Type N Feasibility Study

submitted
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EXECUTIVE SUMMARY

Between June 2004 and August 2006, we conducted an assessment to determine whether enough non-fish-bearing basins with the appropriate characteristics were available to populate study blocks in the proposed Type N Experimental Buffer Treatment Study. As originally proposed, this research study was to comprise a total of 20 sites, with five blocks of four different riparian buffer treatments (including reference sites) distributed across three physiographic regions. Site-selection criteria (limits on geographic range, elevation, gradient, lithology, basin size, stream order, and stream network geometry) were developed and basins meeting those criteria were identified using Geographic Information Systems (GIS). Cooperation was established with landowners, and ownership criteria (e.g., stand age and harvest timing) were determined. We field-verified the criteria identified by GIS and specified by landowners, the presence of target amphibian species, and fish endpoints (Type F/N boundary). A database was developed to manage this information and assist in the selection of suitable basins, resulting in the final selection of basins and grouping of those basins into blocks.

We identified a pool of 35,957 non-fish-bearing basins in western Washington using the Washington Department of Natural Resources (WADNR) GIS hydrolayer recently updated to include a last-fish point based on a GIS-logistic regression model. Application of site-selection criteria using GIS reduced this pool to 6,125 qualifying basins from the target regions: the Olympic Peninsula, the Willapa Hills, and the South Cascades. Ownership criteria further reduced this pool to 496 qualifying basins. Field verification of GIS and ownership criteria then reduced the pool to 131 basins. Of these, amphibian surveys were conducted at 115 basins to verify presence of Forests and Fish (FFR)-designated stream-breeding amphibian species (coastal tailed frog [*Ascaphus truei*], and three species of torrent salamanders [*Rhyacotriton*]). We used tailed frog detection as an indicator of the presence of stream-associated FFR taxa because presence of the coastal tailed frog is highly correlated with presence of the other target amphibian species. Coastal tailed frog was found in 58 basins of the 115 surveyed basins, roughly half of the basins in which amphibian surveys were conducted. After field-verifying the location of fish endpoints at these sites, we determined that 26 of the basins from the remaining pool were either smaller or larger than the basin size defined in our site-selection criteria, leaving 32 basins remaining.

Fourteen of the remaining 32 basins were unavailable for inclusion after final consideration of landowner and logistic requirements. The remaining 18 sites were available for inclusion in the study, enough to populate four of the five proposed study blocks. Results of a power analysis support three blocks as being the minimum sufficient for implementing the amphibian portion of the study. Reduction in the number of study blocks from five to four will slightly reduce the power to detect a difference among blocks for the amphibian demography portion of the study; however this change is insignificant in context of the overall study design.

Hydrological monitoring was restricted to two study blocks because monitoring weirs could not be placed in streams that lacked a suitable site. Reduction in the number of blocks will reduce the sample size and the power to detect a change, but hydrology data

is continuously recorded which will increase measurement accuracy and resolution; and its analysis will not depend on the repeated measures ANOVA model proposed for other response variables. The subsequent reduction of within-site variability will increase the power to detect a significant difference between treatments if a difference exists, at least partially offsetting the loss of replication.

Only eight basins (two blocks) had the stream length (from fish endpoint to downstream tributary junction) needed to conduct the fish-sampling portion of the study. As a result, the fish portion of the study cannot be included in the repeated measures ANOVA analysis. However, the assessment of the response of fish, as a series of case studies, will still provide insight into fish response under differing treatment conditions.

Type N Feasibility Study
Final Report

Aimee P. McIntyre, Marc P. Hayes, and Timothy Quinn

INTRODUCTION

The Type N Feasibility Study was conducted to determine whether enough non-fish-bearing basins with the appropriate characteristics were available to populate the study blocks for the Type N Experimental Buffer Treatment Study (herein the Type N Study, Hayes et al. 2005). This report describes the process and outcome of this evaluation, which began in June 2004 and continued through August 2006.

Over this two-year period, the site-selection process included the following steps which are explained below:

1) Establish geographic criterion;
2) Identify non-fish-bearing basins using GIS (Geographic Information Systems);
3) Develop site-selection criteria;
4) Develop a database and ArcGIS map to manage information and assist with selection of basins;
5) Establish landowner cooperation and determine ownership criteria;
6) Field-verify qualifying basins; and,
7) Final selection of basins and grouping into blocks.

A flow chart in Figure 1 summarizes the steps in this process.

SITE-SELECTION PROCESS

Establish Geographic Criterion

The Type N Study was meant to include the greatest number of Forests and Fish (FFR)-designated stream-breeding amphibian species (Hayes et al. 2005), so the geographic area addressed included only the three physiographic regions where the greatest number of species overlapped: Olympic Peninsula, Willapa Hills, and South Cascades (south of the Cowlitz River; Figure 2).

Identify Basins using GIS

GIS screening of basins was completed using the Washington Department of Natural Resources (WADNR) hydrolayer, which included points where the fish occupancy was predicted to end based on the recently developed last-fish model (WFPB 2002). The hydrolayer identified 35,957 non-fish-bearing basins across three physiographic regions in western Washington, defined as the study area.

Develop Site-selection Criteria

We applied a set of selection-criteria to the pool of 35,957 non-fish-bearing basins within the study area (see Table 1 for a complete list of criteria). These criteria included physical factors that influence amphibian distribution (i.e., elevation, gradient, lithology, basin size, and stream order), the presence of target FFR stream-associated amphibian species, and presence of 75 m or more of stream between the fish endpoint and the next downstream tributary junction (the minimum stream length necessary for the downstream assessment of fish). Target FFR stream-associated amphibian species included coastal tailed frog (*Ascaphus truei*) and three species of torrent salamander (*Rhyacotriton*). Since coastal tailed frog is the only FFR target amphibian species that occurs throughout the entire study area it became the focal species.

The assemblage of target amphibian species rarely occurs above 1,219 m (4,000 ft) elevation in Washington State and the upper elevation limit within their range declines slightly with increasing latitude (Dvornich et al. 1997). Therefore, we included only those basins below 1,067 m (3,500 ft) and 1,219 m (4,000 ft), respectively, in the Olympic Peninsula and South Cascades physiographic regions. An upper elevation exclusion limit was unnecessary for the Willapa Hills because the maximum elevation (Boisfort Peak: 948 m [3,110 ft]) was well within the elevation range of all target amphibian species.

Target amphibian species have been shown to have a greater probability of occupancy on competent lithologies (Dupuis et al. 2000, Wilkins and Peterson 2000). Finding study basins occupied by target amphibian species would be difficult on incompetent lithologies (Hayes et al. 2005). Therefore, we included only those basins that were composed of a competent lithology as identified by the Washington Department of Natural Resources (WADNR) or could potentially be competent depending on weathering and age. To accomplish this task, we worked with Patrick Pringle (Geology and Earth Resources Division of WADNR), who classified all of the lithology types in the WADNR geology layer into 4 categories: *always competent*, *probably competent*, *probably not competent*, and *never competent*. As we were interested in being as inclusive as possible, we only excluded basins dominated by a lithology type classified as *never competent*.

We limited basins to those with stream gradient between 5 and 50% slope because coastal tailed frogs are known to occur in streams with these slopes (3-27 degrees gradient; Adams and Bury 2002). This range also captures almost the entire gradient range over which the remaining target amphibian species are found (Adams and Bury 2002). We also restricted the basin size to second-order (Strahler 1952) because coastal tailed frogs do not regularly reproduce in small (first-order) basins in western Washington (Hayes et al. 2006).

Basins were also screened for size. To maximize the influence of the treatment on treated units and thus the potential of an effect resulting in differences among treatments, harvest unit size had to equal or approach the size of the non-fish-bearing study basin. The lower size limit was largely driven by landowners, who indicated that they would not typically harvest a unit less than 12 ha (30 ac) in size. Forest Practices regulations constrained the upper size limit, which sets a 49-ha (120-ac) upper limit on harvest unit size without review by an interdisciplinary team (WFPB 2001). Since treatments were meant to reflect forest practices as currently implemented, we constrained selection to basin sizes between 12 and 49 ha (30 and 120 ac).

Lastly, we excluded basins where the modeled fish endpoint was located at the confluence of two tributaries (i.e., at a tributary junction). The original study design called for fish sampling in a minimum 75-m reach immediately downstream from the fish endpoint (Hayes et al. 2005). Therefore, in order for a basin to be included in the fish portion of the study, at least 75 m of stream had to exist between the fish endpoint and the next downstream tributary junction. The presence of a tributary within this 75 m could confound the effects of the Type N treatment if this portion of the basin were treated differently from the experimental treatment.

After applying the site-selection criteria listed above to the pool of basins identified using the WADNR last-fish model, we were left with 6,125 non-fish-bearing basins, all of which were identified in an ArcGIS data layer.

Develop a Database Linked to ArcGIS

We created a GIS data layer coverage that delineated all non-fish-bearing basins meeting the site-selection criteria (6,125 basins). An Access database was created and data were collected on site-selection criteria for each of these basins. The Access database was linked to the GIS coverage. The database was composed of three primary tables with information on individual basins, ownership, and stands. Basin information included the spatial location (e.g., drainage, elevation) and a suite of physical descriptors (e.g., basin size, gradient). Ownership information included the owner or owners of the basin (e.g., number of landowners and their respective areas of ownership within the basin) and projected harvest time. Ownership information could only be included after landowner cooperation and determination of ownership criteria were established (see next section). Stand information included details on stands located in each basin (e.g., areas of stands and their ages, dominant tree species). All data were not collected for basins that were eliminated through the screening process.

Establish Landowner Cooperation and Determine Ownership Criteria

Landowners across the selection area were contacted for their interest in participation. Interested landowners committed to sharing information about stand ages, conditions, and timber harvest plans. In order to participate, landowners committed to making their best attempt at harvesting basins to our specifications (treatment layout and timing) and to allow access to their land throughout the study period of 15 years, which would allow for 2 years pre- and post- harvest data collection, the treatment year, and at least one round of post-treatment sampling that would occur in years 14 and 15 (i.e., beginning 10 years after the treatment application year). One landowner (Olympic National Forest) was hesitant to make this 15-year commitment, and so we compromised with an 11-year commitment, which would allow for 2 years pre- and post-harvest data collection, the treatment year and approximately one generation to pass for the slowest maturing of the target species, coastal tailed frog (estimated to average 8 years). We anticipate that most, if not all, basins will still be available for further study 10 years post-harvest and possibly beyond.

Landowner interest was established and additional data were collected for basins overlapping their ownership. This information included basin location, ownership patterns and distributions of stands by age class, and projected harvest timing. We queried landowners to verify the average minimum age at harvest and most agreed that 30 years was this minimum. The maximum stand age was established as 80 years, since harvest of stands over 80 years is infrequent in Washington State. We restricted potential study basins to those that would have a stand age ranging between 30 and 80 years when treated (harvest during study year 3, or April 2008 through March 2009). Because study treatments were intended to mimic standard harvest operations, we selected basins where >70% of the stands were within the target stand age range. Further, we only included basins owned wholly or mostly (>80%) by a single entity to eliminate problems associated with coordinating timber harvest across multiple owners.

The method of data acquisition varied between landowners. Four public landowners initially took interest in participating, including Gifford Pinchot and Olympic National Forests, Olympic National Park, and WADNR. Public landowners supplied us with GIS coverage of their ownership boundaries and stand delineations that included ages or age ranges of forested stands. Coverage with ownership boundary and stand age information was overlain on the GIS coverage of qualifying basins (see previous Site-selection criteria).

Ten private (n = 8) and tribal (n = 2) landowners initially took interest in participating. Private landowners were provided with either the coverage of qualifying basins or maps of basins overlapping their ownership. Seven of the landowners (The Campbell Group, Green Crow, Hancock Forest Management, Makah Nation, Merrill & Ring, Port Blakely Tree Farms, and Quinault Nation) screened basins on their own and provided information about which basins might be usable based on stand age, harvest timing, and selected owner-specific exclusions. Three of the private landowners (Longview Timber [formerly Longview Fibre], Rayonier, and The Weyerhaeuser Company) created maps with the GIS basin overlay including information on stand ages and projected harvest. We visited the offices of these landowners in order to view these maps and record data on stand age and conditions, and harvest timing.

Basins were assigned to one of four treatment types. The treatment types included in the Type N Study are: 100% buffer (all of the non-fish-bearing stream length buffered by a two-sided 50-ft buffer), one application of the current buffer allowable under Forests and Fish (at least 50% of the non-fish-bearing stream length buffered by a two-sided 50-ft buffer), 0% buffer (none of the non-fish-bearing stream length buffered), and an unharvested reference (30-80 year old stand) that represents a previously harvested site. Search for reference basins was restricted to public ownerships because private landowners wanted to avoid excluding basins from harvest over the length of the proposed study period. Most private landowners allowed some flexibility to change the timing of timber harvest forward or backward a couple of years, so we limited our search for basins on private lands to those that had a projected harvest timing within 5 years of the proposed harvest treatment window (April 2008 through March 2009). We searched for basins that were projected for harvest from 2006 - 2010 (two years before and two years after the projected harvest timing for the study). Due to restricted harvest activities on federal and park lands, basins located on National Forest and National Park lands were deemed unlikely candidates for harvest treatment. However, we could not assume that all basins on National Forest lands would be available as references, because some areas were scheduled for thinning. Basins located on state lands were available to be included as both treatment and reference basins. We were initially advised by WADNR to ignore harvest-timing requirements on state lands and to examine all basins meeting site-selection and stand age criteria.

Not all of the 6,125 basins meeting site-selection criteria overlapped with land owned by cooperating landowners, and therefore not all basins were queried for age and harvest information. Since some landowners queried basins on their own, we do not know the exact number of basins that were queried; however, we do know that >4,480 (>73%) of the 6,125 qualifying basins were queried. Of the 14 participating landowners, 6 had basins that met stand age and harvest-timing criteria.

Three of four public landowners had basins meeting stand age and harvest-timing criteria (Table 2). We identified 16 potentially qualifying basins within the Olympic National Park; however, these basins were located on unmanaged lands, considered by CMER to be inappropriate for inclusion because they lacked previous harvest disturbances or data on major non-harvest disturbances. Therefore, these basins were excluded from further consideration. Of 843 state-owned basins, 320 (38%) met stand age criteria; however, since WADNR advised us to ignore harvest-timing requirements during this step, this proportion over-represents the actual number of basins that would ultimately be available for inclusion in the study.

Three of 10 private landowners had basins on their ownership meeting stand age and harvest-timing criteria (Table 2). Green Crow and Merrill & Ring indicated that some of the qualifying basins on their ownerships met the stand age criteria and that they were willing to consider further participation, however site visits revealed that the dominant geology in these basins was not a competent lithology. Hancock Forest Management and Port Blakely Tree Farms identified no basins meeting both stand age and harvest-timing criteria. Two Makah-owned basins met stand age criteria, and one was possible once harvest-timing constraints were considered. However, neither the Makah nor the Quinault were able to commit during our planning window. Fifty-five qualifying basins meeting stand age criteria were identified on The Campbell Group lands. However, The Campbell Group underwent reorganization soon after these basins were identified and withdrew from participation in the study. After stand age and harvest-timing criteria were considered 496 (8%) of the 6,125 qualifying basins remained in the selection pool (Table 2).

Field Verify Qualifying Basins

Once basins were selected for site-selection and ownership criteria, the remaining pool of 496 basins were field-evaluated for the following:

1) **Site-selection (GIS) criteria:** Verify gradient and lithology data obtained from GIS maps (see Site-selection criteria);
2) **Ownership criteria:** Verify general stand age (see Establish landowner cooperation and determine ownership criteria), i.e., a general determination of dominant stand age was made to ensure stands were >30 years.
3) **Amphibian presence:** Presence of target amphibian species was assessed using a light-touch sampling approach (Quinn et al. 2007); and
4) **Fish endpoint:** verification of the last-fish point location using electroshocking.

Between 13 April - 30 August 2005, we visited 344 (69%) of the 496 basins that matched our GIS and ownership criteria. The remaining 152 basins (31%) were not visited in the field for a variety of reasons including: the basin was inaccessible (access was blocked by a gate on non-participating landowner; the time required to effectively access it was too long), or the basin was actually located on a small piece of private land surrounded by WADNR-owned land. Using GIS maps of basins and state and landowner maps, crews of two located basins and modeled fish endpoints in the field. Once a basin was identified, field crews assessed the basin for GIS and landowner criteria by evaluating stand age and presence of recent harvest in study reaches along the stream, basin lithology, and stream gradient. Crews excluded a basin from consideration if any GIS or ownership criteria were not met.

Lithology was the criterion that was least often met. Of 279 basins for which competency were recorded, 107 basins (38%) did not meet the criteria for competent lithology. Seventy-nine of 302 basins (26%) did not meet the gradient criteria. We recorded stand age and recent harvest data for 328 of the 344 (95%) basins visited. Stand age data were correct at 242 basins (74%) and there was no recent harvest along the stream at 248 basins (76%). Other reasons for excluding a basin from the remaining candidate pool included: active harvest in or near the basin, evidence of recent thinning, basin located on non-participating private ownership, steep slopes making access into the basin too dangerous, and basins dominated by deciduous trees.

Of the 344 basins visited, 131 basins (30%) met GIS and ownership criteria. Once GIS and ownership data were verified, crews evaluated the basin for conditions suitable for amphibian presence and sampling. Primarily, we were interested in flow conditions in the basin. If a basin did not have flowing water, or had extremely low levels of water, then amphibian surveys were not conducted at that basin. Of the 131 basins meeting GIS and ownership criteria, we have flow data for 129. Of these 129, 101 (78%) had adequate flow for amphibian sampling, 6 (5%) had low water flow, and 22 (17%) had no water in the basin.

In general, if field verification revealed that basins did not meet GIS or ownership criteria and did not meet flow conditions, these basins were not surveyed for target amphibian species. However, in cases where GIS, ownership or flow criteria were nearly met, we sampled for target amphibian species with the intent of keeping as many basins as possible in the candidate pool. Therefore, even though only 99 basins met both site-selection and amphibian sampling criteria, we conducted amphibian surveys at 115 basins. Teams of two surveyed a 100-m stretch of stream, beginning at and working upstream of the modeled fish endpoint (or the closest approximation of that point). Samplers turned over available cover objects within the wetted stream channel, searching for target amphibian species using a longitudinal light-touch method (Quinn et al. 2007). Areas of small gravel-sized substrates were sifted through, and an aquarium net was used to capture amphibians. If no coastal tailed frog larvae were found in the first 50-m sampled and surveyors believed that this area did not adequately represent the basin as a whole then the remaining 50-m was sampled in an upstream area thought to be more suitable amphibian habitat.

Of the 115 basins sampled for target FFR amphibian species, 69 (60%) had at least one species present. Coastal tailed frog was found in 58 (50%) of the basins, and torrent salamanders were found in 50 (44%) of the basins. Previous surveys demonstrated that if you detect coastal tailed frog at a site, a high probability (>0.9) exists of finding other in-stream-breeding amphibians (WDFW, *unpublished data*). Therefore, we considered any basin where coastal tailed frog had been found (58 basins) to remain in the candidate pool for eventual inclusion in the study.

Of the 58 basins in the remaining candidate pool, 10 were removed for reasons including: only tailed frog adults found (no evidence of reproduction), presence of steep and unsafe conditions, surface water going subterranean after less than 50 m, presence or evidence of mass wasting, presence of fish found during amphibian sampling resulting in a contraction of the basin to a size less than the minimum size (<30 ac), and the basin was already included in another study. Forty-eight basins remained in the candidate pool for inclusion in the study at the conclusion of this screening. Basins were located on all six of the ownerships that had basins meeting site-selection and ownership criteria (Table 3).

The remaining 48 basins were sampled using electrofishing in order to identify the fish endpoint in the field. A field crew from Weyerhaeuser, working with a Washington Department of Fish and Wildlife crew, visited all 48 basins and conducted fish surveys to determine the fish endpoint. Most fish surveys (92%) were conducted during the three-month period from December 2005 to February 2006. Fish surveys at five basins were conducted outside of this three-month period (one in March, two in April and two in June) due to accessibility (snowfall blocking access).

Fish surveys generally began at or near the modeled fish endpoint. Electrofishing confirmed presence or absence of fish at that location. If fish were observed, then the surveyors moved upstream, electroshocking until no more fish were seen. They continued sampling upstream of the last fish until they reached a blockage or change in habitat believed to preclude fish. The fish endpoint was then set at the last observed fish. If no fish were seen at the modeled fish endpoint, then samplers moved downstream, sampling until a fish was observed. If a fish endpoint could not be determined due to flow conditions or low conductivity, a basin would be revisited until the fish endpoint could be established. In eight instances, the fish endpoint location was not established. In all of these cases a habitat feature thought to exclude fish from moving upstream (e.g. a large waterfall) was observed far enough downstream of the modeled fish endpoint that the resulting basin size exceeded the maximum size criteria (>120 ac).

Modeled and field-verified fish endpoints for four (8%) of the 48 remaining candidate basins were at or near the same location verified using GIS and topographic maps and considering topography and stream dendritic pattern. Thirty-seven (77%) had field-verified fish endpoints located downstream of the modeled fish endpoint location, and 7 (15%) had field-verified fish endpoints located upstream of the modeled fish endpoint location. For those basins where the field-verified fish endpoint was downstream of the modeled point, the magnitude of change ranged from approximately 24 m to over 1340 m. For those where the field-verified fish endpoint was upstream of the modeled point, the magnitude of change ranged from approximately 31 m to 200 m. Verification of fish endpoint in the field resulted in 17 basins (35%) being removed from consideration. Sixteen of these basins were now too large for inclusion (no longer meeting the maximum 49-ha [120-ac] size requirement). One basin expanded (via movement of the fish endpoint downstream) to include forest stands that did not meet the minimum stand age requirement of 30 years. Two basins expanded to include multiple landowners, which could be included for further consideration pending discussion with those landowners. At one basin, the location of the field-verified fish endpoint moved upstream from the modeled point resulting in the basin being split into two sub-basins, both of which met study criteria. As a net result, we were left with 32 basins for potential inclusion after field verification of fish endpoint (Table 3).

Finding basins suitable for the fish portion of the study proved difficult. We required at least 75 m below the fish endpoint where fish sampling could be conducted, established as the minimum stream length necessary in order to conduct fish sampling. Of the remaining 32 basins that met site-selection, ownership, and fish endpoint verification, 13 did not meet the requirements for being included in the fish portion of the study either because the fish endpoint was located at a tributary junction (9 basins), or a tributary junction was less than 75 m downstream from the fish endpoint (4 basins). Therefore, only 19 basins meeting site-selection, landowner, amphibian presence, fish endpoint, and fish sampling criteria remained (Table 3). Of these, two basins had multiple landowners, and three had culverts that blocked fish passage located at or near the field verified fish endpoint, making them less than ideal for the fish portion of the study unless these culverts were going to be removed.

Final Selection of Basins and Grouping into Blocks

Our desired result was to find 20 basins, grouped into five blocks of four treatment basins per block. We also wanted the five blocks to be distributed among the three physiographic regions represented by the proposed study area (Olympics, Willapa Hills, and South Cascades). Finally, we did not want basins within a block to overlap two physiographic regions. After the application of all selection criteria and field verification, there were 32 basins available for inclusion in the study, of which only 19 (59%) would work for the fish component.

At this point, we focused our attention on working with landowners with candidate basins. Basins identified for harvest treatments required landowners to commit to harvesting the basin during April 2008 through March 2009. Likewise reference basins required landowners to restrict harvest activities within the basin until 2020 with the exception of the Olympic National Forest, which committed through 2016. Some landowners (notably WADNR) had instructed us to find basins that would work for our study and then determine if those basins could fit into a harvest plan. Thus, we risked getting through the entire screening process only to find out that a basin could not be managed according to the study design. Fourteen additional basins were unusable due to landowner restrictions. Below, we list the reasons why a particular owner was unable to commit a basin to the study:

- Five WADNR basins could not be included because the area was already scheduled for thinning and slope instability issues in these basins precluded our treatments from being applied.
- Three Olympic National Forest basins were excluded because clearcut harvesting was not an option.

- One WADNR basin was scheduled for harvest and was therefore unavailable for inclusion as a reference. However, WADNR was hesitant to commit this basin as a treatment basin because there was a concern that the new marbled murrelet (*Brachyramphus marmoratus*) strategy, when it went into effect, would designate nearby habitat as marbled murrelet habitat, making harvest in this basin impossible.
- One WADNR basin had a timber sale planned for fiscal year 2007, and while WADNR was willing to consider changing the sale within that fiscal year, they could not reschedule it for a different fiscal year.
- One WADNR basin fell within known marbled murrelet habitat making it an option as a reference only. We did not require two references in that area and WADNR preferred that we use another.
- We opted to exclude one WADNR basin because of dual ownership in the basin and the presence of a small amount of recent harvest in the basin.
- One WADNR basin was not available for inclusion as a reference because it was scheduled for harvest prior to our harvest window.
- Finally, one basin located on Longview Timber was originally committed as a treatment basin, but was harvested outside of the treatment window and thus was no longer available for the study.

After all considerations, 18 basins met all selection criteria and harvest timing requirements for inclusion in the study (Table 4). We identified enough basins to populate four complete blocks, each with four basins to receive one of the four treatment types (Figure 2). The distribution of basins was such that we could have one block of four basins in the Olympic physiographic region, two in the Willapa Hills, and one in the south Cascades (Table 5). We also had two extra basins in the Willapa Hills that we opted to include as a "half block", knowing that each additional basin would add more power to our analysis and that these two basins could potentially act as back-ups in the event that another basin fell through for reasons beyond our control.

Of the 18 basins available, 11 had the necessary configuration for enabling the fish-sampling portion of the study. Four of these 11 basins were in the Olympics, five in the Willapa Hills, and two in the south Cascades. Since four sites were required per block, and blocks could not overlap among physiographic regions, we could populate only one block in the Olympic and one in the Willapa physiographic regions for fish work (Table 5). Export work would be conducted in the same two blocks as fish sampling (Olympic and Willapa 1 Blocks). Physical constraints associated with the other complete blocks (Willapa 2 and South Cascade Blocks), including lack of suitable low-gradient reach (both blocks) for flume installation and lack of access due to snow in winter and spring (South Cascade Block), prevented us from conducting export and flow work.

The next step was assigning basins to one of the four treatment types. As mentioned previously, basins located on certain ownerships were not available for certain treatment types (e.g., basins located on National Forest were likely not available as treatment basins, and basins located on private land were unavailable as reference basins). Given these constraints we randomized the assignment of treatments as follows:

- Olympic Block: Four basins were available in the Olympics physiographic region, and one of the four treatment types was randomly assigned to each basin forming the Olympic Block (Figure 3).
- Willapa 1 Block: Ten basins were available in the Willapa Hills physiographic region. Eight of these 10 basins were spread throughout the coastal region of the Willapa Hills. The other two were located south and east of the others and so were paired together (Willapa 3 Block). Since we wanted to have one complete block in the Willapa Hills that could be used for the fish portion of the study, we first considered the five basins that were suitable for fish and how to organize one block out of these. Four of the five basins were located on state land, and one of the basins was on privately owned land. Of the four state-owned basins, two needed to be used as references (for the fish block and other complete block in the Willapas) and the other two would be treatments. We randomly selected two of the four state-owned basins to act as references, and the others became treatments. We then randomly selected one of the two reference basins for inclusion in the Willapa 1 block. The privately owned basin was only available as a harvest treatment. With this private basin and the other two state-owned treatment basins we had three treatment basins. Treatment type was randomly assigned to each of these three basins, and when coupled with the selected reference basin became the Willapa 1 Block (Figure 4).
- Willapa 2 Block: The remaining state-owned reference was used for the Willapa 2 Block. We then randomly assigned harvest treatments to the remaining three basins in western Willapa Hills, and together these became the Willapa 2 Block (Figure 5).
- Willapa 3 Block: The two remaining basins became the Willapa 3 "half block". Originally it was thought that we could populate an entire block in this area as there were eight basins (six potential harvest basins and two potential references). However, it turns out that this area has unstable slopes and the only treatment type that could be applied was the 100% buffer. One of these basins was in an area scheduled for thinning. WADNR agreed to make the harvest of this basin a clearcut, but due to slope instability in the area the basin was only available for the 100% buffer treatment. The other basin was only available as a reference (Figure 6).
- South Cascade Block: Four basins were available in the South Cascade physiographic region. One of these was located in the Gifford Pinchot National Forest and was only suitable as a reference. Harvest treatments were randomly assigned to each of the three remaining basins, and when coupled with the reference basin became the South Cascade Block (Figure 7).

CONCLUSION

Our site-selection process resulted in 18 basins being available for inclusion in the study (see Figures 8-23). We have enough basins to populate four of the five proposed study blocks. Measurement of most proposed elements can be completed across all four study blocks. The exceptions are measurement of fish and hydrology, the latter of which requires placement of a weir, which can only be effectively done in two blocks.

Results of a power analysis indicate that three blocks would be the minimum sufficient for implementing the amphibian portion of the study and its supporting elements (see

Hayes et al. 2005 for details of the study design). Reduction in the number of study blocks from five to four will slightly reduce the power to detect a difference among blocks for the amphibian demography portion of the study; however this change is insignificant in context of the overall study design. Considering proposed levels for α and β of 0.1 each, the loss of one block reduces the effect size required to detect a difference among treatments by an estimated 3%. The reduced number of blocks should not affect the overall results of the amphibian genetics portion of the study because the power to detect a difference for the genetic markers is extremely high (i.e. 0.98).

Hydrological monitoring was restricted to two study blocks because monitoring weirs could not be placed in streams that were too steep or large. The reduction in the number of blocks will reduce the sample size and the power to detect a change. However, the use of Turbidity Threshhold Samplers, remotely triggered pump samplers, and calibrated flumes will increase measurement accuracy and resolution. The subsequent reduction of within-site variability will increase the power to detect a significant difference between treatments if a difference exists, at least partially offsetting the loss of replication. Temperature sampling will still occur at all study sites, and the reduced number of blocks from five to four is not anticipated to significantly impact temperature monitoring, with a power equation for a two sample t-test and 90% confidence level estimating a reduction in the likelihood of detecting a 1.0 C increase in temperature from 90% to 83%.

Ten of the 18 basins lacked the stream length (from fish endpoint to downstream tributary junction) needed to conduct the fish-sampling portion of the study, restricting it to eight basins, or two blocks. As a result, there will not be the sample size necessary to provide statistical differences between treatments and the fish portion cannot be included in the repeated measures ANOVA model proposed for a number of the other variables. However, the downstream fish information, as a series of case studies, will still provide insight into fish response under differing treatment conditions.

The 18 basins are distributed among 12 watershed administrative units (WAU) throughout the three physiographic regions: East Fork Humptulips (2), Lower Clearwater (1), Lower North (1), Nemah (2), Skomakawa (1), South Fork Grays (1), South Fork Willapa (4), and West Fork Washougal (2) Rivers; Wishkah Headwaters (1); and Hamilton (1), Smith (1), and Trout (1) Creeks (Table 8).

Most basins meet site-selection criteria, with some exceptions (Table 6). All basins meet the elevation criteria as determined at the field verified fish endpoint location, ranging in elevation from 22-730 m (72-2395 ft). All basins meet the requirement for competent lithology. Basins are dominated by 7 lithology subtypes: basalt flows and flow breccias (9 basins), basalt flows (3 basins), andesite flows (2 basins), continental sedimentary deposits or rocks (1 basin), tectonic breccia (1 basin), terraced deposits (1 basin), and tuffs and tuff breccias (1 basin). All basins meet the criteria for gradient, with average within basin gradients ranging from 14-34% slope (8-19 degrees of gradient). Sixteen basins are second-order or higher, with two first-order, nine second-order, and seven third-order basins (Strahler 1952). Though site-selection criteria limited us to second-order basins and higher, order changed based on the field-verified fish endpoint location differing from the location of the modeled fish endpoint. Sixteen of the 18 basins met site-selection criteria for size. Basins range in size from 12-76 ha (31-188 ac). Two basins exceed the size range established during site selection, one slightly at 124 ac (50 ha) and the other at 188 ac (76 ha). One of these basins is being used as a reference. The other basin overlaps two landowners and only the land on Longview Timber ownership will be harvested as part of a treatment. Additionally, this basin is assigned the 100% buffer treatment; so only 105 ac will be harvested in order to implement the treatment. Numbers of sensitive sites (headwall seeps, side-slope seeps, Type Np intersections, and headwater springs) varies among sites (Table 7).

With final site selection nearly completed, pre-treatment sampling of all response variables began in May 2006.

LESSONS LEARNED

Site selection for the Type N Study was a detailed and time consuming process. Many lessons were learned which could be of value for researchers designing and implementing similar landscape-scale studies. Lessons learned include:

- **Time.** Finding sites that meet the specifications of the study design can be time consuming and arduous. Taking the time to ensure that sites meet the specified criteria prior to initiating the study will decrease the chances of an unsuitable site being included initially, and set the stage for a successful study.
- **Selection criteria.** Outline selection criteria in detail, as soon as possible, allowing the site-selection process to be applied consistently from the beginning.
- **Flexibility.** Allow for flexibility in certain selection criteria. Alter expectations and/or study design if necessary in order to obtain the number of sites needed for a robust statistical analysis, without compromising the integrity of the study design.
- **Communication.** Establish open communication at the onset of site selection. Develop working relationships with participating landowners. Communicate with participants on a regular basis and keep them informed of the overall progress of site selection. Do not limit your communication with a landowner to a single individual, but communicate with all of the individuals necessary to ensure that everyone understands the expectations associated with a specific site. Be certain to inform a landowner if you were not able to locate a site that meets your criteria on their ownership.
- **Expectations.** Develop a list of expectations that can be shared with participating landowners. Outline the research objectives, time line and commitment, expected treatments (in our case timber harvest), timing of treatments, and any other limits that the study will impose upon a site.
- **Recordkeeping.** Record and store data in a manner that makes it accessible. The amount of information collected during the site-selection process can grow exponentially through time, and is dependent on the scope of the study and numbers of sites and selection criteria. Clear and consistent data tracking will ensure that all of the information for each site is being recorded and stored in a manner that makes it easily searchable. Maintain records for all sites, even those that are considered unsuitable, as you may want access to that information if you end up relaxing a particular criterion in order to obtain the necessary number of sites.

- **Mapping.** Ensure that locations and boundaries of selected sites are adequately mapped (preferably in ArcGIS) and locations described. Maps of chosen basin with boundaries defined should be distributed to participating landowners so that they have the exact location of sites you wish to include. Inquire whether landowners want site boundaries marked in the field. Hopefully, landowners will be able to put the maps you provide them on file, preferably in a database, that would alert all employees that there is an active research project going on in a particular area and what management limits there may be.
- **Directions.** Record directions to all sites field-visited and keep them on file. Later, if a location is chosen for a study site, you will have directions on how to access the site on record.
- **Permits.** Obtain all access and sampling permits necessary prior to the onset of site selection or data collection. Ask landowners if they would like to be informed when you are on their land. Contacting landowners every time you access a site, or at the least prior to each sampling session or field season, gives you the opportunity to remind landowners that you are out there and that a particular site is being used for research. It also provides the opportunity for landowners to share any updated information on management activities, road closures, or other pertinent information.
- **Treatments.** If your research requires implementation of a treatment (in our case, timber harvest) be sure to stay as involved as possible with the design and implementation of those treatments. Provide all of the necessary information for the landowner to apply the treatment the way you intend. In our case, we did site visits with foresters in the field, aided in the layout of riparian buffers, reviewed Forest Practices Applications (FPA) prior to submittal, reviewed timber sale contracts (when applicable), and participated with pre-harvest meetings with timber purchasers and contractors.

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Table 1. Site-selection criteria for each step of the site-selection process, with corresponding limits to each of those criteria.

Step in Process	Criterion	Limit
Geographic criterion	geographic range	Olympic Peninsula, Willapa Hills, and South Cascades physiographic regions of Washington State
Site-selection criteria (obtained with GIS)	elevation	< 1,067 m (3,500 ft) for the Olympic Peninsula < 1,219 m (4,000 ft) for the South Cascades no limit for the Willapa Hills
	gradient	5 – 50% (3 – 27 degrees gradient)
	lithology	competent (or any lithology that could potentially be competent, i.e., potentially producing long-lasting large clasts or coarse grain sizes)
	basin size	12 – 49 ha (30 – 120 ac)
	stream order	second (Strahler 1952)
	stream network geometry	75 m or more of stream between the fish endpoint and next downstream tributary junction
Ownership criteria	stand age	>70% of stands in basin between 30 and 80 years old during harvest treatment window
	harvest timing	treatment basins: harvest Apr 08 – Mar 09 reference basins: no harvest
	time commitment	15 years
	area owned	>80% owned by single participating landowner
Field verification	site-selection (GIS) criteria	verify site-selection data obtained from GIS
	ownership criteria	verify stand age
	amphibian presence	verify presence of *Ascaphus truei*, and *Rhyacotriton*
	fish endpoint	verify fish endpoint using electroshocking

Table 2. Numbers of non-fish-bearing basins by ownership meeting site-selection and ownership criteria. A dash (-) indicates that the landowner did not provide the number of qualifying basins overlapping their ownership.

	Number of Non-fish-bearing Basins	
Landowner	**Site-selection Criteria**	**Ownership Criteria**
Public		
Gifford Pinchot National Forest	106	8
Olympic National Forest	414	63
Olympic National Park	16	0
WADNR	843	320
Private		
Green Crow	-	0
Hancock Forest Management	-	0
Longview Timber	329	41
Makah Nation	17	0
Merrill & Ring	-	0
Port Blakeley Tree Farms	104	0
Quinault Nation	287	0
Rayonier	872	24
The Campbell Group	-	0
Weyerhaeuser	1,492	40
Total number of basins available for further consideration	**>4,480**	**496**

Table 3. Numbers of non-fish-bearing basins meeting site-selection, ownership, and fish end-point criteria. Type N Criteria basins meet site-selection, ownership, and stand criteria; Fish Criteria basins meet fish sampling criteria (i.e., has at least a 75-m reach downstream of field verified fish endpoint that is suitable for fish sampling).

	Number of Non-fish-bearing Basins		
Landowner	**Qualifying Basins**	**Type N Criteria**	**Fish Criteria**
Public			
Gifford Pinchot National Forest	1	1	0
Olympic National Forest	5	4	2
WADNR	32	20	13
Private			
Green Crow	0	(1*)	(1*)
Longview Timber	2	2	1
Rayonier	4	2	2
Weyerhaeuser	4	3	1
Totals	**48**	**32**	**19**

* At one basin (owned by WADNR) the field verified fish endpoint moved downstream of the modeled fish endpoint onto a second landowner (Green Crow), so the basin overlaps two landowners. Most of this basin is located on WADNR ownership and so is counted there.

Table 4. Distribution of selected non-fish-bearing basins across participating landowners.

	Number of Non-fish-bearing Basins	
Landowner	**Type N Basins**	**Suitable for Fish**
Public		
Gifford Pinchot National Forest	1	0
Olympic National Forest	1	1
WADNR	10	6
Private		
Green Crow	(1*)	(1*)
Longview Timber	1	1
Rayonier	2	2
Weyerhaeuser	3	1
Totals	**18**	**11**

* At one basin (owned by WADNR) the field verified fish endpoint moved downstream of the modeled fish endpoint onto a second landowner (Green Crow), so the basin overlaps two landowners. Most of this basin is located on WADNR ownership and so is counted there.

Table 5. Distribution of selected non-fish-bearing basins across the three physiographic regions. Suitable for Study basins are those that can be included in the study when not accounting for the fish portion of the study; Suitable for Fish basins are those that have the correct dendritic pattern necessary for inclusion in the fish portion of the study; and Used for Fish are those actually included in the fish portion of the study.

	Number of Non-fish-bearing Basins		
Physiographic Region	**Suitable for Study**	**Suitable for Fish**	**Used for Fish**
Olympic	4	4	4
Willapa Hill	10	5	4
South Cascades	4	2	0
Total	**18**	**11**	**8**

Table 6. Site-selection criteria for all 18 basins included in the Type N Study. Treatment is the assigned harvest treatment type (0% = no buffer, FPB = current Forest Practices buffer, 100% = all buffered, and REF = unharvested reference). Elev is the elevation (m) at field-verified fish endpoint, lithology is the dominant lithology type, Gradient is the stream gradient (degrees), Order is Strahler order, and Size is the basin area (ac).

Block	Landowner	Treatment	Elevation (m)	Lithology	Gradient (◦)	Order	Size (ac)
Olympic	Rayonier	0%	233	basalt flows and flow breccias	17	2	32
	Rayonier	FPB	277	basalt flows and flow breccias	14	3	34
	WADNR	100%	72	tectonic breccia	15	3	68
	Olympic NF	REF	163	basalt flows and flow breccias	10	3	124
Willapa 1	Weyerhaeuser	0%	87	terraced deposits	9	3	69
	WADNR	FPB	197	basalt flows and flow breccias	11	1	31
	WADNR	100%	198	basalt flows and flow breccias	10	2	78
	WADNR	REF	200	basalt flows and flow breccias	11	2	43
Willapa 2	WADNR	0%	159	basalt flows	12	2	43
	Weyerhaeuser	FPB	183	basalt flows and flow breccias	19	2	46
	Weyerhaeuser	100%	22	basalt flows and flow breccias	12	3	64
	WADNR	REF	228	basalt flows and flow breccias	10	2	81
Willapa 3	WADNR	100%	351	basalt flows	11	2	60
	WADNR	REF	241	basalt flows	8	3	92
South Cascade	WADNR	0%	438	andesite flows	16	1	39
	WADNR	FPB	450	andesite flows	9	2	57
	Longview Timber	100%	730	continental sedimentary deposits or rocks	9	3	188
	Gifford Pinchot NF	REF	601	tuffs and tuff breccias	12	2	114

Table 7. Numbers of sensitive sites by type in all 18 Type N Study basins. Treatment is the assigned harvest treatment type (0% = no buffer, FPB = Forest Practices Buffer, 100% = all buffered, and REF = unharvested reference).

Block	Treatment	Tributary Junctions	Side-Slope Seeps	Headwall Seeps	Headwater Springs
Olympic	0%	3	1	0	4
	FPB	5	3	0	6
	100%	9	6	3	10
	REF	8	2	0	9
Willapa 1	0%	4	3	1	5
	FPB	0	2	0	1
	100%	4	3	0	5
	REF	2	1	2	3
Willapa 2	0%	2	11	0	3
	FPB	1	0	0	2
	100%	6	2	0	7
	REF	4	10	2	5
Willapa 3	100%	7	6	2	8
	REF	3	5	0	4
South Cascade	0%	0	0	0	1
	FPB	3	2	0	4
	100%	13	10	0	14
	REF	2	0	0	3

Table 8. Distribution of sites across Water Resource Inventory Areas (WRIA) and Watershed Administrative Units (WAU); 0% = no buffer, FPB = Forest Practices Buffer, 100% = all buffered, and REF = unharvested reference.

Block	Treatment	WRIA	WAU
Olympic	0%	Lower Chehalis	East Fork Humptulips River
	FPB	Lower Chehalis	Wishkah Headwaters
	100%	Queets/Quinalt	Lower Clearwater River
	REF	Lower Chehalis	East Fork Humptulips River
Willapa 1	0%	Willapa	Lower North River
	FPB	Willapa	South Fork Willapa River
	100%	Willapa	South Fork Willapa River
	REF	Willapa	South Fork Willapa River
Willapa 2	0%	Willapa	Nemah River
	FPB	Willapa	Nemah River
	100%	Willapa	Smith Creek
	REF	Willapa	South Fork Willapa River
Willapa 3	100%	Grays/Elochoman	South Fork Grays River
	REF	Grays/Elochoman	Skamokawa River
South Cascade	0%	Salmon/Washougal	West Fork Washougal River
	FPB	Salmon/Washougal	West Fork Washougal River
	100%	Salmon/Washougal	Hamilton Creek
	REF	Wind/White Salmon	Trout Creek

Figure 1. Flow chart depicting the decision process and number of basins remaining in the selection pool throughout site selection. For decision steps (represented by diamonds) the number of basins not meeting the criteria is not always depicted.

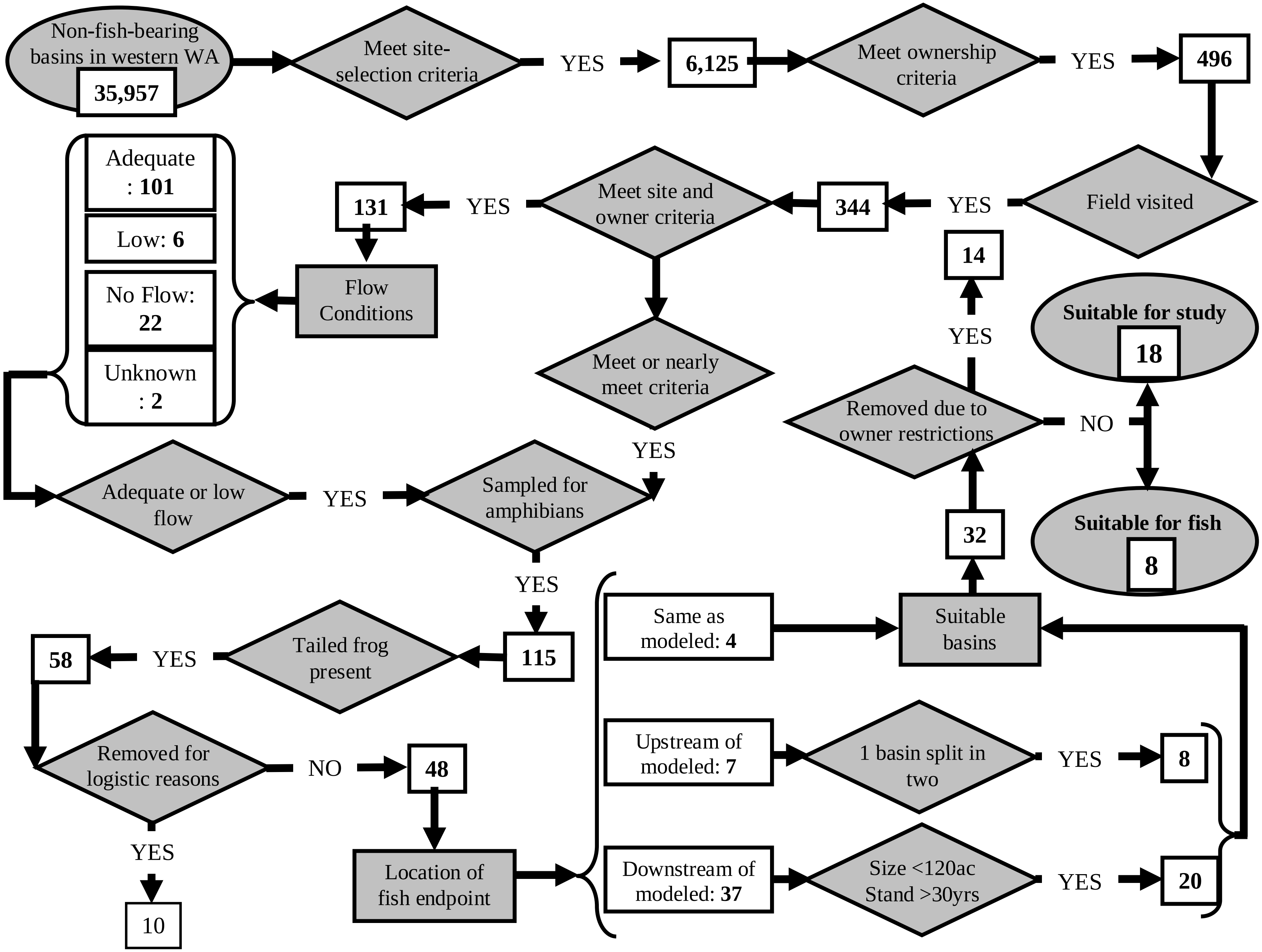


Figure 2. Geographic area addressed included only the three physiographic regions where the greatest number of FFR stream-associated species overlapped in Washington State: Olympic Peninsula (green outline), Willapa Hills (blue outline), and South Cascades (south of the Cowlitz River; red outline). Only coastal tailed frog and Rocky Mountain tailed frog are found outside of the geographic range represented by the study (black outline).

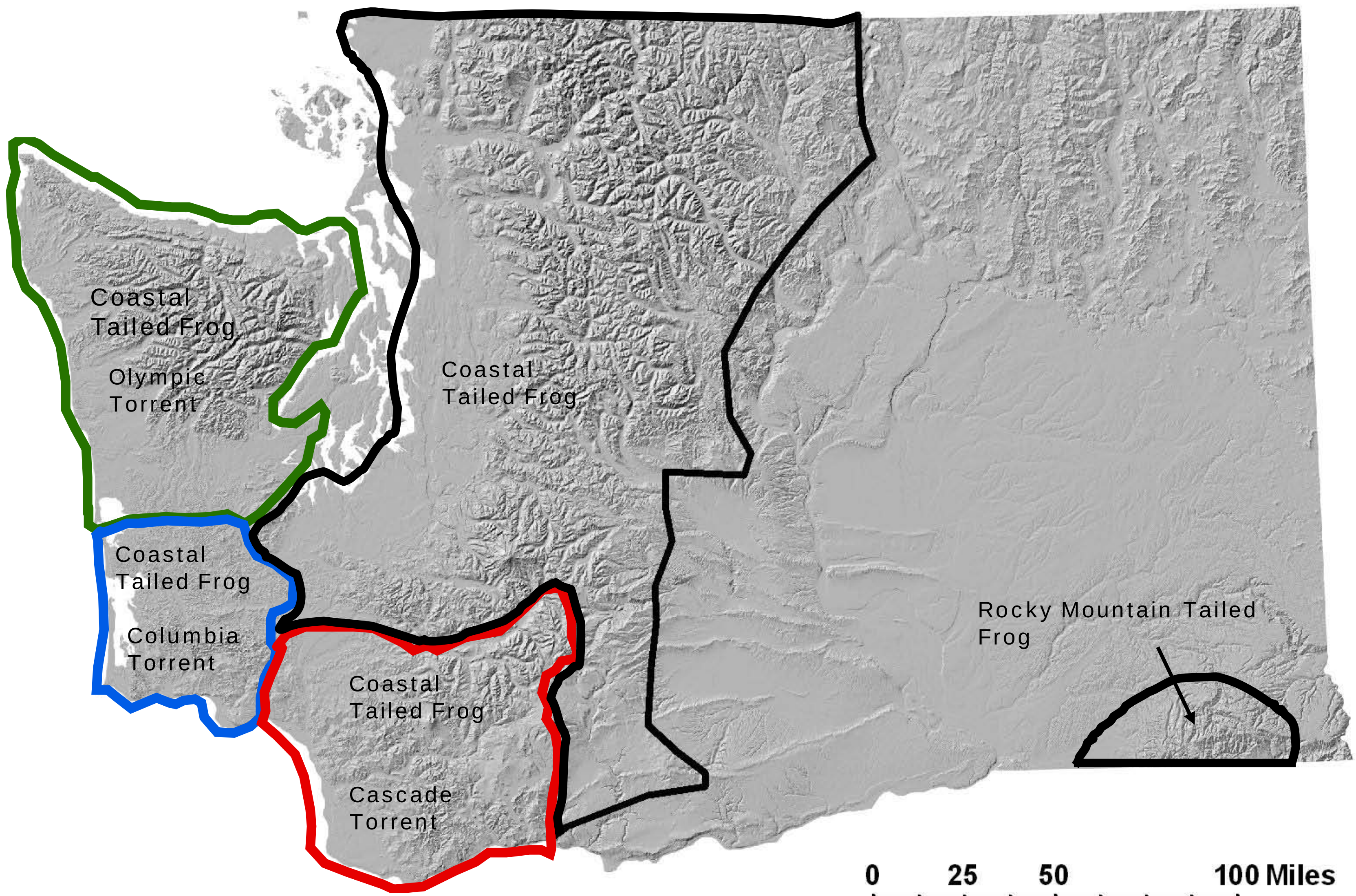


Figure 3. Distribution of selected non-fish-bearing basins throughout the study area in western Washington. Basins are grouped into four complete blocks (Olympic, Willapa 1, Willapa 2, and South Cascade with four basins each), and one "half block" (Willapa 3 with only two basins).

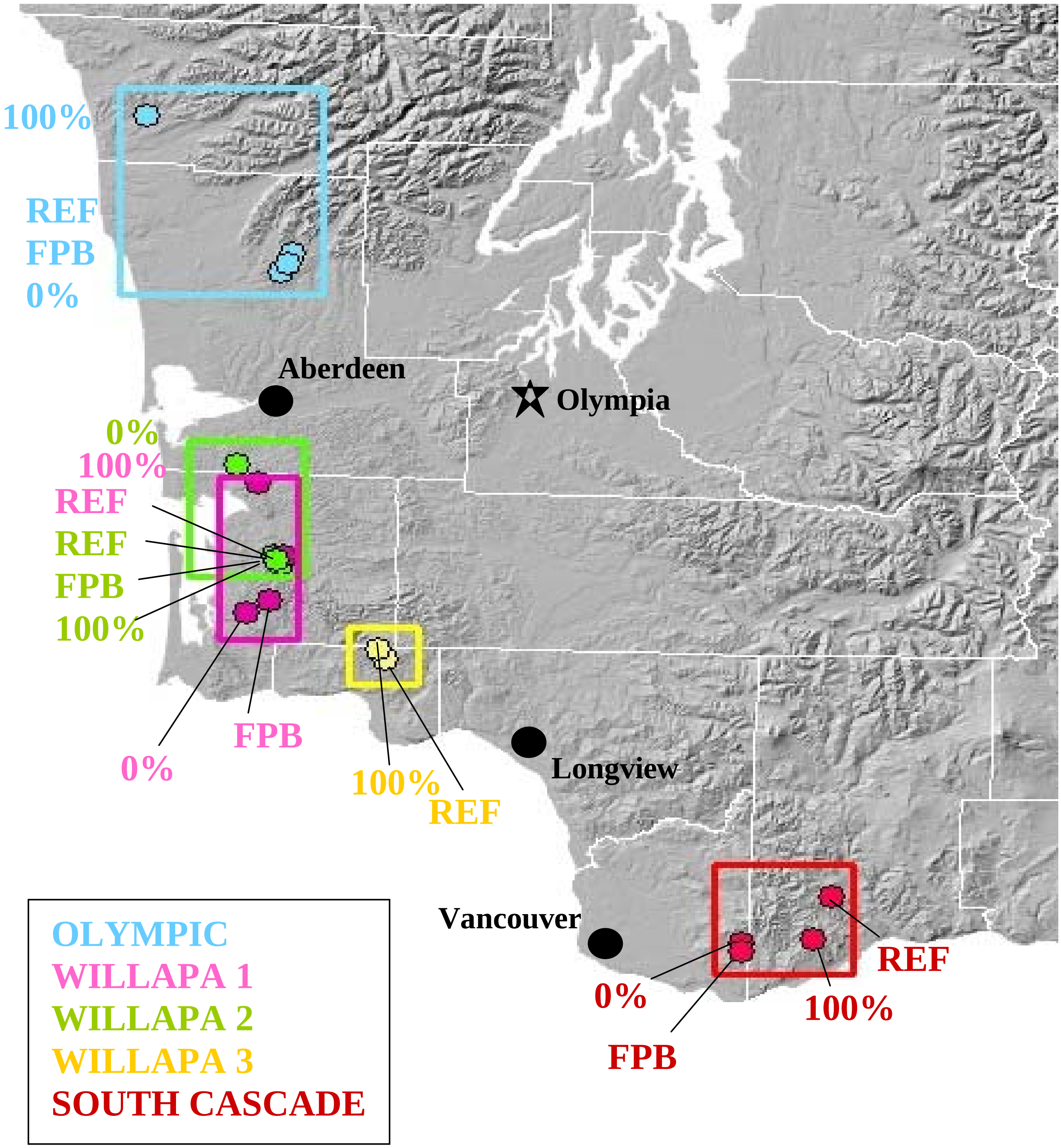


Figure 4. Four basins selected for the Olympic Block. 0% = no buffer, FPB = Forest Practices Buffer, 100% = all buffered, and REF = unharvested reference.

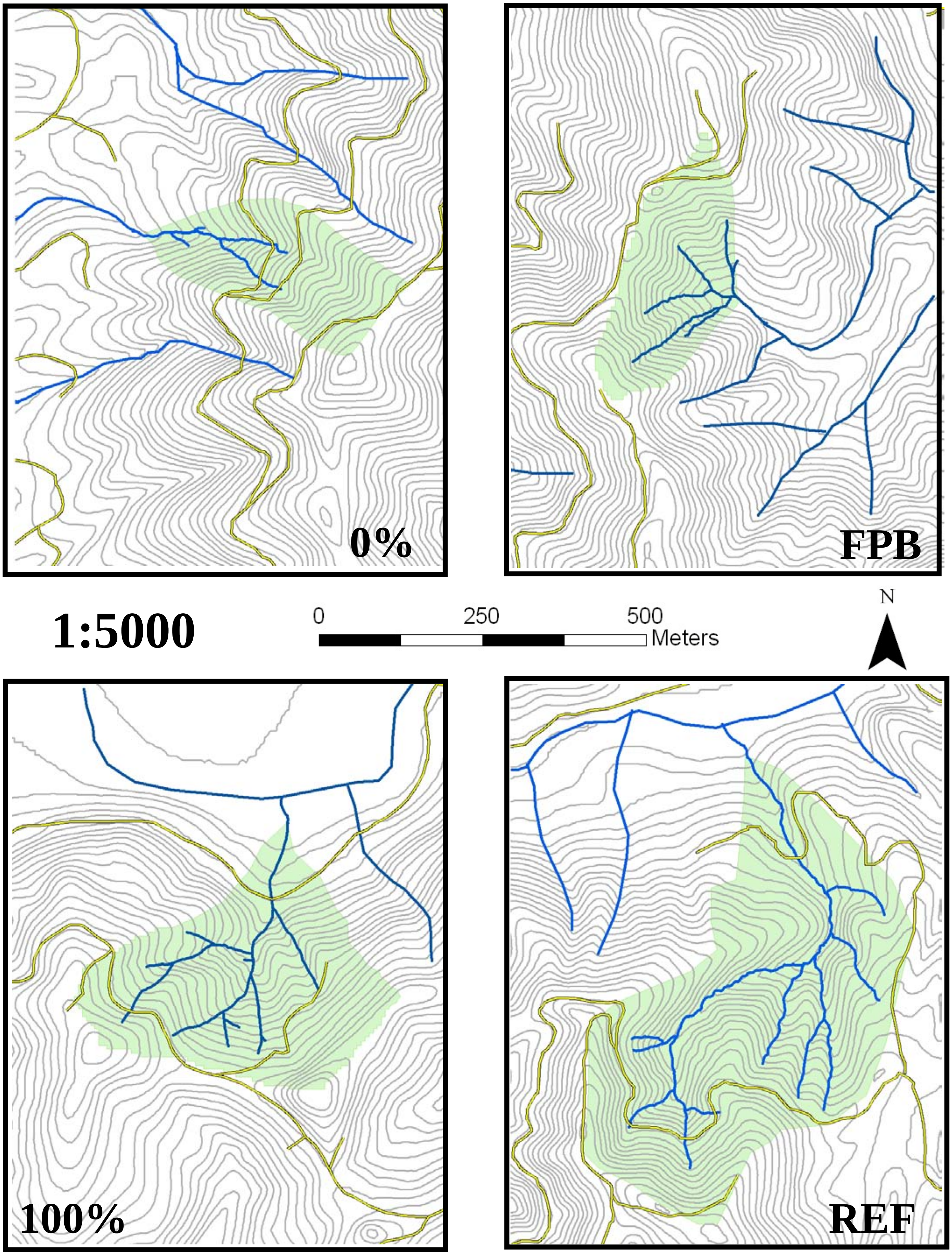


Figure 5. Four basins selected for the Willapa 1 Block. 0% = no buffer, FPB = Forest Practices Buffer, 100% = all buffered, and REF = unharvested reference.

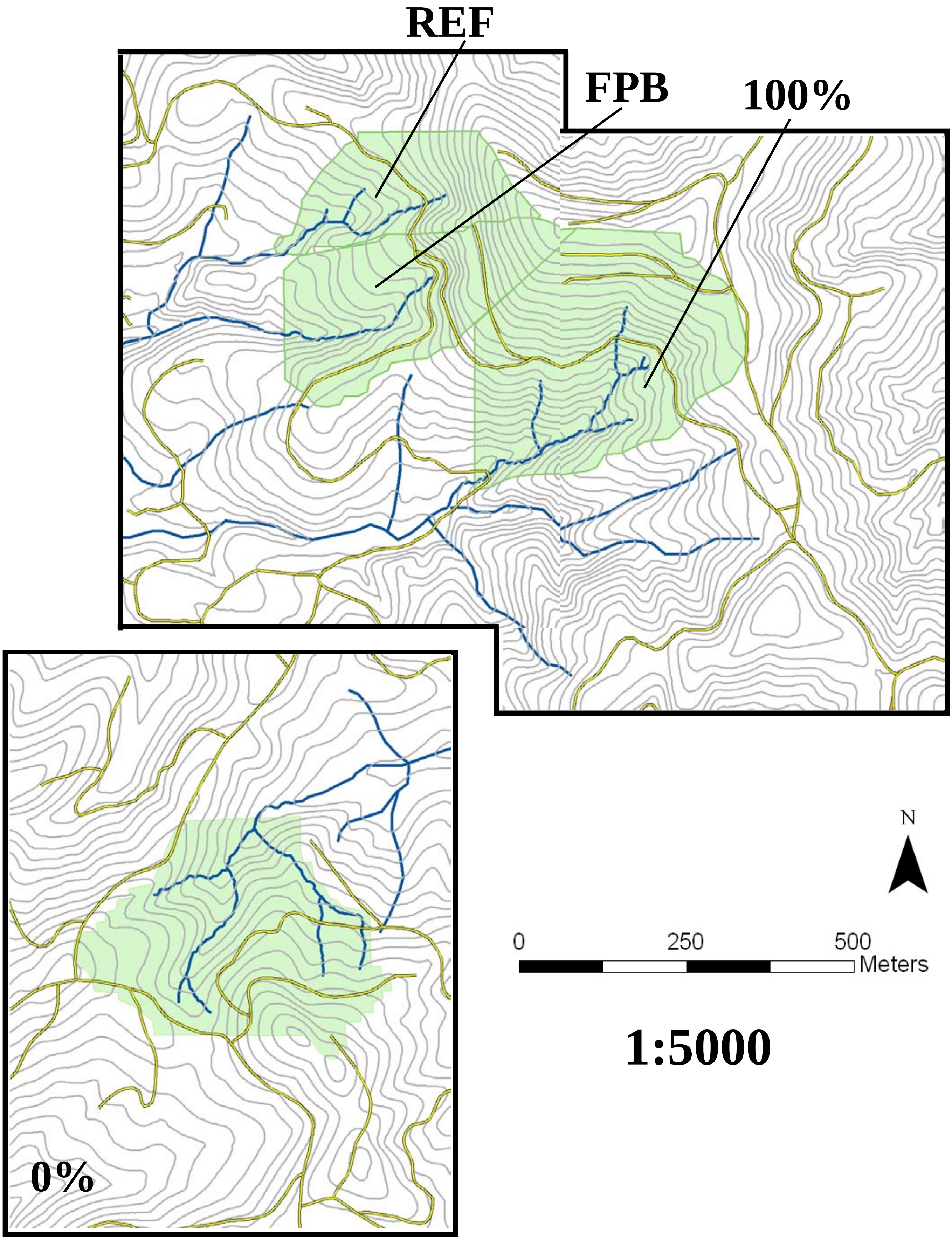


Figure 6. Four basins selected for the Willapa 2 Block. 0% = no buffer, FPB = Forest Practices Buffer, 100% = all buffered, and REF = unharvested reference.

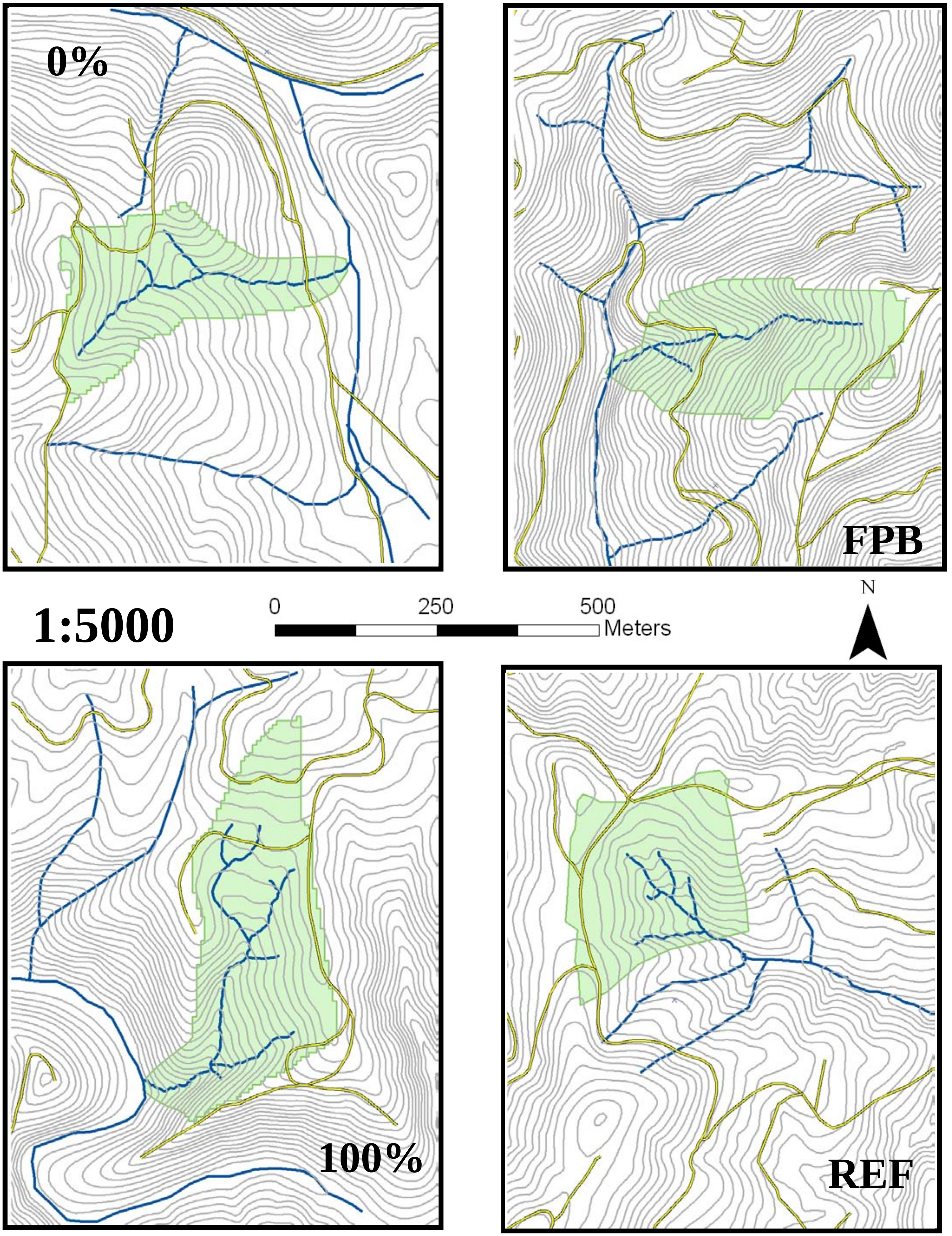


Figure 7. Two basins selected for the Willapa 3 Block. 100% = all buffered, and REF = unharvested reference.

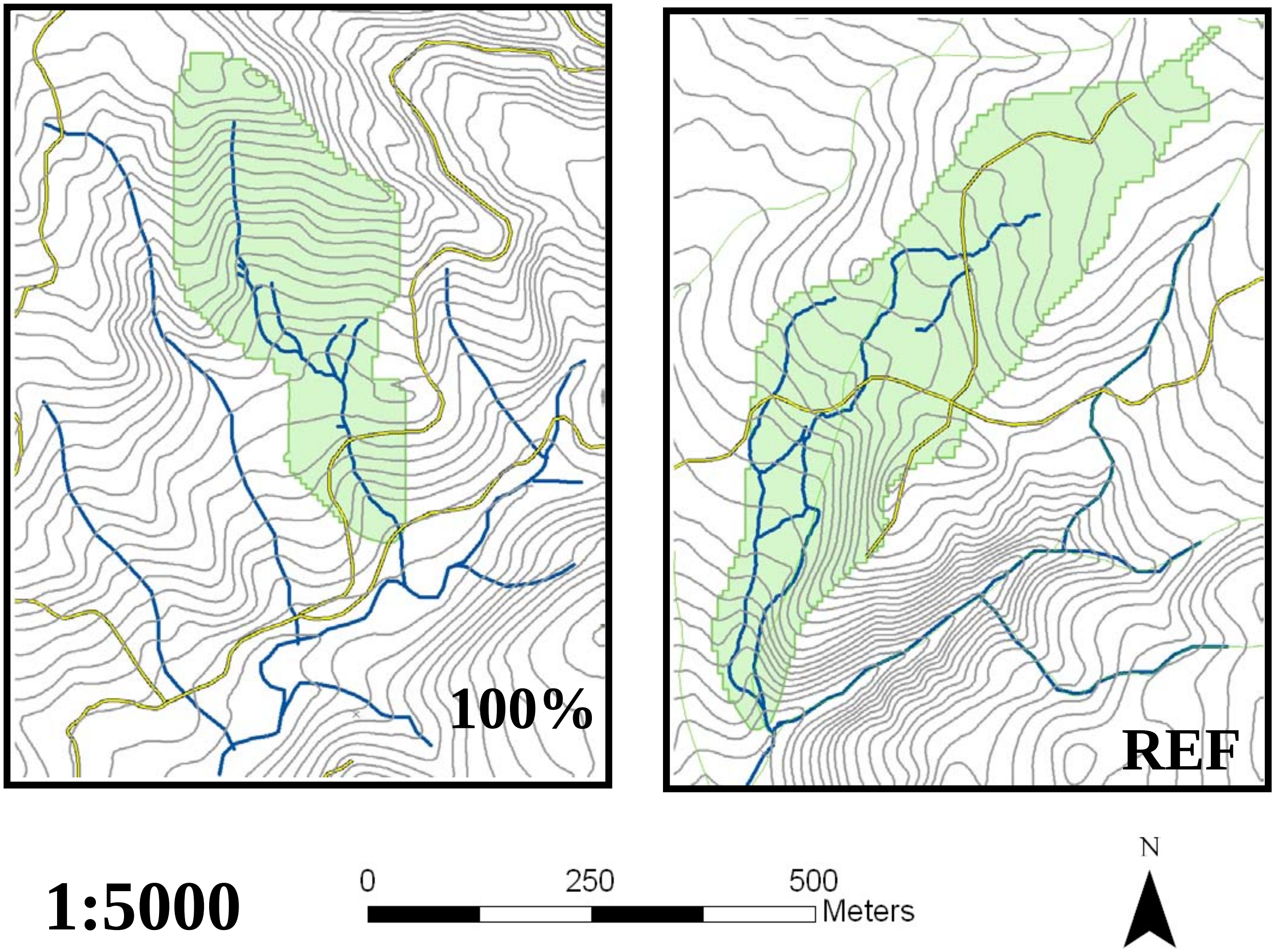


Figure 8. Four basins selected for the South Cascade Block. 0% = no buffer, FPB = Forest Practices Buffer, 100% = all buffered, and REF = unharvested reference.

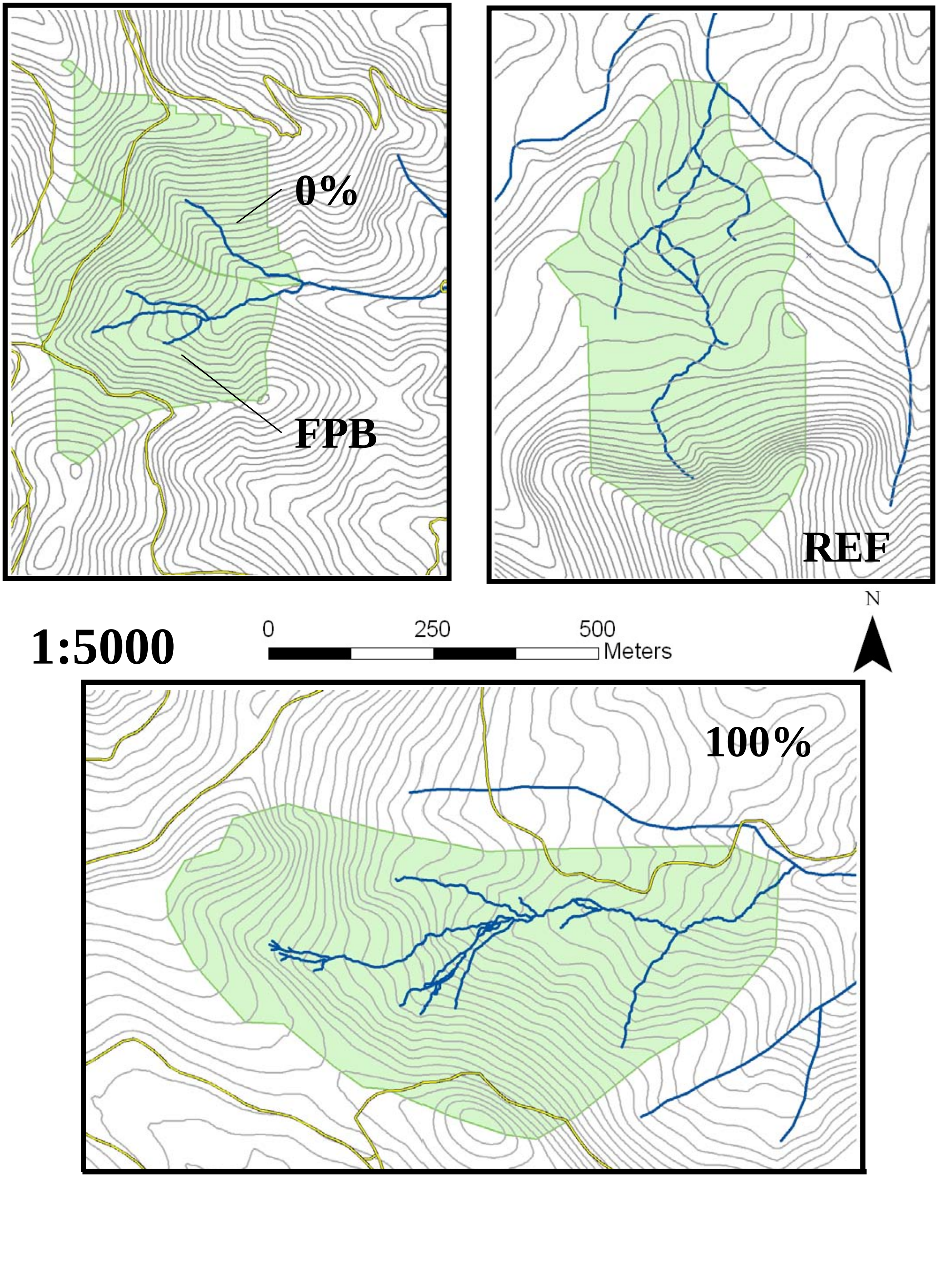


Figure 9. Olympic Block 0% buffer treatment basin, located on Rayonier ownership.

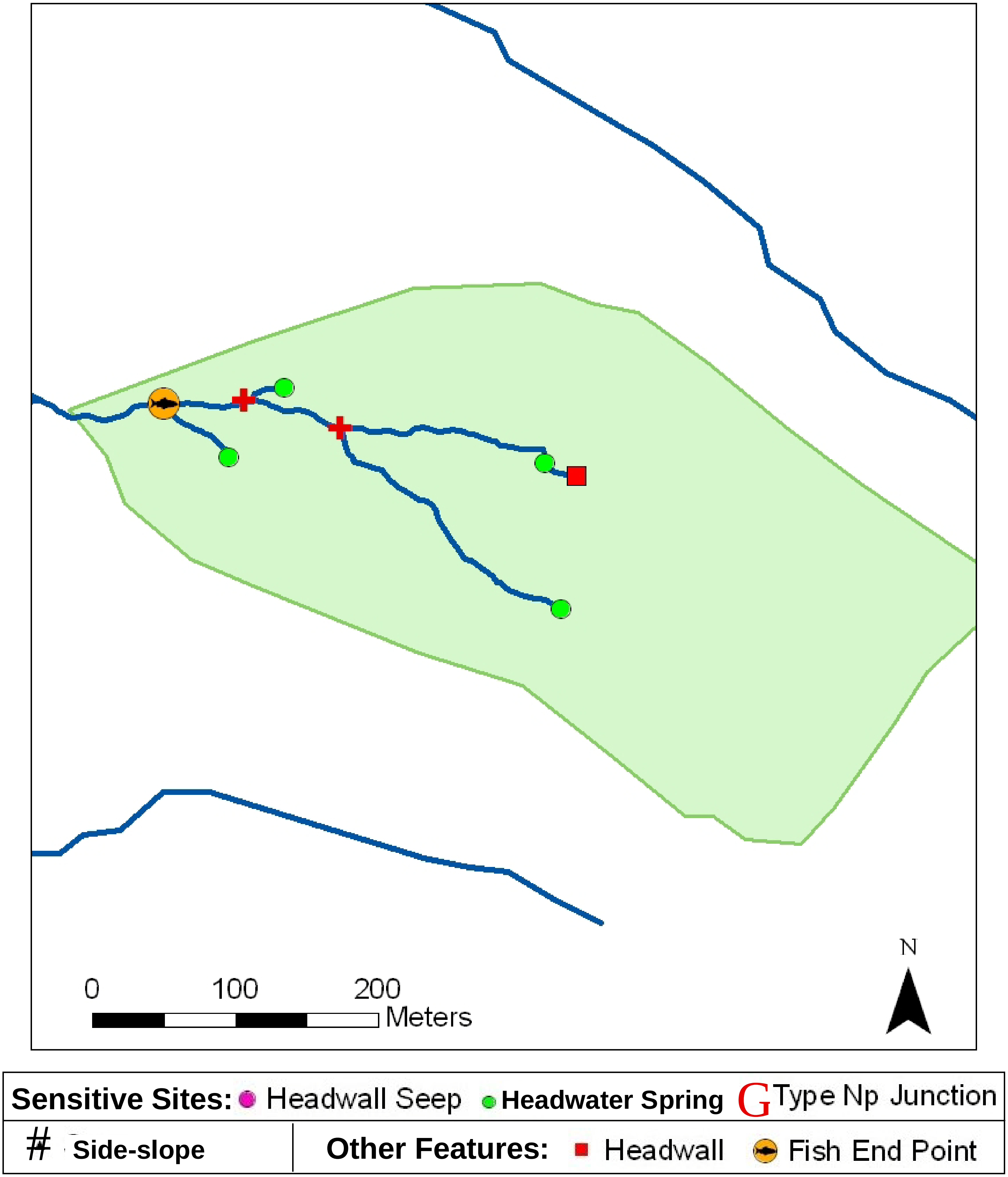


Figure 10. Olympic Block Forest Practices buffer treatment basin, located on Rayonier ownership.

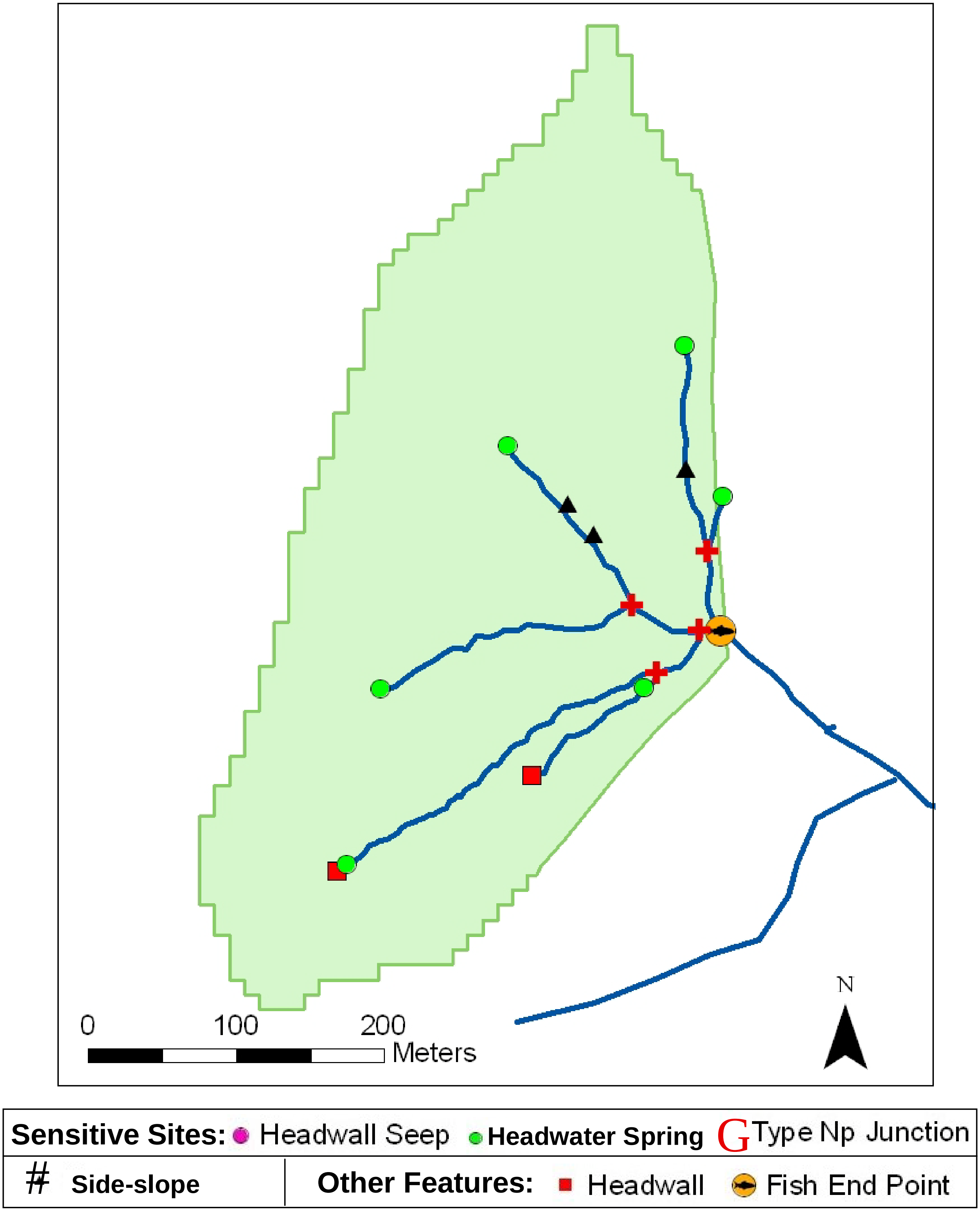


Figure 11. Olympic Block 100% buffer treatment basin, located on WADNR ownership.

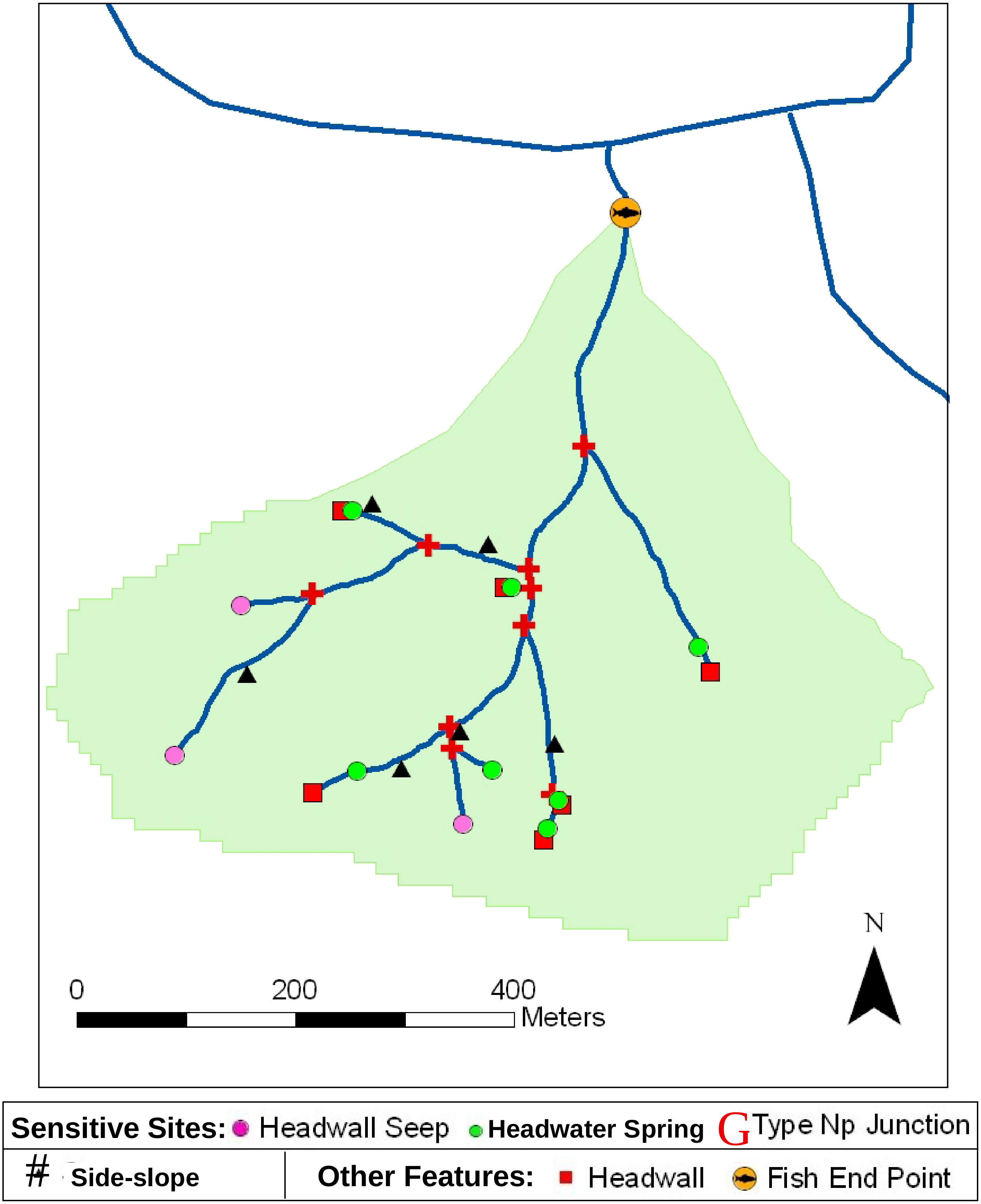


Figure 12. Olympic Block reference basin, located on Olympic National Forest ownership.

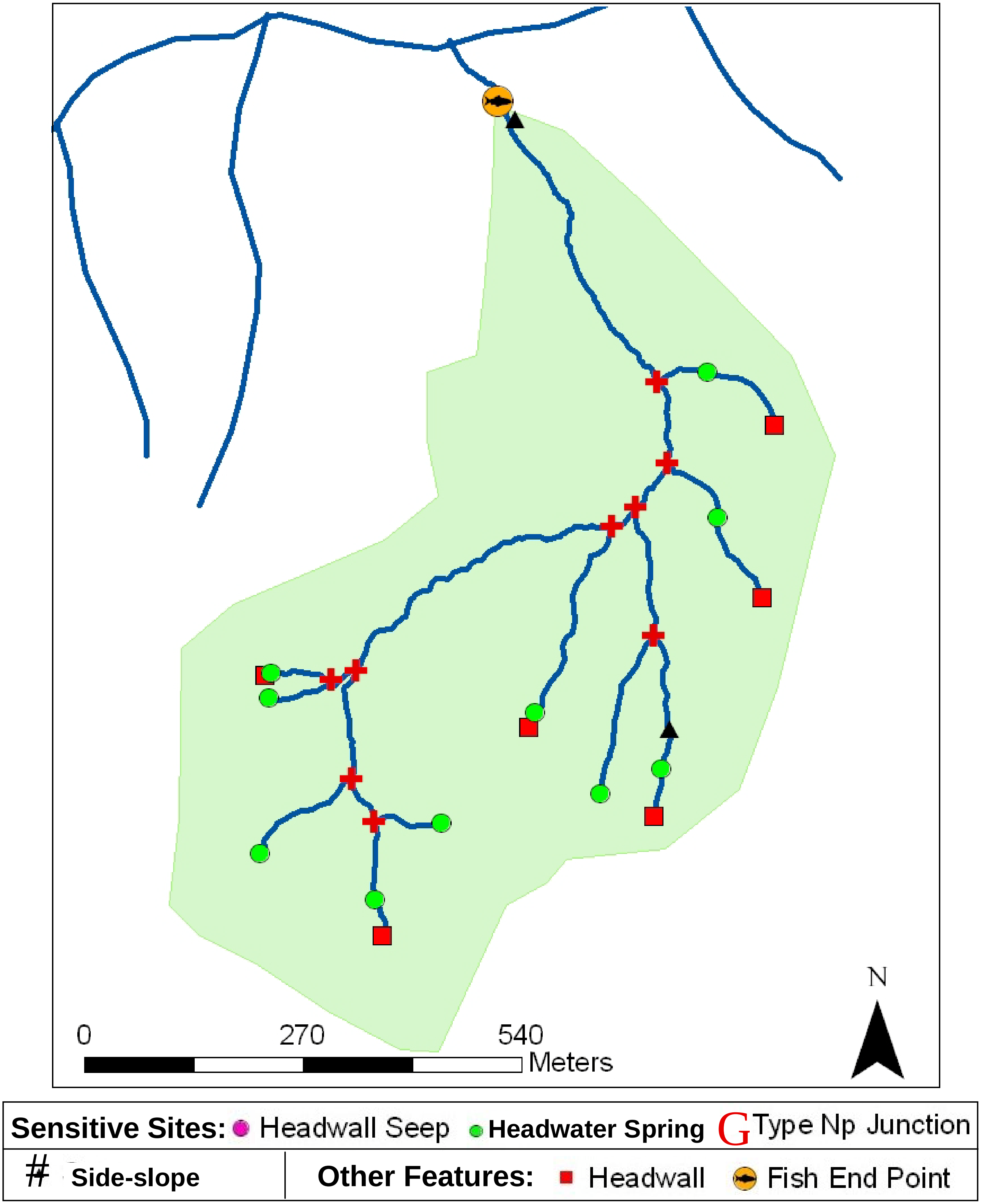


Figure 13. Willapa 1 Block 0% buffer treatment basin, located on Weyerhaeuser ownership.

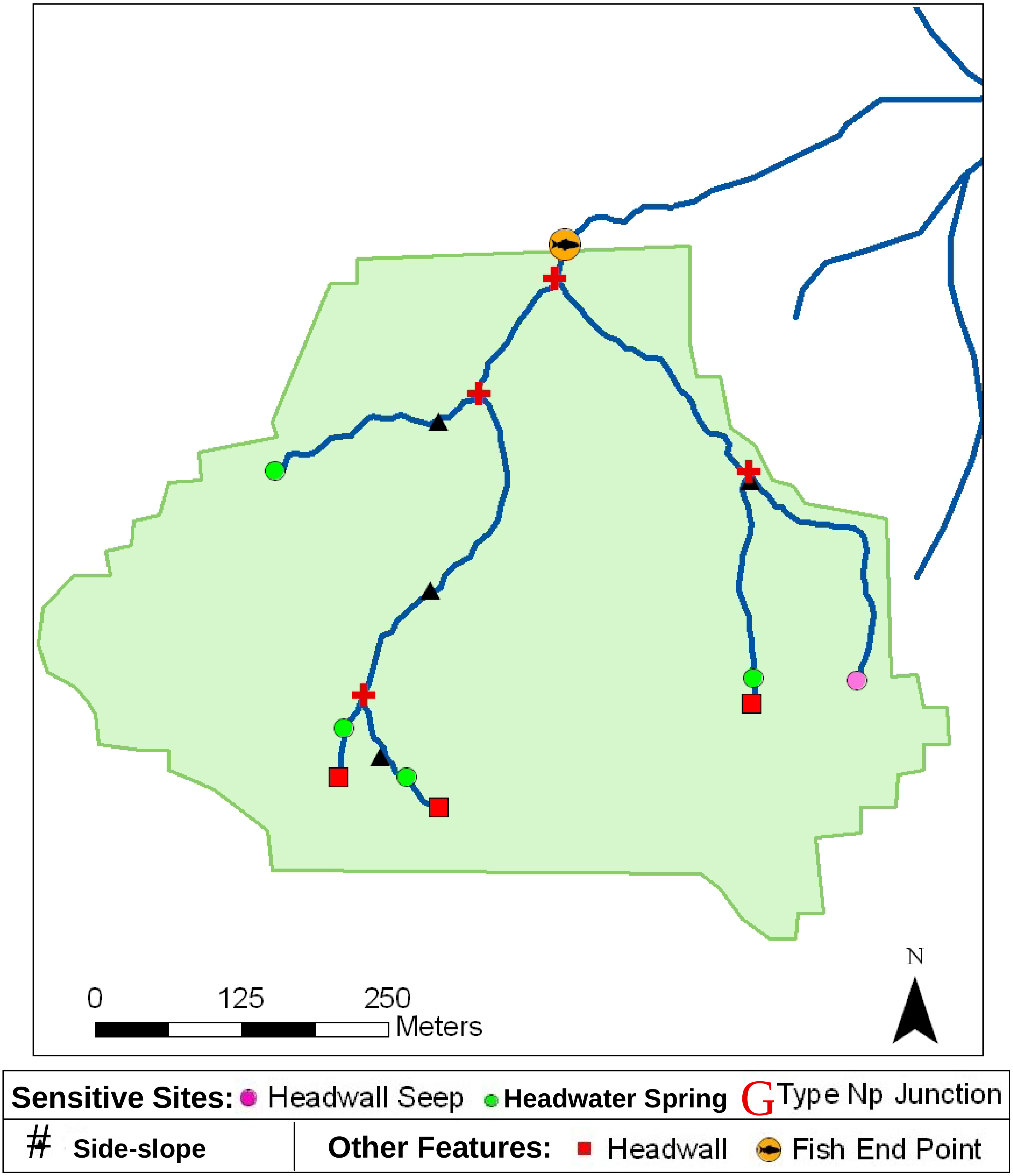


Figure 14. Willapa 1 Block reference (REF) and Forest Practices buffer treatment (FPB) basins, located on WADNR ownership.

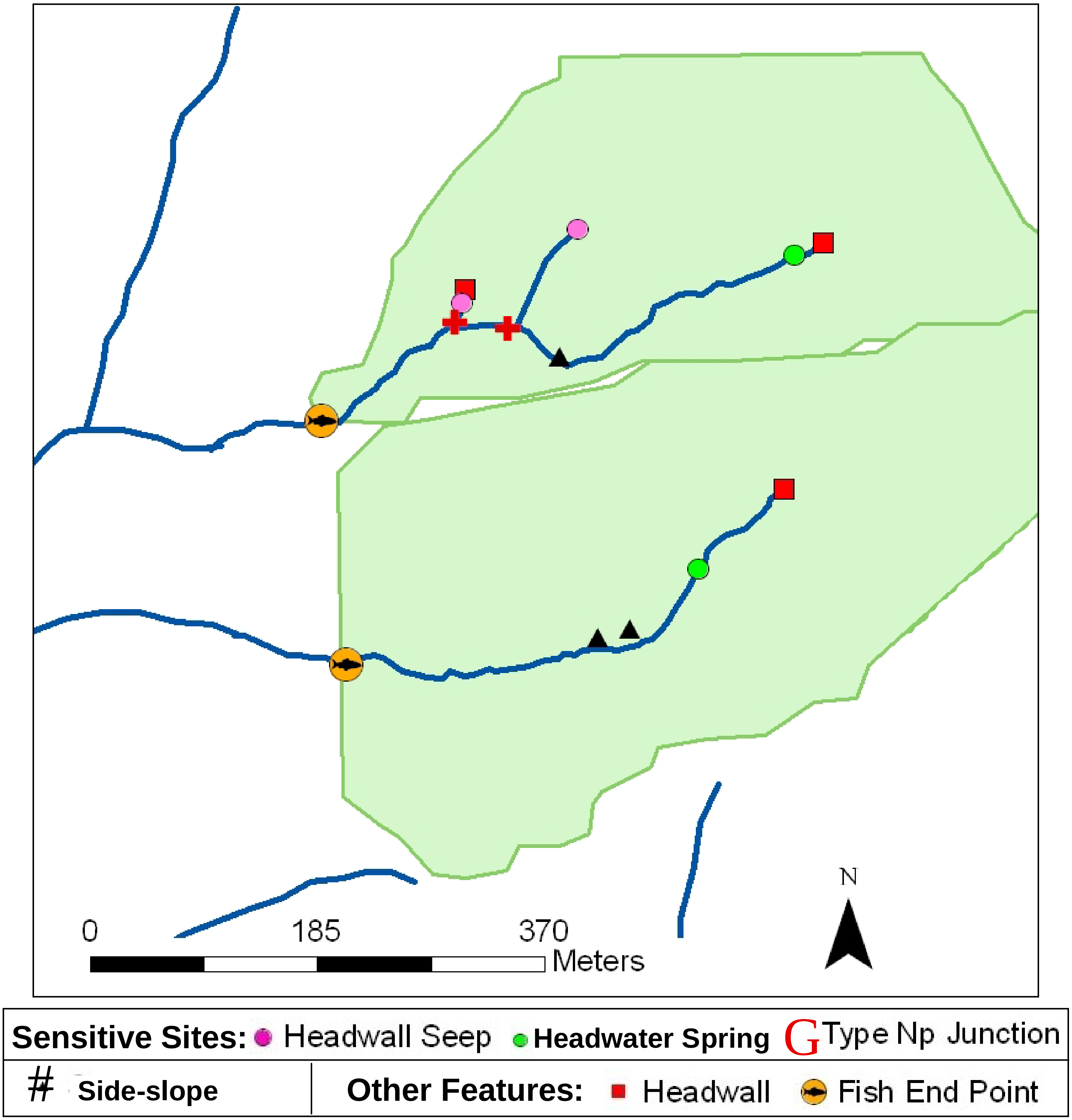


Figure 15. Willapa 1 Block 100% buffer treatment basin, located on WADNR ownership.

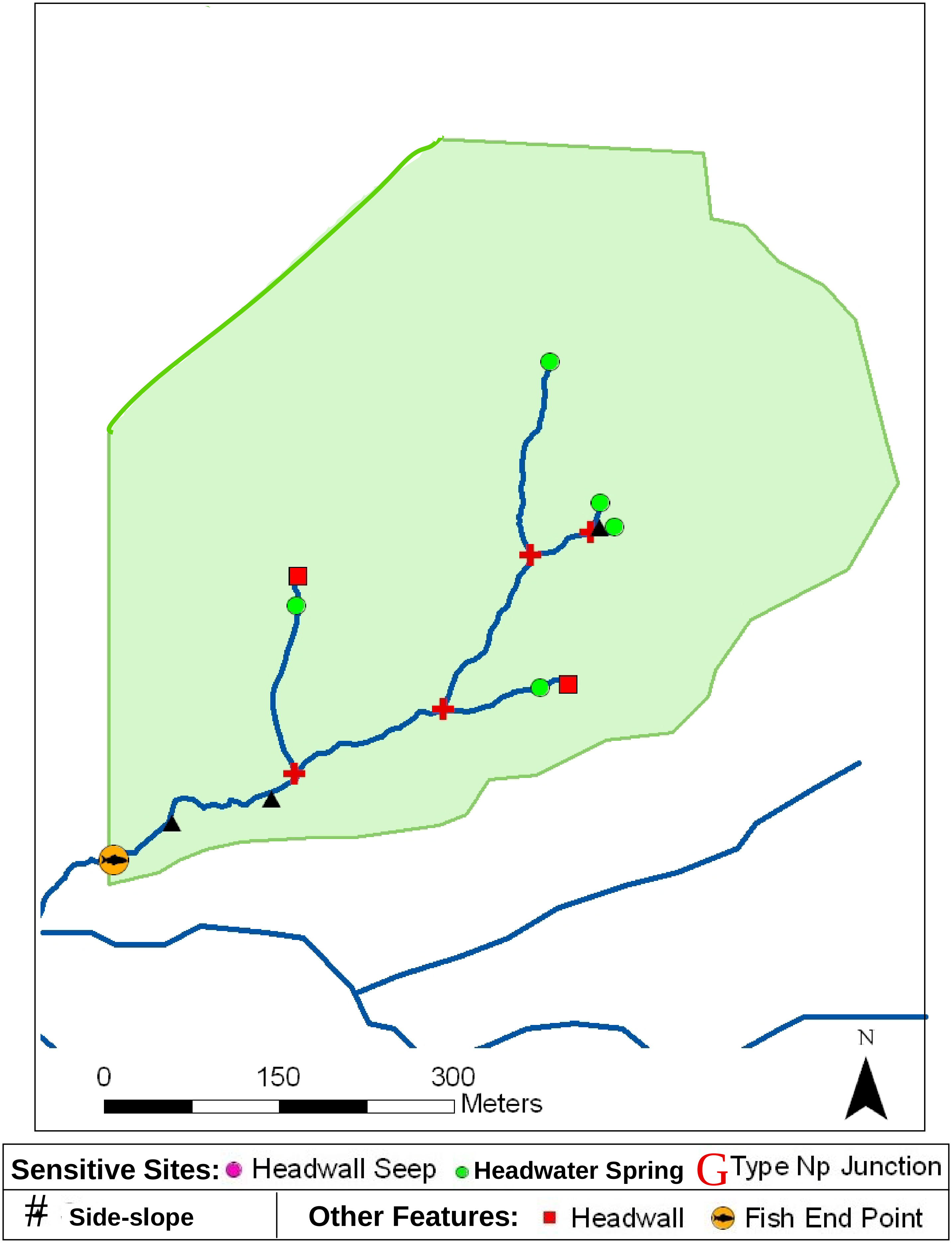


Figure 16. Willapa 2 Block 0% buffer treatment basin, located on WADNR ownership.

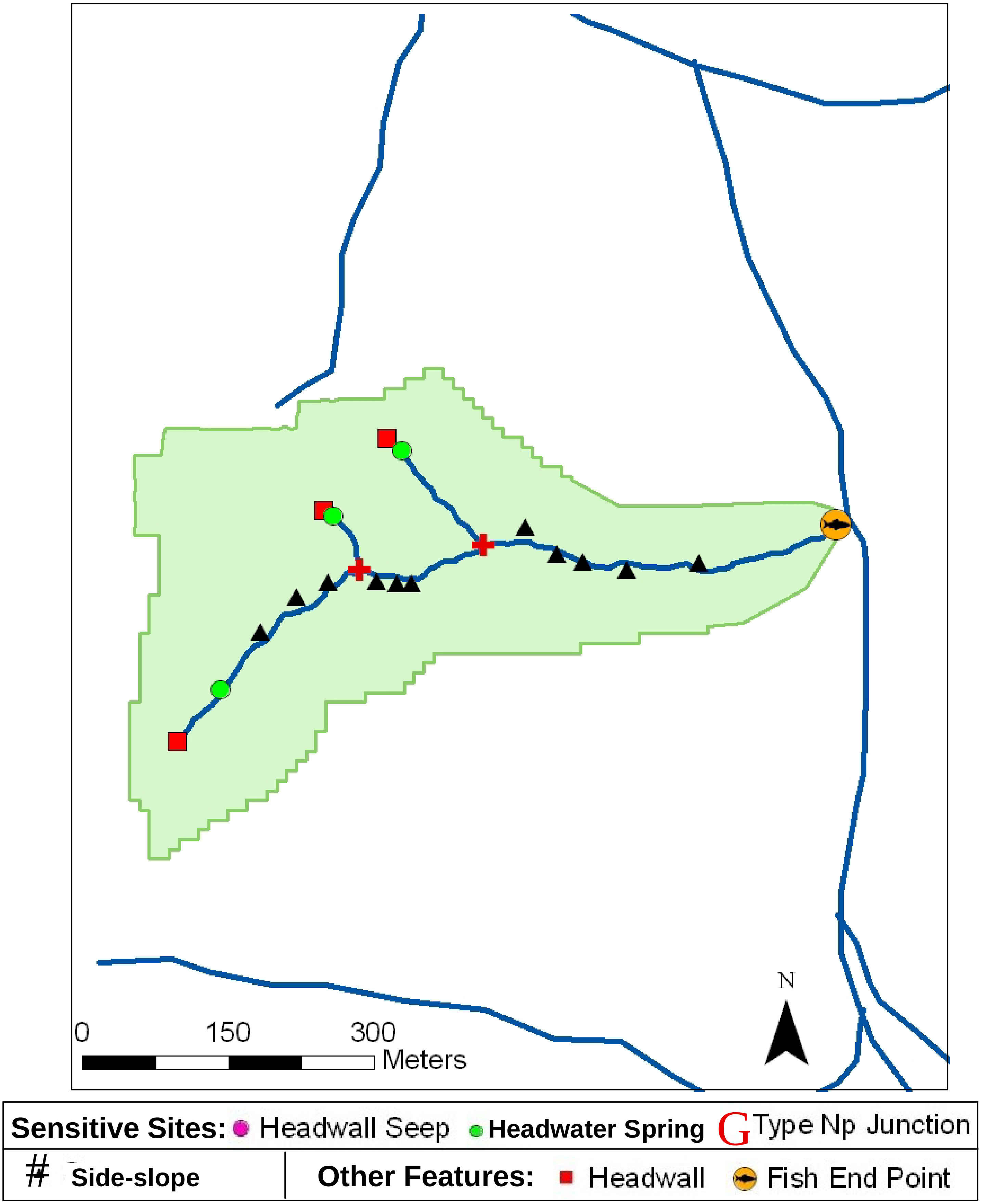


Figure 17. Willapa 2 Block Forest Practices buffer treatment basin, located on Weyerhaeuser ownership.

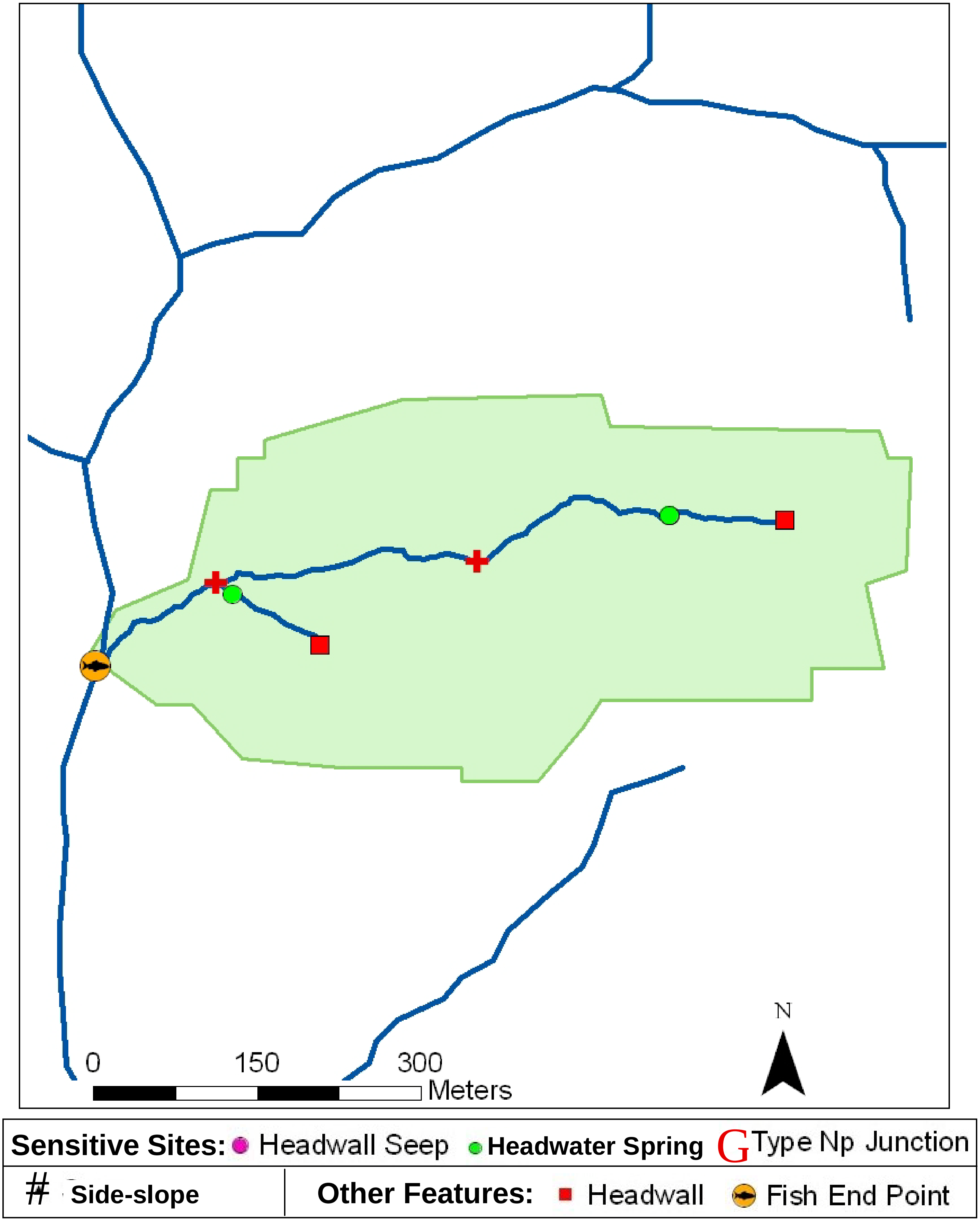
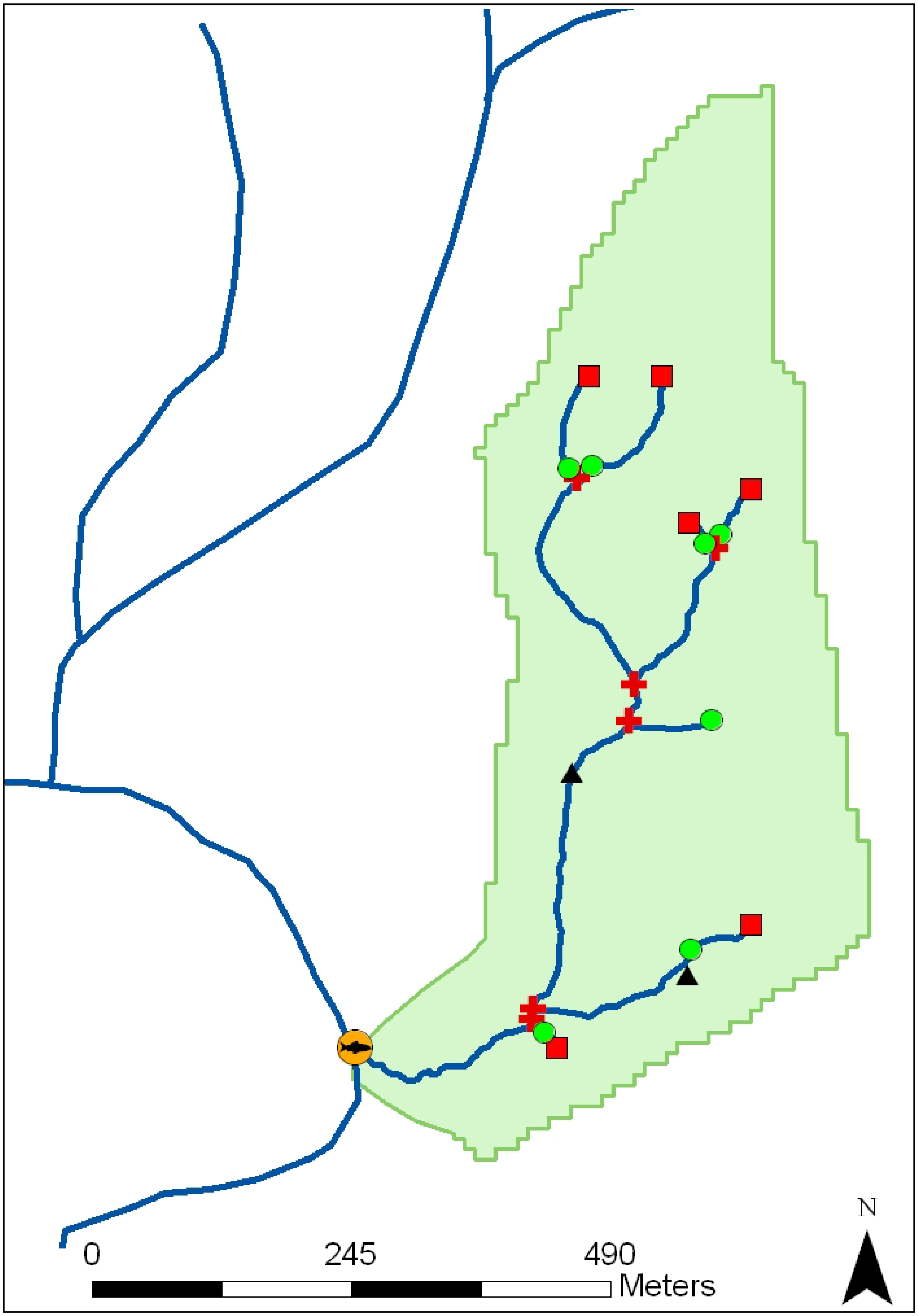


Figure 18. Willapa 2 Block 100% buffer treatment basin, located on Weyerhaeuser ownership.



Sensitive Sites: Headwall Seep	Headwater Spring	G Type Np Junction
# Side-slope	Other Features: Headwall	Fish End Point

Figure 19. Willapa 2 Block reference basin, located on WADNR ownership.

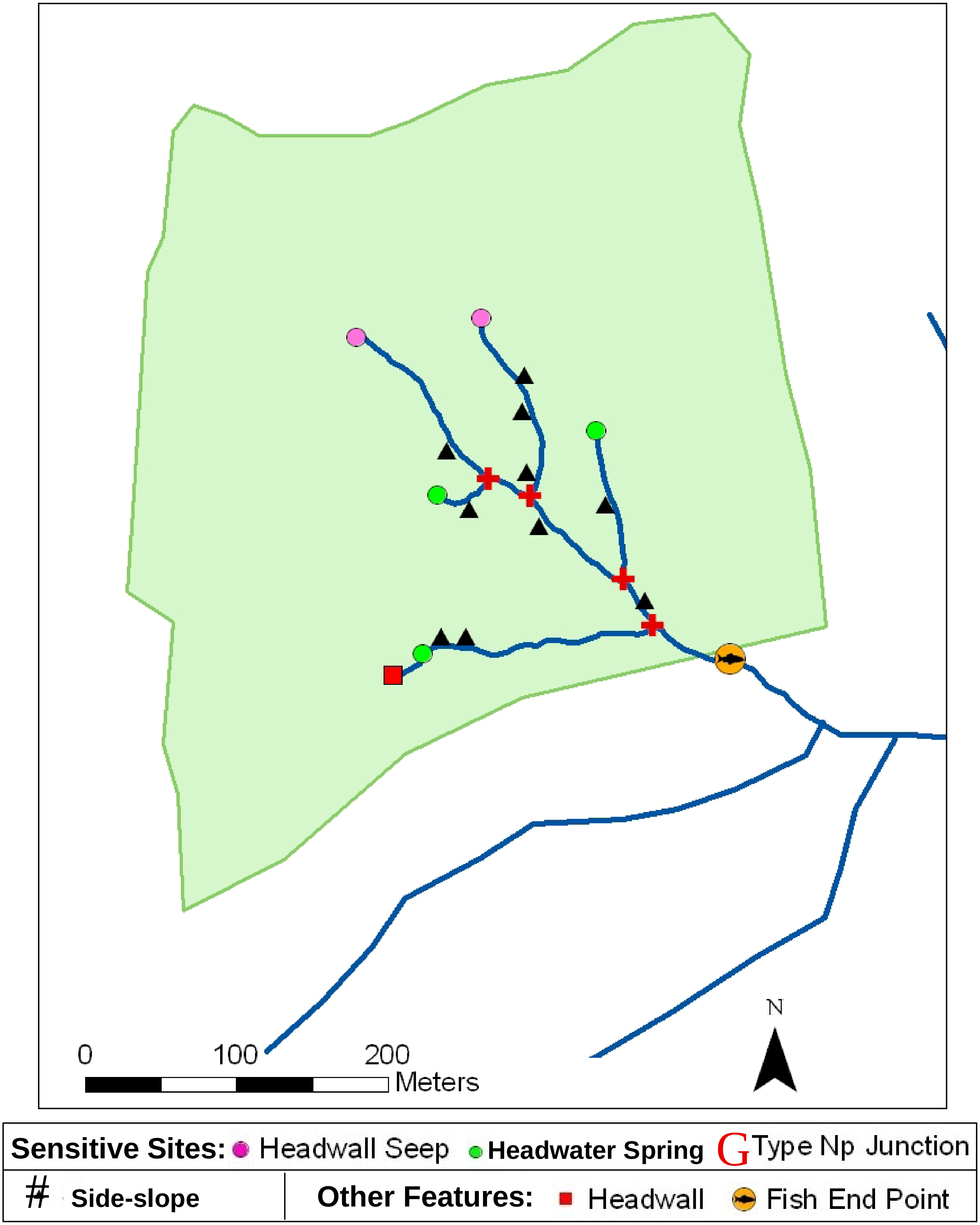


Figure 20. Willapa 3 Block 100% buffer treatment basin, located on WADNR ownership.

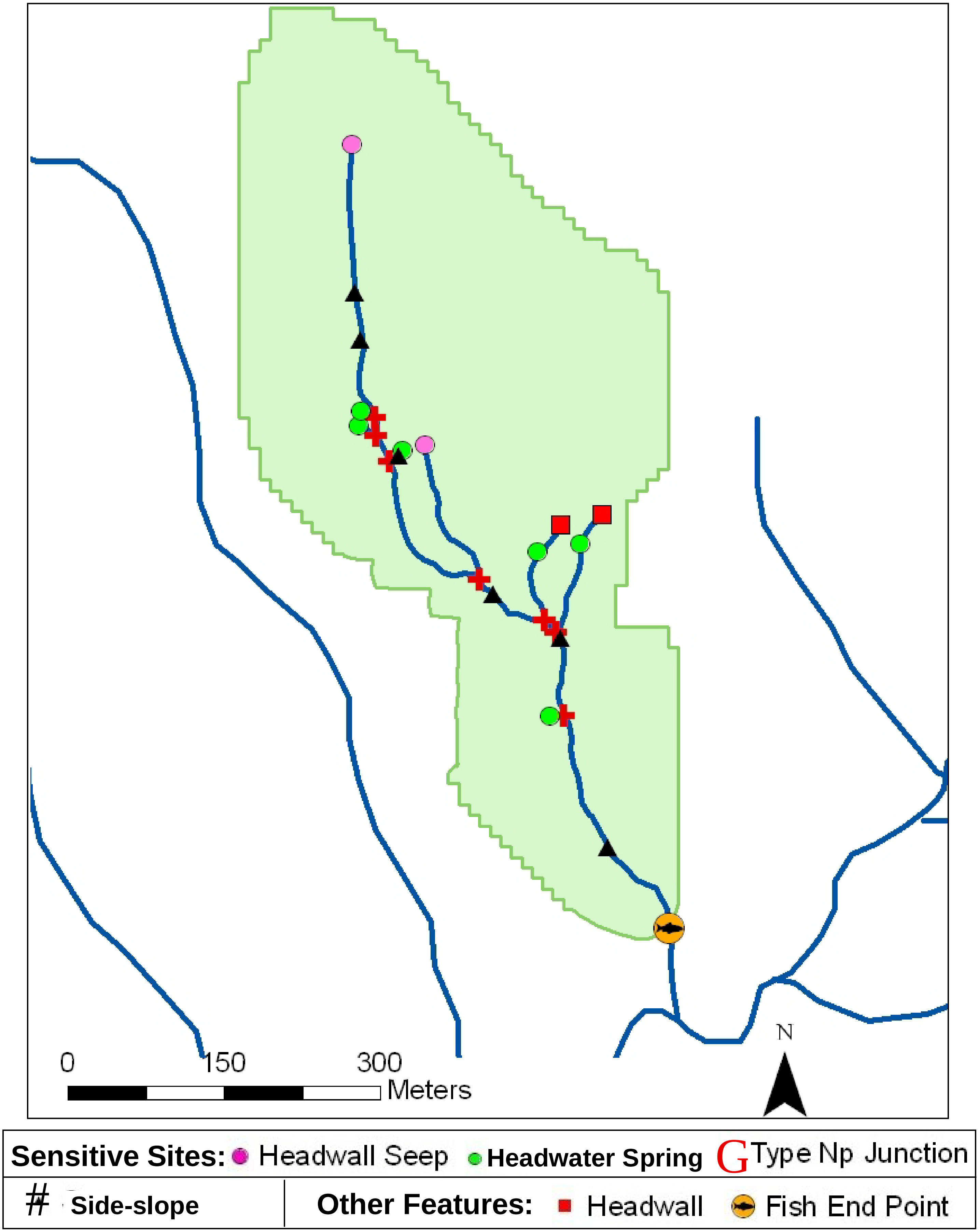


Figure 21. Willapa 3 Block reference basin, located on WADNR ownership.

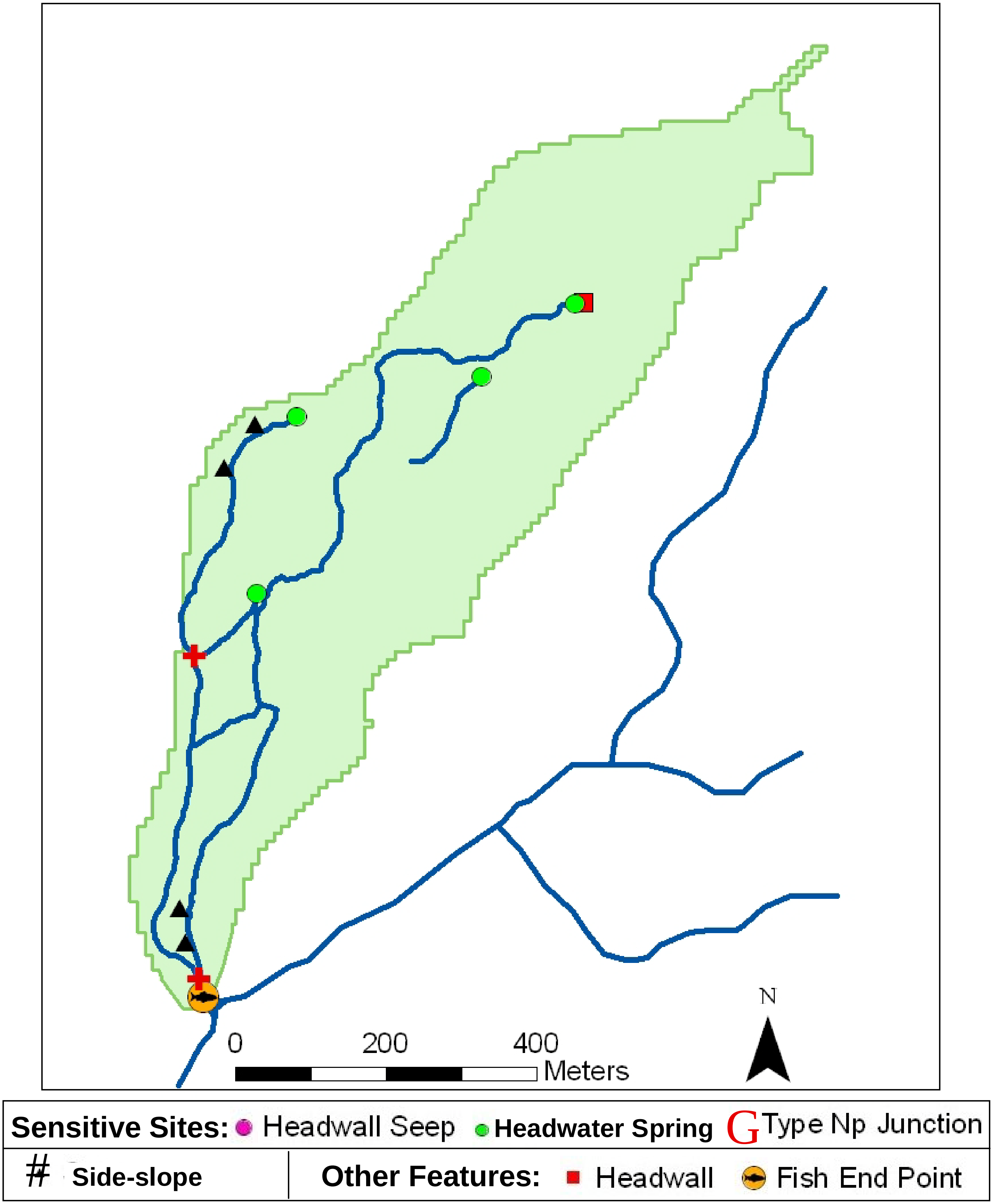
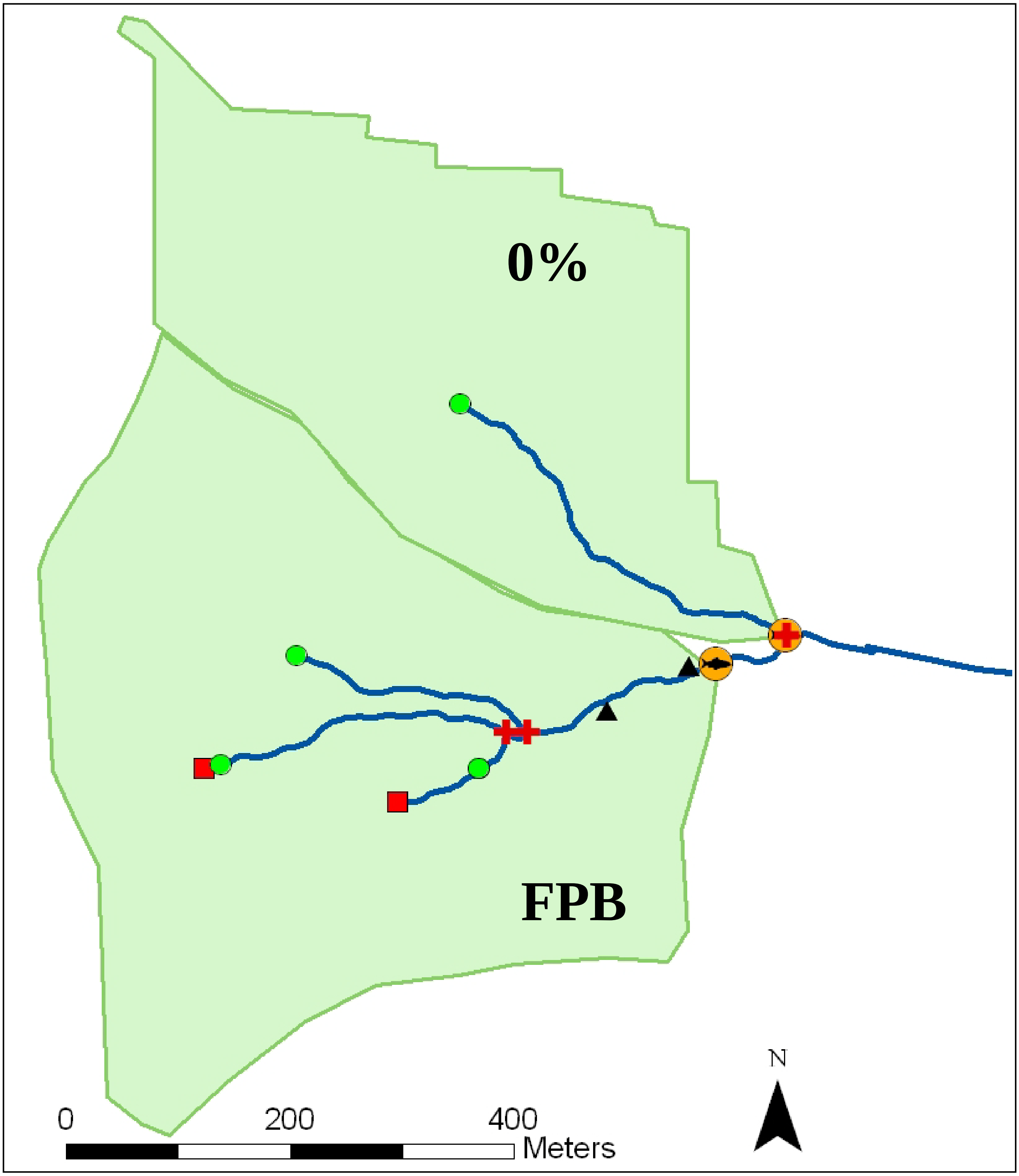


Figure 22. South Cascade Block 0% buffer (0%) and Forest Practices buffer (FPB) treatment basins, located on WADNR ownership.



Sensitive Sites: Headwall Seep **Headwater Spring** G Type Np Junction

Side-slope **Other Features: Headwall Fish End Point

Figure 23. South Cascade Block 100% buffer treatment basin, located on Longview Timber ownership.

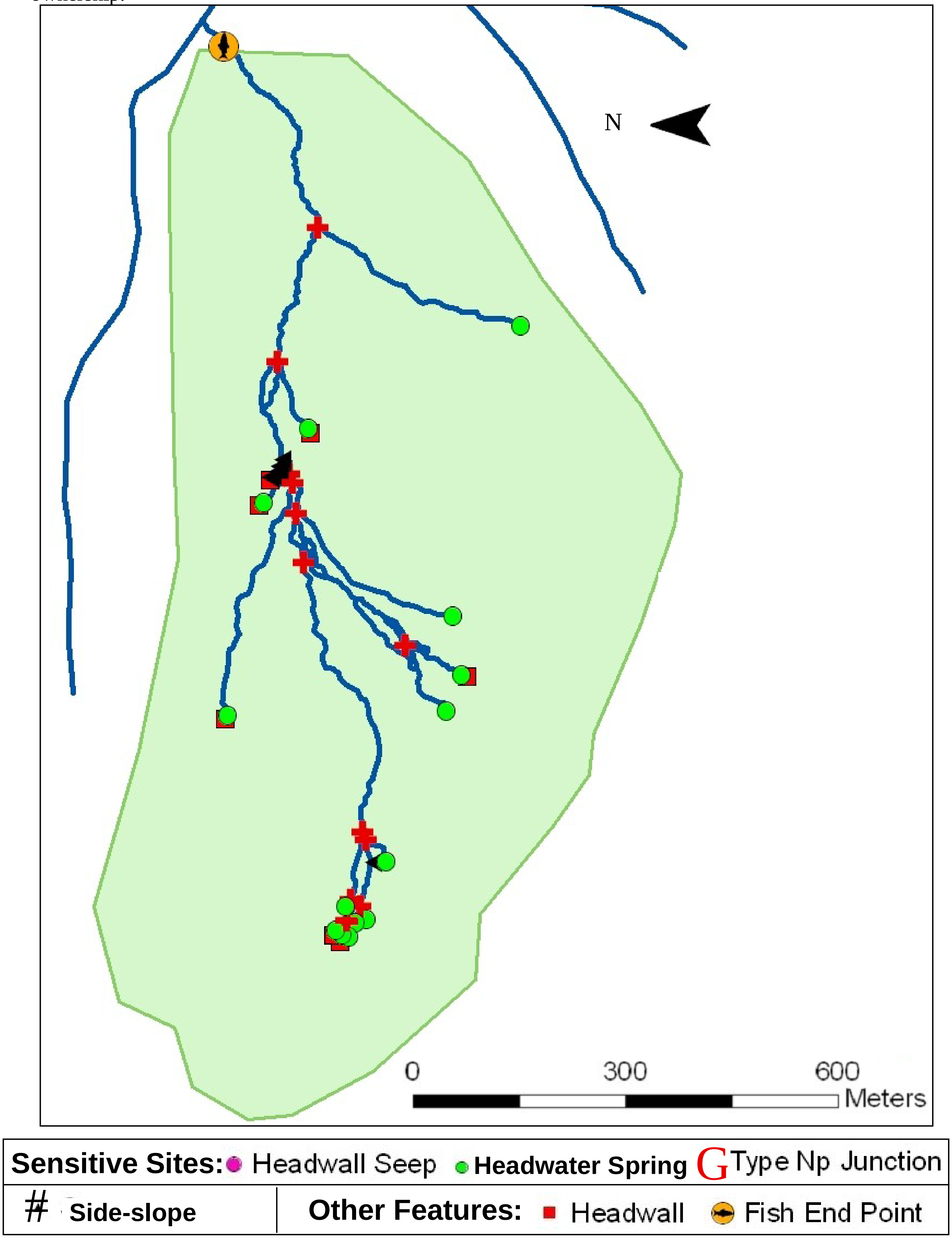


Figure 24. South Cascade Block reference basin, located on Gifford Pinchot National Forest ownership.