in Pathfinder Office).

**Table 2 GPS Auto-generated Attributes to Capture**

|                   |                      |                      |
|-------------------|----------------------|----------------------|
| PDOP              | Update Status        | Height               |
| Correction Status | Data File Name       | Vertical Precision   |
| Receiver Type     | Total Positions      | Horizontal Precision |
| Date Recorded     | Filtered Positions   | Standard Deviation   |
| Time Recorded     | Data Dictionary Name | Position             |

Data should be exported using the same coordinate system used in the field (UTM, NAD83 Conus, Zone 12 or 13, meters).

The downloaded and differentially corrected field data will be QA/QC'd by the project lead and GIS technician at the end of each field excursion to catch any data edits or additions necessary (as in areas drawn on field maps when satellite reception was not possible).

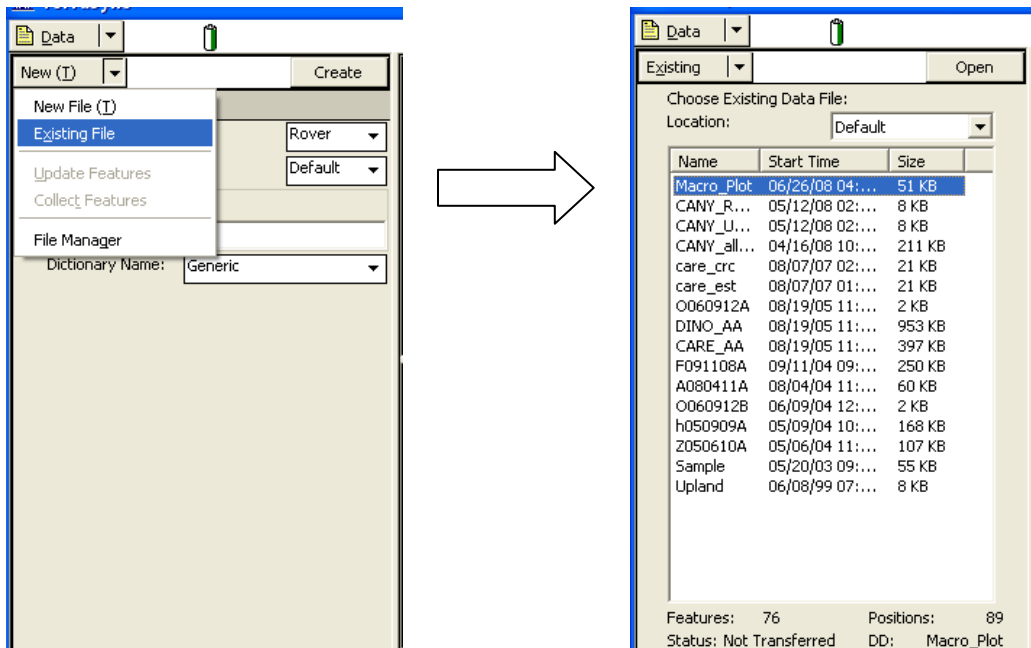
#### 1.7 Uploading to the working Invasive Database

Once the GPS field data is validated and verified (GPS points given a visual review, additions added, attributes checked and corrected if necessary) in ArcMap, the data is ready to be uploaded into the working Invasive Database. The GPS data is exported from ArcMap into an Excel spreadsheet for importing into the Invasive Database (see SOP 7, in development).

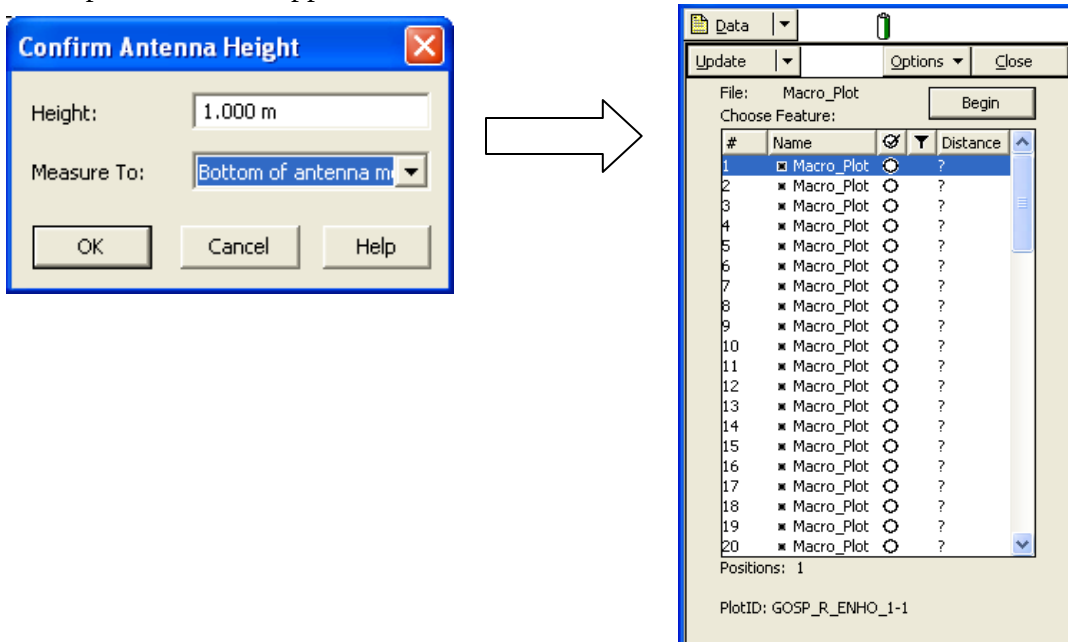
## 2 Appendix A

### 2.1 Beginning Invasive Exotic Plant GPSing

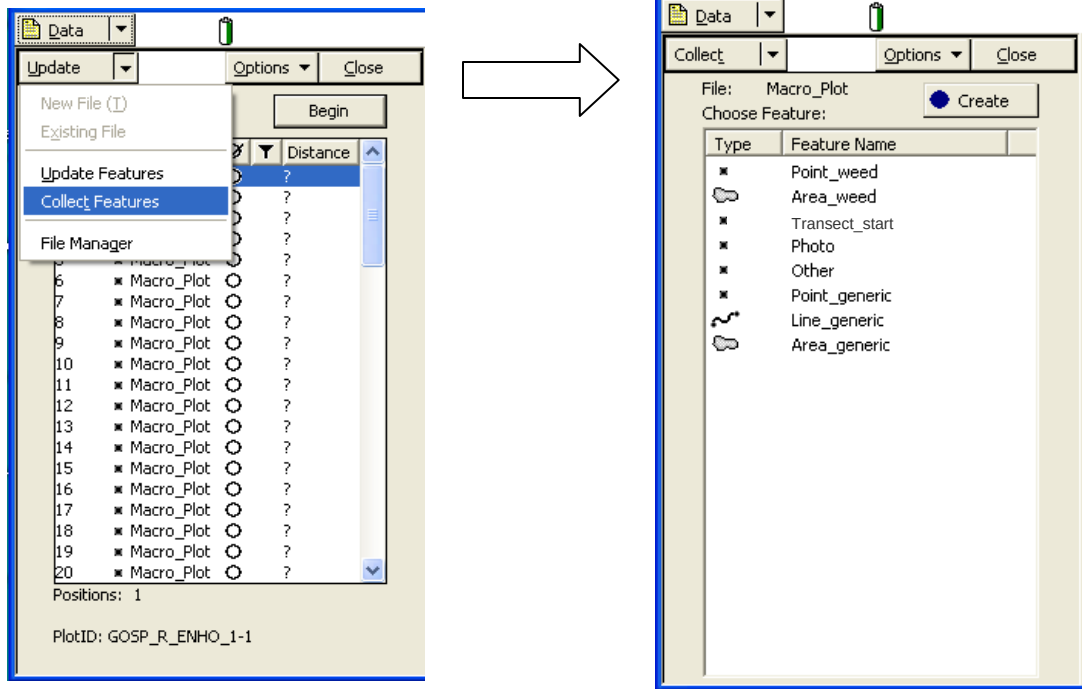
Open TerraSync. To open the transect start points, from the opening satellite status screen, choose Data/Existing File. Choose the file (“Macro\_Plot”, in this example) and tap the Open button.



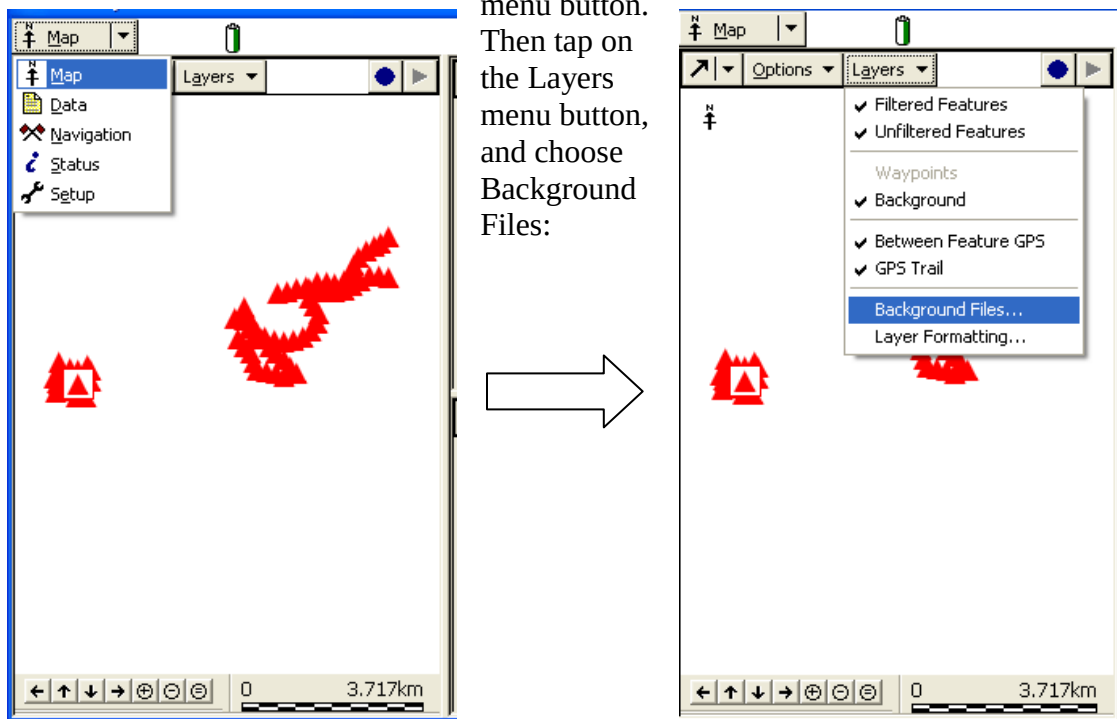
The Confirm Antenna Height window will appear, enter 1.000 m for Height, and choose “Bottom of antenna mount” for the Measure To: portion. Once you’ve set this, most of the time you can merely OK this window. A list of all the predetermined locations of macroplots will then appear.



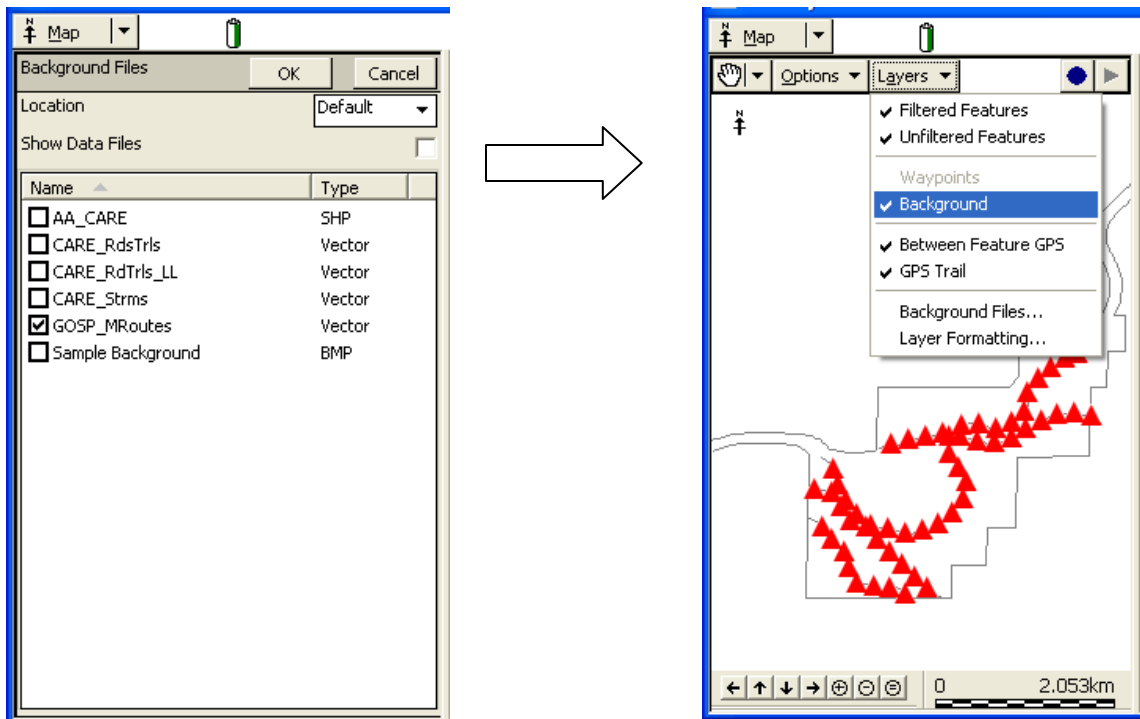
From the list of transects, change the function from Update to Collect features (the drop down list under the top left button). This will change the screen to display the features in the Invasive Data Dictionary:



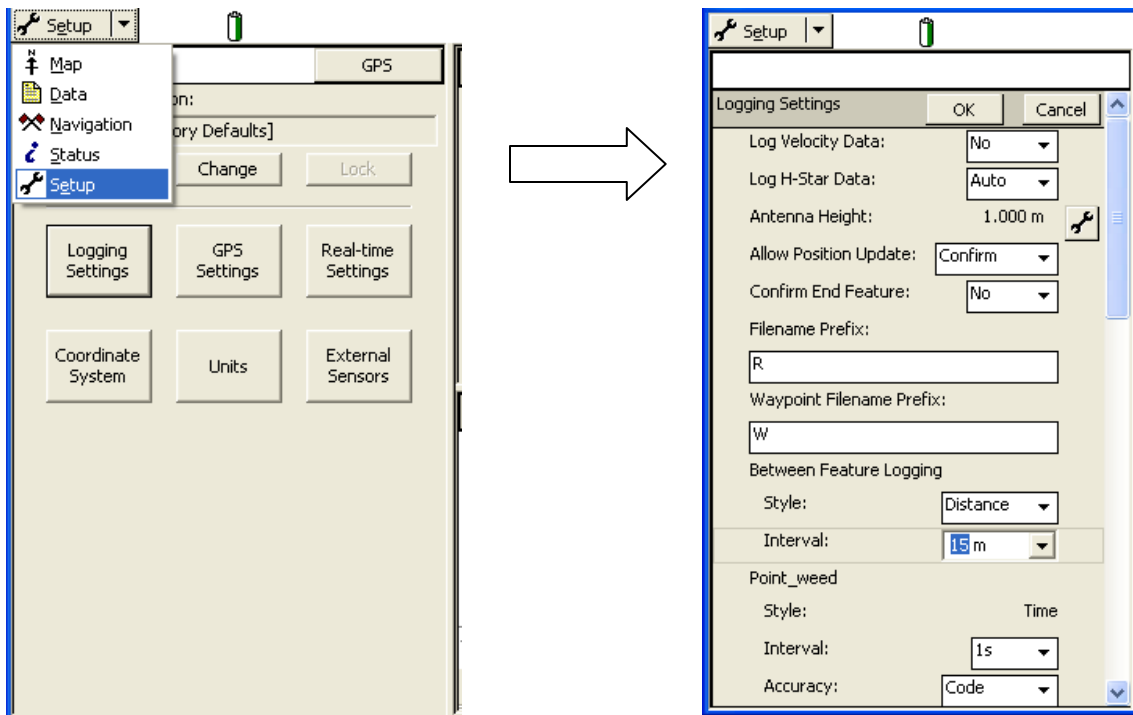
To set up the background layers to assist in navigation, choose Map from the upper left menu button. Then tap on the Layers menu button, and choose Background Files:



Check the check box next to the layer file(s) you need displayed and click OK. Make sure on the Layers menu that Background is checked; if not, merely tap it to check it. Then your background layer(s) will appear on your map screen:

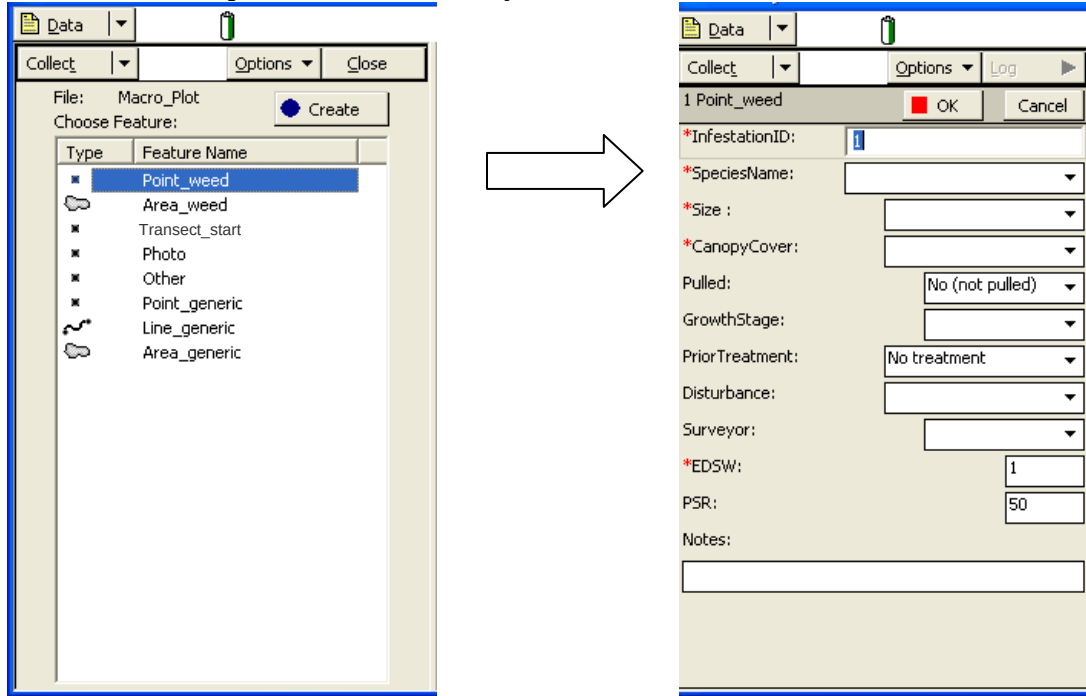


To track the routes you take and collect “negative” data, you’ll need to ensure that the Between Feature Logging feature is enabled and set to 15 meters. Tap the button menu on the upper left corner and choose Setup. On the Setup Menu, choose Logging Settings. On the logging settings screen, scroll down until you see Between Feature Logging. For Style, choose Distance and for Interval, type in your EDSW. Tap OK. This sets the Between Feature distance for the file, so you won’t have to change it again.



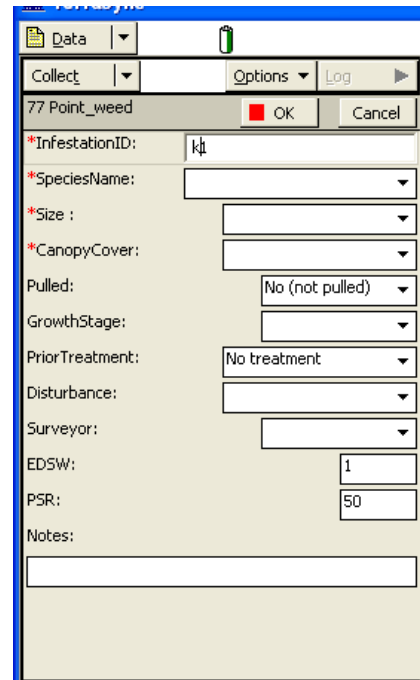
## 2.2 Collecting Point Weed features

Now you're ready to collect GPS data. A lot of the data you'll be collecting will be Point\_Weed data. From the Map screen, change to the Data screen and you're data dictionary items will be there. To create a Point\_Weed, highlight it and tap the Create button. This will open the data dictionary.



Please note that the items which are required are displayed with a red \*; this means that you **must** fill in *at least* those items before TerraSync will allow you to close the feature and move on.

The first time you open this data dictionary/macropoints file, for the first Point\_Weed you take, you will need to insert a letter code (assigned to each individual prior to field work) for InfestationID. Tap the area in front of the number. Ensure that the number is not highlighted, and insert your letter code. As you go from one Point\_Weed to another, your letter code will stay and the number will increase by one for each point collected.



Fill in the necessary and appropriate fields. You may wish to use the Pause/Log button at the top while filling in the data. This pauses the GPS unit from continuing to receive satellite signals.

The screenshot shows a data entry form titled '77 Point\_weed'. At the top, there are buttons for 'Collect', 'Options', and 'Log'. Below these are 'OK' and 'Cancel' buttons. The form contains the following fields:

- \*InfestationID: k1
- \*SpeciesName: Halogeten
- \*Size: 1 to few plants
- \*CanopyCover: Low (1 - 5 %)
- Pulled: No (not pulled)
- GrowthStage: (empty)
- PriorTreatment: No treatment
- Disturbance: Livestock
- Surveyor: R. Weissinger
- EDSW: G. Lenhart
- PSR: R. Houk
- Notes: (empty)

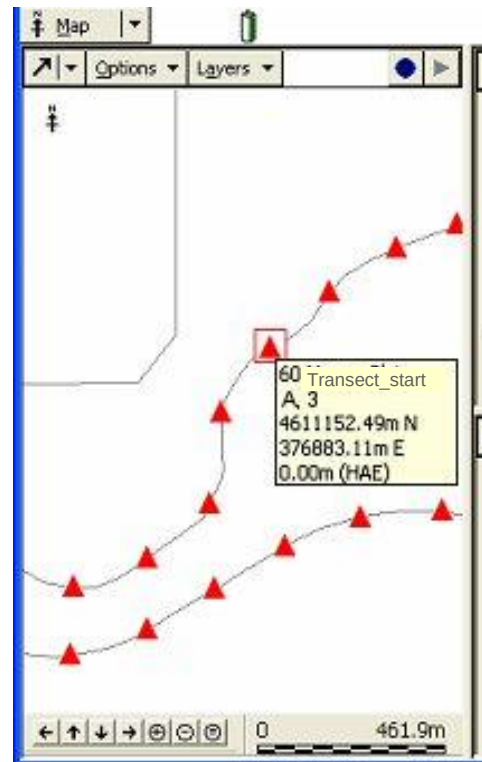
You'll notice as you go through the items that there are a fair number that will be the same throughout the monitoring route and/or park (EDSW, PSR, Surveyor, perhaps even SpeciesName). Once you've closed an open feature, tap the Options button. Choose Repeat. This will repeat the data taken for the next series of points, leaving ALL data fields filled in (the InfestationID number will continue to update). Be sure to change any fields that do need changing. The Repeat function can be toggled on and off, using the Options/Repeat menu.

The left screenshot shows the 'Options' menu open, with 'Repeat' selected. The right screenshot shows the resulting data entry form titled '78 Point\_weed'. The fields are as follows:

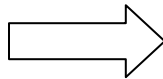
- \*InfestationID: k2
- \*SpeciesName: Halogeten
- \*Size: 1 to few plants
- \*CanopyCover: Trace (<1%)
- Pulled: Yes (pulled)
- GrowthStage: (empty)
- PriorTreatment: No treatment
- Disturbance: Livestock
- Surveyor: R. Weissinger
- EDSW: 25
- PSR: 50
- Notes: (empty)

### 2.3 Logging Transect Starts

Transect start points are created in the office and uploaded to the GPS unit. These points are placed on the monitoring route, and will not be in the exact location where the plot needs to be placed (see SOP#3). These points are placed the correct distance apart, but you will need to move to the appropriate side and distance away from the monitoring route. Notice that the second line of identifying text is the unique ID.



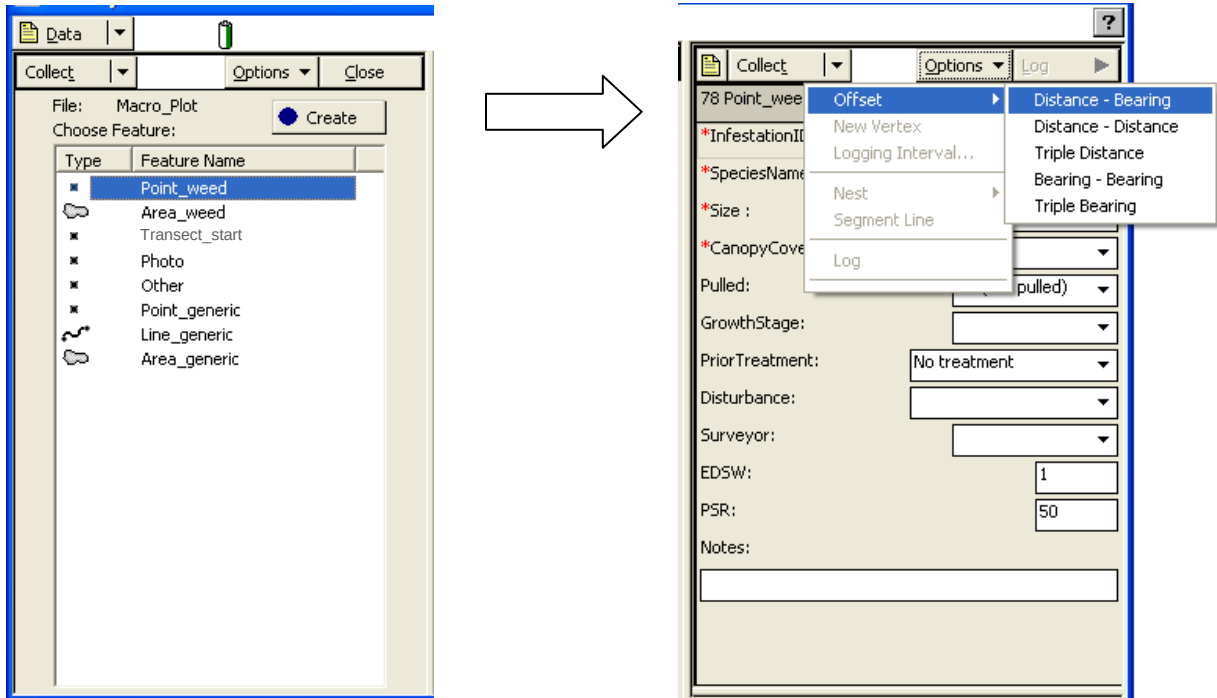
For each transect, you need to log a GPS location. When you arrive at a transect point, update (collect satellite data) for that transect start point. Double tap on the point to enter the data dictionary and allow a new and accurate position to be recorded.



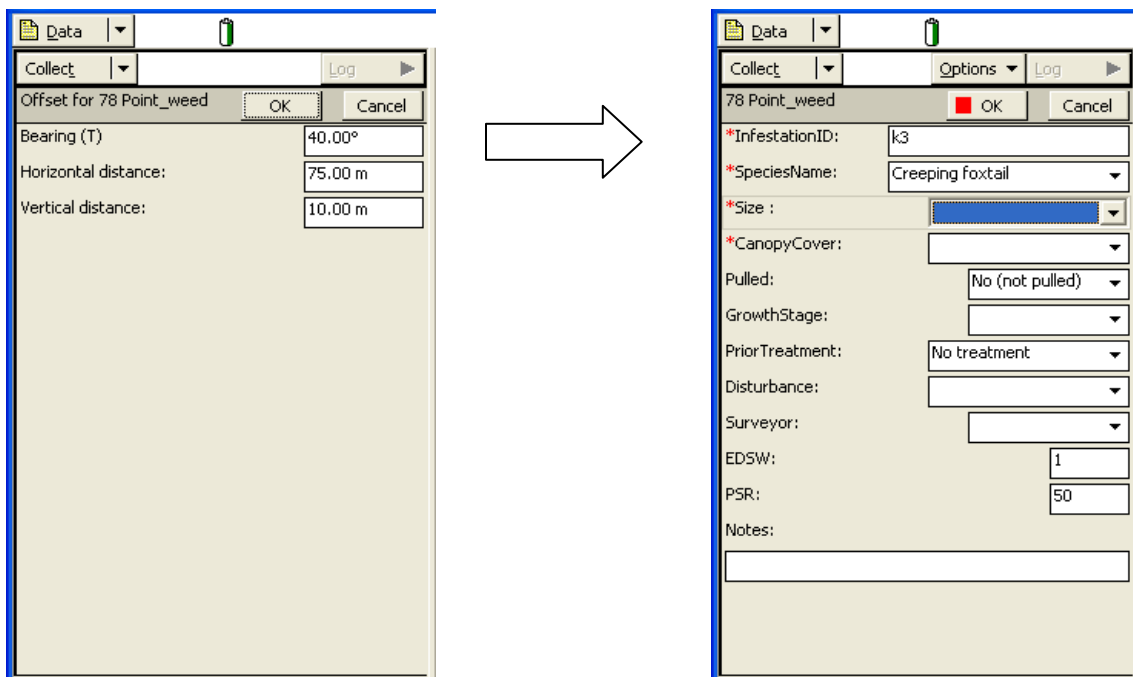
Notice that the PlotID is already filled in. Once you log the point, the 'Mark as updated:' check box will be checked. Fill in the EDSW (in meters), and unless you wish to type in some comments about the site, that is all you need do on the GPS unit for transects.

## 2.4 Offsetting a Point feature

If a weed population is noted in a difficult location (such as across a drainage/river), but you'd like to log the species you see there, you can do that with the Offset feature. Create the Point\_Weed feature and tap the Options dropdown menu. Select Offset/Distance – Bearing.

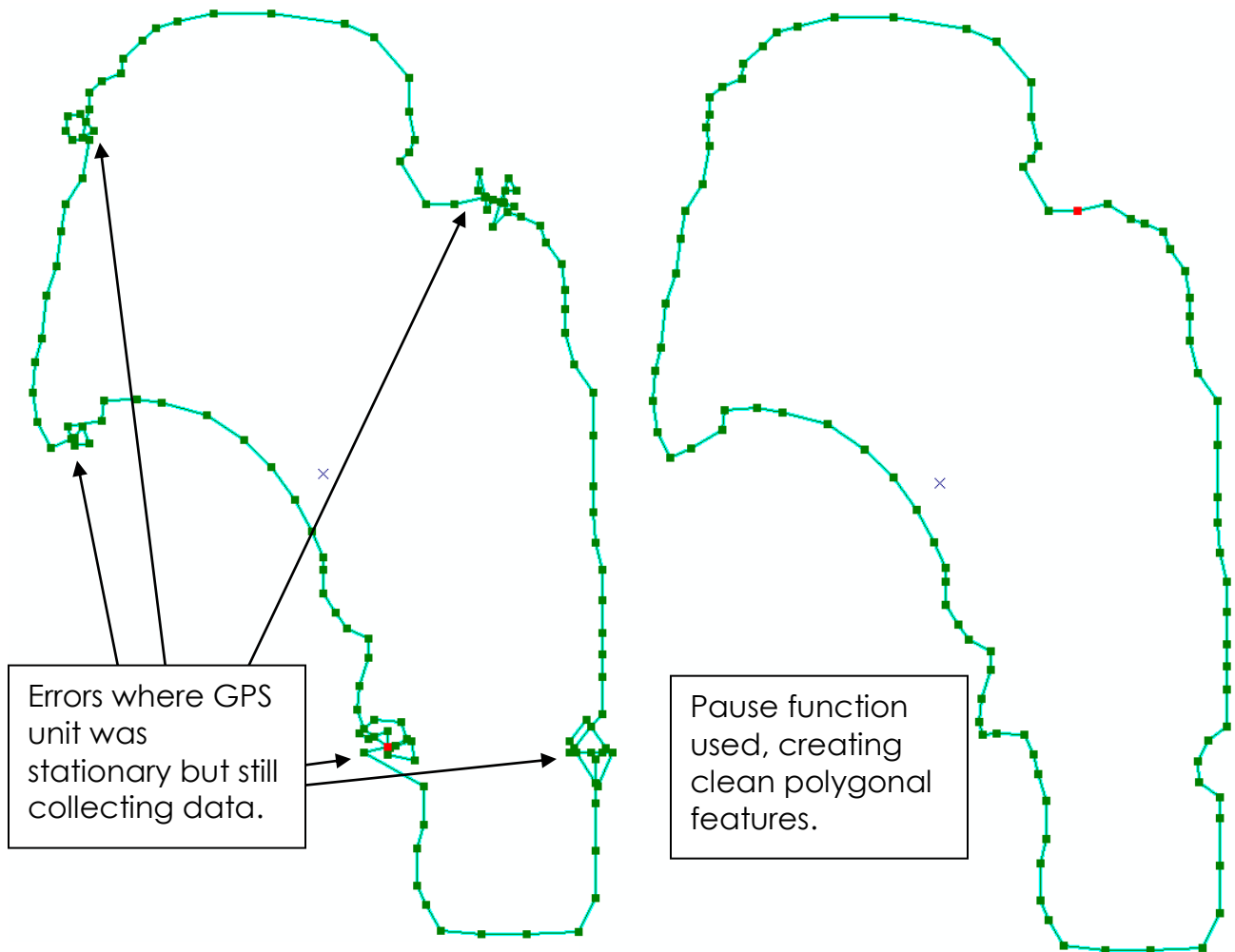


The Offset screen will appear. Fill in your bearing and horizontal distance (Vertical distance is optional) describing where the point is in relation to you, then tap OK. The data dictionary for that point feature will appear, allowing you to fill in the information necessary to collect the location.



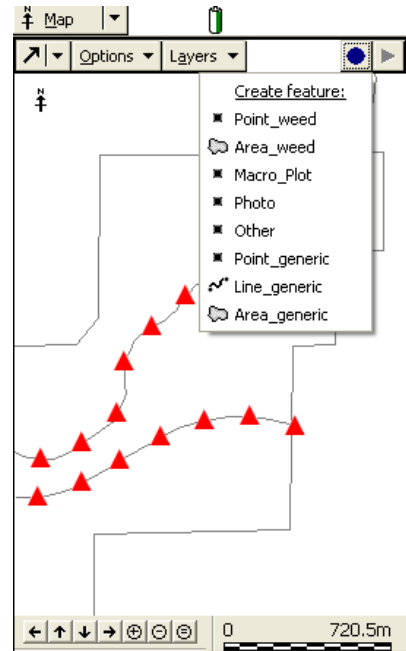
There is one other point feature, Other, included in the Invasive Data Dictionary for your use. If you need to mark a location of something else in the field (the location of your vehicle, an archaeology site, etc.), use the Other feature point.

If you choose to map an invasive exotic plant infestation as a polygon feature (Area\_Weed), the data dictionary items are the same as they are for Point\_Weed. When collecting an Area\_Weed feature, you will need to walk the perimeter of the infestation in its entirety while the GPS is mapping your progress. As you walk, it is important that you do not stop moving while the GPS is collecting locational data, or the polygon will have errors. If you need to navigate over difficult terrain or someone stops you to ask questions, etc., pause the logging of the polygon until you are ready to resume.

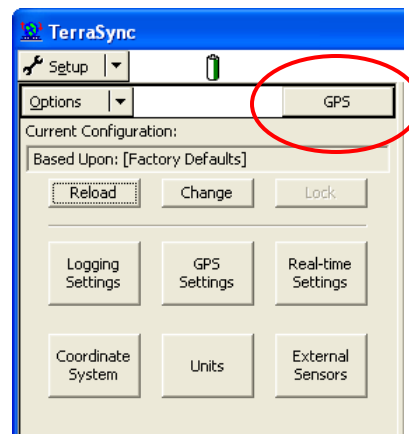


## 2.5 Other Tips:

- When in the Map view on the GPS unit, to quickly choose another feature within the data dictionary, tap the blue dot in the upper right. A drop down list of the other features within the data dictionary will appear, allowing you to choose which feature you wish to log.



- Log a point feature for a minimum of 10 “hits” (10 seconds).
- Holding the power button down for 30 seconds will soft re-boot the XM GPS. Holding the power button down for 60 seconds will hard re-boot the XM GPS. Neither of these re-boots will lose any data, but you should recheck the coordinate system.
- To re-boot the Junos, there is a little hole on the top left side (next to the expansion card). Push that with the tip of the stylus to re-boot the Juno.
- To conserve on battery life (generally 8 hours on XMs and 4+ hours on Junos), turn the unit off if you aren’t using it to navigate. It is recommended that TerraSync be closed *prior* to turning off the unit.
- There is a sliding button near the power button, if it is slid down, this will “lock” the Juno off so it won’t turn on while bouncing around in a backpack or something. Using this to turn the unit off (and on) seems to help conserve battery life.
- If the GPS gets disconnected, go to the Setup screen and tap the GPS button on the upper right side.
- The NCPN has a copy of the TerraSync Guide, which goes into more detail about the many functions of TerraSync. Please contact the GIS technician if you would like to take a look at it.
- Label the back (or case) of your GPS unit with your name on a piece of masking tape so you’ll be able to use the same unit throughout a field stint.
- Report any idiosyncrasies with the Trimble GPSes to the NCPN data management staff.



# Early Detection of Invasive Exotic Plants in the Northern Colorado Plateau Network

## Standard Operating Procedure (SOP) 8: Data Analysis and Reporting

**Version 1.0 (May 2008)**

### Revision History Log:

| Prev. Version # | Revision Date | Author | Changes Made | Reason for Change | New Version # |
|-----------------|---------------|--------|--------------|-------------------|---------------|
|                 |               |        |              |                   |               |
|                 |               |        |              |                   |               |
|                 |               |        |              |                   |               |
|                 |               |        |              |                   |               |
|                 |               |        |              |                   |               |

This SOP details the analysis and reporting procedures for data collected in the NCPN Invasive Exotic Plant Monitoring Protocol. Analytical and reporting procedures in this SOP are relatively basic. Enhancements are expected over time as experience working with the upland data accumulates and as the full suite of potentially supporting data provided by other vital signs monitoring (e.g., land condition) of the NCPN become available. The procedures described in this version, however, provide a solid basis for future enhancements.

### **I. Park Communication**

Within 30 days (preferably sooner) of monitoring, the park weed manager will be notified of particularly important or significant new invasions (i. e. species with high invasive potential found in a canyon that was formerly weed-free). Prior to each year's sampling NCPN staff will communicate with park staff to review the Priority 1 invasive exotic plant list, determine if there are any extra area weed searches desired and confirm plans for that year's monitoring routes.

### **II. Vital Sign and Park Briefs**

A vital sign brief will be prepared annually that gives a brief overview of invasive exotic plant monitoring throughout the network. A park vital sign brief will also be prepared annually which gives an overview of all NCPN activities (including invasive exotic plants) that took place over the past year. These briefs are designed to quickly give a status of the resource at the park.

### **III. Annual Reports**

On annual basis monitoring reports will be submitted to the park. These reports summarize monitoring data collected during the year and provide an update on the status of invasive plants in selected areas. Reports will be prepared and distributed by May of the next calendar year following data collection.

- A. Template - The report template for regional natural resource technical reports should be followed (<http://www.nature.nps.gov/publications/NRPM/index.cfm>). Natural resource reports are the designated medium for disseminating high priority, current natural resource management information with managerial

application. The natural resource technical reports series is used to disseminate the peer-reviewed results of scientific studies in the physical, biological, and social sciences for both the advancement of science and the achievement of the National Park Service's mission.

- B. Information and Estimates to Be Included in Annual Reports – The annual reports will focus on reporting the locations and cover of species during the most recent field work and the amount of change since the previous sampling.
  - 1. Monitoring Routes and Extra Areas - Reports will include the time spent surveying and kilometers and hectares covered. Summary statistics will include number of invasives per 100 m along monitoring routes, size and canopy cover of each invasion, tree size when appropriate, maps with locations and presence/absence of species by monitoring route. Weed free areas will be noted on maps.
  - 2. Monitoring Plots – Summary statistics will include percent cover of invasive exotic plant species by monitoring route. When applicable, correlations between percent cover of invasive exotic plants and other plot variables will be conducted.
  - 3. Evaluate operational aspects of the monitoring program, such as whether any sampling locations need to be eliminated or moved due to access problems, whether the sampling period remains appropriate (the optimal sampling season could conceivably change over time in response to climate change), etc.
- C. Long-term Trends – After sufficient time has passed long-term trends for some species may be estimated in annual reports.
  - 1. Reporting will focus on trends in species distributions: spread rates by habitat type and trends in number of detections. Because some portions of parks will only be sampled infrequently (e.g. every five years) statistical analyses in which sample size is equivalent to number of years (e.g., regression) should only be done after enough data points are obtained to allow sufficient statistical power.
  - 2. Place network results within the larger context of established invasive plant species population changes throughout the Pacific, as measured by regional efforts.
  - 3. Two complicating issues will present challenges to long-term trend analyses. First invasive exotic plants and plant cover in general is quite low in many NCPN parks resulting in many 0s in plots and low percent cover (<1% cover of IEPs). Second, managers will likely act to reduce the densities of a number of the invasive species. These actions are likely to vary both spatially and temporally within parks and among parks. Unless the histories of such management actions are documented and made available to the analyst, interpretation of observed long-term patterns may prove difficult.

#### **IV. Analyses**

Data summary routines that will be undertaken include 1) maps for invasive plant distribution and infestation sizes in portions of each park sampled; 2) summary statistics and correlation analyses from plot-based samples and 3) changes in invasive species distribution and abundance over time in re-sampled units. Additional analyses that can be undertaken with the data include spatial interpolation and other modeling to help predict habitats prone to invasion. Data from the vegetation monitoring protocol will also be useful for these analyses.

Due to the complications of many plots with no IEPs present and removal of IEPs for control reasons, long term trend analysis will prove challenging. When IEPs are present in low densities at a park or a particular monitoring route we may be able to examine long term trends from the monitoring data by examining the actual number of infestations along a monitoring route as opposed to using the actual quadrat data. This method will prove problematic when IEP densities increase because the methods are to be rapid and are therefore qualitative and somewhat subjective. Therefore, when densities increase for IEPs we can use quadrat data for analyses.

*Sampling Designs* – Sampling designs for each NCPN park unit were created. These ranged from fairly simple designs at small parks such as monitor all roads, trails, and riparian corridors in the park every two years to more complicated re-visit designs at larger parks. The sampling design for each park unit with invasive plant monitoring is documented in a separate report. These reports should be consulted to determine the proposed sampling objective of the current sampling design for each park unit.

It is important to examine the realized levels of variance components after at least 5-yr of monitoring to evaluate the efficacy of the extant sampling design. The recommended frequency of assessments thereafter will vary. Variance assessment is based on all data collected to date, not just observations of the current monitoring event. The utility of this assessment will depend on the number of plots with observations and the number of revisits. However, periodic checking of the assumptions of the sampling design affords timely opportunity to invoke enhancements to meet the original monitoring and sampling objectives. Even well-researched estimates can become obsolete over time due to substantive changes in system conditions, such as those resulting from climatic change.

#### *Frequentists Survey-Design Status and Trend Assessments*

Trend assessments of complex survey designs are performed using a mixed-effects ANOVA model (Larsen et al. 1995) or using repeated measures ANOVA. Time is treated as a fixed effect while site and year are random effects. Site refers to the plot and year is the same as time. Both site and year are treated as categorical variables; time is treated as a continuous variable. The output from this model is a measure of the intercept and slope, the significance of the slope and intercept being different from zero, and measures of the variance and covariance of the regression parameters. A significant slope indicates a significant trend at least at the alpha level used to assess significance. Trend assessments are performed separately for each invasive pathway type (road, trail, riparian) in a park unit. This may also be further stratified by management unit in larger parks. Regression analyses could also be employed to estimate rates of change or the trajectory of change (i.e., linear or nonlinear).

Status is the condition of the attribute and is derived in two ways. If the trend slope is not significantly different from zero, mean and variance of status is simply the mean and variance of all measures of the attribute up to the current time period. If the slope is significant, then status is the solution of the regression model for the latest time period of the data used to generate the trend line.

Geostatistical temporal modeling (Kyriakidis and Journel 1999) and general linear models (Manley 2001) may also be used to identify whether or not the spatial patterns are changing over time. Interpretation of trends will require assessment by park managers of any park management actions that may have affected invasive species abundance in areas surveyed.

#### *Bayesian Assessment of Trends*

Bayesian methods for trend assessment identify the probability of different slope-parameter values (Gelman et al. 2000, Wade 2000) given the observed data. This differs from frequentist methods which calculate the probability of observing data given a specific value for a parameter, such as the null hypothesis. Assessing the probability of different slope values is potentially

important for various reasons. First, sampling designs are largely based on a few key features. The minimum detectable trend at a reasonable power level for many of the other attributes listed in Table 1 likely will be considerably much higher. Estimating the probability of slope values may be the best way to provide insight into trends for these attributes. Second, even for the key features around which sampling designs were based, Bayesian methods may reveal the potential of declining trends before rejecting the null hypothesis that the regression slope equals 0 with conventional statistics.

The technical calculations of Bayesian methods are beyond the scope of this SOP. Wade (2000) provides a readable overview, and Gelman et al. (2000) provide in-depth explanations of the underlying mathematics of various analytical methods. In short, a Likelihood distribution is generated from the sample data which provides the probability of observing the data for every possible parameter value. Combining this with a prior distribution produces a posterior distribution which is used to make inference about parameters. The prior distribution reflects previous knowledge about the distribution of parameters. In the absence of such knowledge, a non-informative distribution can be used, which essentially is a uniform distribution across the range of the Likelihood distribution. In subsequent analysis, the posterior distribution of previous assessments is used as the prior distribution. The posterior distribution allows assessments of the probability of user-selected parameter values. The probability of various increasing and decreasing slopes should be evaluated based on the posterior distribution and the consequences of not alerting management of a potential trend. The result of this assessment is the derivation of the probability of different levels of decline/increase. Even though conventional statistics may not reveal a significant trend, relatively high probabilities (e.g., >0.70) of trends with a Bayesian method may warrant special attention.

Bayesian methods for trend assessments are recommended, but exact guidelines are not provided. As data become available for trend assessments, Bayesian procedures should be developed. With experience, specific guidelines for Bayesian analysis of trend should be documented in this section of the SOP.

## **V. References**

Gelman, A., J. B. Carlin, H. S. Stern, and D. B. Rubin. 2000. Bayesian Data Analysis. Chapman & Hall/CRC, New York.

Larsen, D. P., N. S. Urquhart, and D. L. Kugler. 1995. Regional scale trend monitoring of indicators of trophic condition of lakes. Water Resources Bulletin, 31:117-140.

Wade, P. R. 2000. Bayesian methods in conservation biology. Conservation Biology, 14:1308-1316.

# Early Detection of Invasive Exotic Plants in the Northern Colorado Plateau Network

## Standard Operating Procedure (SOP) 9: Developing a List of Priority 1 Invasive Exotic Plants

**Version 1.0 (May 2008)**

### Revision History Log:

| Prev. Version # | Revision Date | Author | Changes Made | Reason for Change | New Version # |
|-----------------|---------------|--------|--------------|-------------------|---------------|
|                 |               |        |              |                   |               |
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This SOP explains the process of gathering and compiling invasive species lists to use in subsequent profiling and prioritization/ranking exercises. The final product will be a broad list of Priority 1 non-native species occurring at each park that observers will be trained on for the monitoring routes. Additional species will be on the list for consideration for future years. The list will be evaluated each year a park is monitoring.

### Procedures

1. Create a “master” table in a word processing or spreadsheet/database application to organize the species, source, and occurrence information that will be compiled. A master list should include all non-native species known to be present within a park as well as any species that are not known to be present, but are known to be invasive and are on local, county, or weed management area lists that include the park.
2. Consult state designated weed lists for targeted state(s) for possible species that may be moving into the area of the park.

There are several ways to find this information, however, one of the better resources for this information is the Invaders Database System, ([http://invader.dbs.umt.edu/Noxious\\_Weeds/](http://invader.dbs.umt.edu/Noxious_Weeds/)), housed at University of Montana – Missoula. In many cases, such as in CO, a state will categorize or prioritize weeds on its list to guide coordinate state and county efforts and it may even provide management recommendations or directives for individual species (eradication, containments, suppression, etc.). The Invaders Database System is one of the few web resources that provides this information.

The Center for Invasive Plant Management also has state weed lists for all western states and Canadian provinces: ([http://weedcenter.org/inv\\_plant\\_info/invasive\\_info.htm](http://weedcenter.org/inv_plant_info/invasive_info.htm))

The federal site [Invasivespecies.gov](http://invasivespecies.gov) also provides state list information at: <http://invasivespecies.gov/geog/main.shtml>

The most updated sources for weed information, should lists change, will likely be the state's websites (accessed 4/2/2010):

Arizona: <http://www.azda.gov/PSD/quarantine5.htm>

Colorado: <http://www.colorado.gov/cs/Satellite/Agriculture-Main/CDAG/1174084048733>

Utah: <http://www.utahweed.org/weeds.htm>

Wyoming: <http://www.wyoweed.org/>

3. Contact county weed management staff to determine if particular counties of interest have their own weed list (many do). Most county weed lists will be a selection of species from the state weed list, but many also include species not found on state lists, such as species of local concern. County weed managers may also be able to comment on countywide occurrence and distribution information, as well as on species that should be flagged for early detection (watch list).

Most states do not have a centralized location on the internet for county weed management offices and phone numbers and employees are subject to change over time. Local park resource managers are often the best source of information. The following resources may also help to find contact information for a particular county or counties:

Arizona:

- State Weed Coordinator's Office: 602-542-3309
- [http://www.land.state.az.us/programs/natural/conservation\\_021004.htm](http://www.land.state.az.us/programs/natural/conservation_021004.htm)

Colorado:

- Troublesome Weeds of the Rocky Mountain West (weed identification booklet distributed by the Colorado Weed Management Association)
- State Weed Coordinator's Office: 303-239-4182
- <http://www.cwma.org/>

Utah:

- Noxious Weed Field Guide for Utah (weed identification booklet distributed by USU and county weed control management)
- State Weed Coordinator's Office: 801-538-7183
- <http://www.utahweed.org/cwma.htm>

Wyoming:

- State Weed Coordinator's Office: 307-777-6585
- Weed and Pest Council/Districts: <http://www.wyoweed.org/addresses.html>

4. Review park datasets and maps from any vegetation community and/or invasive species mapping projects for park-specific presence data.

5. Present the list to park staff for their review. Ideally the park staff is involved throughout this process.

6. Develop the list of Priority Species. The Priority IEP list should include existing IEPs and potential IEPs of high management concern. The monitoring methods were designed to be rapid, therefore field crews are only able to be trained for a maximum of 25-30 species per park. This enables them to develop a focused search image on the target plants, instead of looking for every possible invasive plant species. The likelihood of eradicating these Priority species or containing them within a park is generally high.

7. Develop a list of additional species to be monitored within the quadrats. There may be a desire for some widespread species (i.e. cheatgrass, tamarisk) to be monitored in the monitoring transects. These are generally species that are too widespread to be mapped, but parks may

want to follow trends in these species or establish a baseline. Future changes in management practices or the introduction of a biological control agent (i.e. tamarisk beetle) could then be evaluated over time.

8. Re-evaluate the list annually. Compare monitoring results to target list and re-check the list with state, local, and park staff to ensure invasive exotic plant needs have not changed.

## **Invasive Plant Monitoring Protocol for Park Units in the Northern Colorado Plateau Network**

### **Standard Operating Procedure (SOP) # 10**

#### **Revising the Protocol Narrative and SOPs**

#### **Version 1.01 (July 2009)**

##### **Revision History Log:**

| Prev.<br>Version # | Revision<br>Date | Author    | Changes Made | Reason for Change                              | New<br>Version # |
|--------------------|------------------|-----------|--------------|------------------------------------------------|------------------|
| 1.00               | 7/8/2009         | H. Thomas | Updated MVT  | To reflect changes based<br>on 2008 field work | 1.01             |
|                    |                  |           |              |                                                |                  |
|                    |                  |           |              |                                                |                  |
|                    |                  |           |              |                                                |                  |

This Standard Operating Procedure (SOP) explains how to make and track changes to the Narrative and Standard Operating Procedures for the Northern Colorado Plateau Network (NCPN) Invasive Plant Monitoring Protocol. Individuals editing the Protocol Narrative or any one of the SOPs need to follow these procedures in order to eliminate confusion on how data are collected and analyzed. All observers conducting the monitoring should be familiar with this SOP in order to identify and use the most current methods. The procedures in this SOP are based on the NCPN Protocol Versioning Guidance Document (NCPN-NPS 2009).

##### **Procedures:**

1. Modifications must be reviewed for clarity and technical soundness. Small changes or additions to existing methods will be reviewed in-house by NCPN Inventory and Monitoring staff. An outside review is required for substantive changes in methods. Regional and national staff of the National Park Service and experts outside of the Park Service with familiarity in vegetation and soil monitoring and data analysis will be used to review major changes.
2. Record all changes to a protocol document (Protocol Narrative or SOP) in the document's revision history log, even minor edits like fixing typos or formatting changes. It is not necessary to record the specific edits made, rather just the fact that typos were fixed or formatting changes were made. For minor edits, record the same document version number in the revision history log. For actual protocol changes (e.g., changes in methods, equipment), assign a new version number in the revision history log. Depending on the significance of the changes, it may be okay to combine multiple changes in the same entry in the revision history log. Version numbers increase incrementally by hundredths (e.g. version 1.01, version 1.02, etc.) for minor changes. Major revisions should be designated with the next whole number (e.g.,

version 2.0, 3.0, 4.0 ...). Record the previous version number, date of revision, author of the revision, and the reason for the changes along with the new version number (if applicable).

3. Narrative and SOP updates may occur independently. That is, a change in one SOP will not necessarily invoke changes in other SOPs; a narrative update may not require SOP modifications. The NCPN tracks the narrative and SOP version numbers in a Master Version Table (MVT), which is maintained in this document (SOP #10). Any time a narrative or an SOP version change occurs, a new Version Key number (VK#) must be created and recorded in the MVT, along with the date of the change and the versions of the narrative and SOPs in effect. The VK number increments by whole integers (e.g., 1, 2, 3, 4, 5). Updates to the MVT also must be provided to the NCPN Data Manager for inclusion in the master version table database. *The protocol narrative, SOPs, and data should not be distributed independently of this table.*
4. New versions of the protocol narrative and SOPs must be posted on the NCPN web page. Older versions of the Protocol Narrative and SOPs must be archived in the NCPN Invasive Plant Protocol Library: (R:\Monitoring\_Archive\Invasives\Protocol).

### Invasive Plant Monitoring, Northern Colorado Plateau Network Master Version Table

| Version Key # | Date of Change | Narrative | SOP 1 | SOP 2 | SOP 3 | SOP 4 | SOP 5 | SOP 6 | SOP 7 | SOP 8 | SOP 9 | SOP 10 |
|---------------|----------------|-----------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------|
| VK1           | 5/1/2008       | 1.00      | n/a   | n/a   | 1.00  | 1.00  | 1.00  | 1.00  | n/a   | 1.00  | 1.00  | 1.00   |
| VK2           | 7/8/2009       | 1.00      | n/a   | n/a   | 1.01  | 1.00  | 1.00  | 1.01  | n/a   | 1.00  | 1.00  | 1.01   |
|               |                |           |       |       |       |       |       |       |       |       |       |        |
|               |                |           |       |       |       |       |       |       |       |       |       |        |

## References

NCPN-NPS 2009. Protocol Versioning Guidance Document, Version 1.0. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT.