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Natural Resource Stewardship and Science

Invasive plants in the Queets Valley, Olympic National Park

Former homesteads and surrounding watershed

Natural Resource Technical Report NPS/OLYM/NRTR—2014/898

ON THE COVER
Queets River valley, 1975.
Photograph by: Sally Williams

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Abstract

The Queets Valley contains a wealth and variety of natural and cultural resources for which Olympic National Park is responsible. Starting in 1890, long before establishment of the Park, settlers established scores of homesteads in the valley. The homesteads had all been incorporated into the Park by 1953. Invasive, exotic plants have become established in the clearings associated with the former homesteads, especially since they were vacated. New species have arrived since the end of the homestead era; several species have the potential to continue to spread within the park. The most widespread and abundant of the invasive, exotic plant species are Rubus laciniatus (evergreen blackberry), Cirsium arvense (Canada thistle), and Senecio jacobaea (tansy ragwort).

The clearings are continuing to decrease in size, due to both growth of forest and movement of the channel of the Queets River. However, several of the clearings are still large (two larger than 10 acres) and are likely to persist, and serve as sources of invasive, exotic plants, for many decades. Several native plant species are colonizing the clearings and may show promise for future restoration efforts (especially Carex obnupta (slough sedge), Alnus rubra (red alder), and Picea sitchensis (Sitka spruce)). The invasive, exotic plant species are found in the watershed upstream of the homesteads. A more thorough search for these species in areas other than the homestead clearings is a necessary precursor to effective control.

Introduction

The Queets Valley contains a wealth and variety of natural and cultural resources for which Olympic National Park is responsible. The Queets is one of the most pristine river valleys in the lower 48 states (Balian and Naiman 2005). It is the most complete watershed contained within the park, in that the continuous portion within the park extends closer to salt water than any other river. Development within the watershed has been quite limited (Montgomery and Abbe 2006). The area within the park is predominantly designated wilderness. It is home to temperate rainforest, elk, anadromous salmonids, and archaeological and historic sites including former homesteads dating from the 19th century (Evans 1983).

One aspect of the Park's stewardship of the Queets Valley is the obligation to prevent alteration of the environment by invasive, exotic plants. Management Policies for the National Park Service (NPS 2006) direct that "exotic plant species will not be allowed to displace native species if displacement can be prevented" and that "in general, new exotic species will not be introduced into parks." Further, the policies direct that "exotic plant … species that are not maintained to meet an identified park purpose will be managed—up to and including eradication—if (1) control is prudent and feasible, and (2) the exotic species:

- Interferes with natural processes and the perpetuation of natural features, native species, or natural habitats; or
- Disrupts the genetic integrity of native species; or
- Disrupts the accurate presentation of a cultural landscape; or
- Damages cultural resources; or
- Significantly hampers the management of park or adjacent lands; or
- Poses a public health hazard…; or
- Creates a hazard to public safety."

The Park's General Management Plan (2010) establishes the goal that "ecosystems are free of nonnative species where feasible, with the exception of noninvasive species that are documented as innocuous, and are a contributing element of a cultural landscape." The strategies to achieve this goal include carrying out inventories and monitoring, including tracking the distribution of invasive exotic species; determining the ecological effects of exotic species to assess threats and inform management actions; managing exclusively for native plant species in wilderness; and controlling or eliminating exotic plants where there is a high probability of long-term success.

Euroamerican settlement of the Queets Valley commenced in 1890, decades before establishment of the Park (Evans 1983). At the height of settlement, there were dozens of homesteads along many miles of the river (Williams 1975, Evans 1983) (Figure 1). The homesteaders cleared land for subsistence farming and for livestock pasture (Williams 1975). The area was acquired for the Park in 1940; active homesteads were condemned with the last properties vacated in 1953 (Evans 1983).

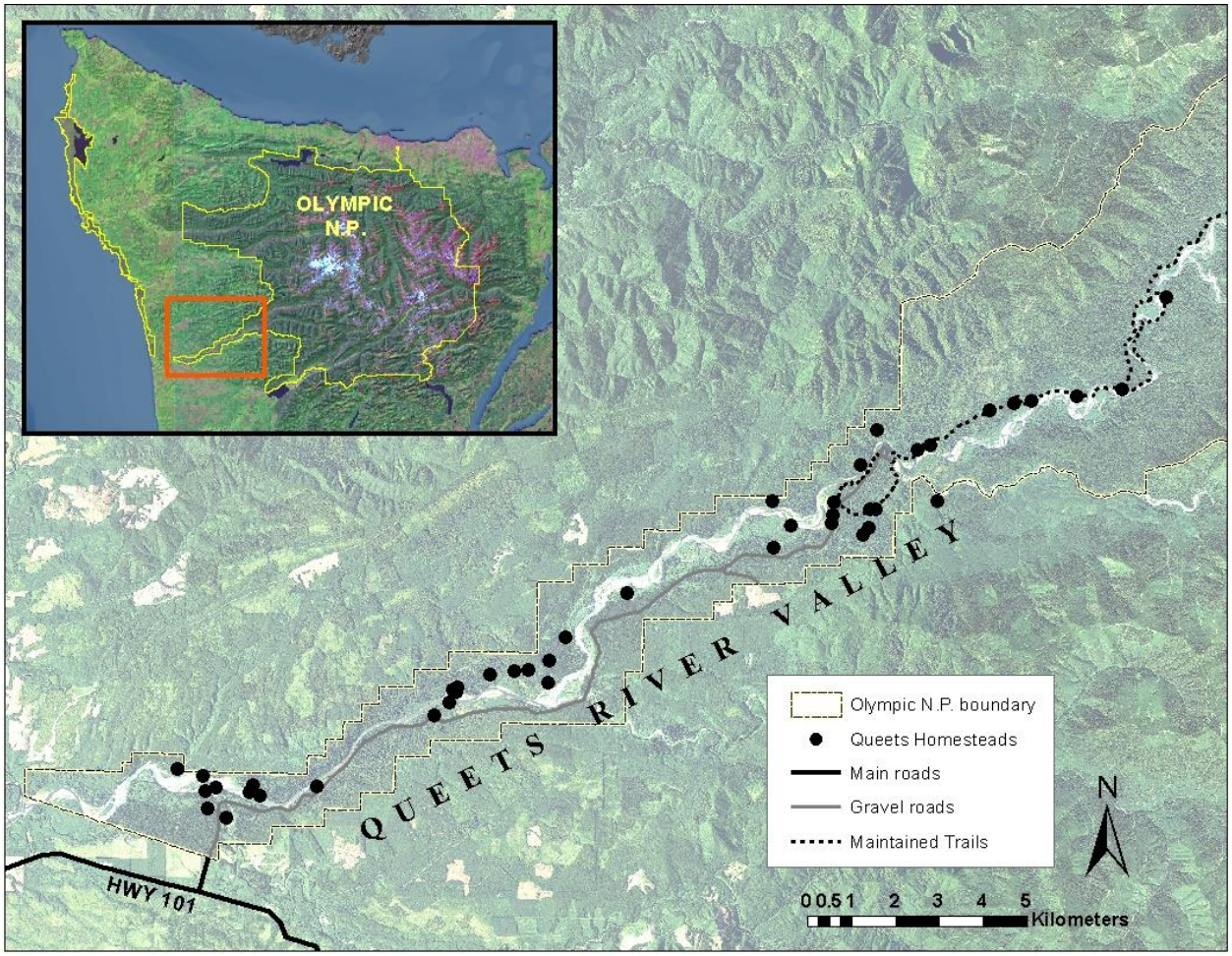

Figure 1. Locations of former homesteads in the Queets valley, Olympic National Park.

Several reports since the 1970s have noted that the areas cleared for many of the homesteads have persisted for decades, which is a surprising situation in the context of a temperate rainforest, and that invasive, exotic plants are present at some of the former homesteads (Williams 1975, del Moral 1985, Riege 2000, Riege and del Moral 2004). The earliest of the reports was also the only comprehensive inventory of the former homesteads, although observation of plant species composition was limited to six of over 40 clearings observed on aerial photographs (Williams 1975). To date, there has been no comprehensive planning for management of vegetation at the former homestead locations. Some control of invasive, exotic plants has been carried out at several of the former homestead locations (see below).

The purpose of this report is to document the current status of invasive, exotic plants at the former homesteads locations, and more generally within the portion of the Queets watershed managed by the Park, within the constraints of available data. We address four questions:

1) To what extent do the former homestead locations identified in the 1970s persist in a non-forested condition?

2) How have the persistent openings changed in size?

3) What is the abundance within the persistent openings of a) invasive, exotic plant species likely to be subject to control, and b) native plant species with the potential to dominate vegetation patches and hence inhibit spread of exotic plants?

4) What is the distribution and abundance of invasive, exotic plant species likely to be subject to control along the Queets River trail corridor and elsewhere in the watershed where Park staff have opportunistically collected data?

The intention of this report is to characterize the current situation to facilitate future planning for vegetation management, rather than to suggest in detail what form that management should take. Specific management goals for the former homestead areas (e.g., whether or not to restore native forest), have yet to be determined.

Plant species in this report are mostly referred to by their scientific names and in some cases by six-character codes derived from those names. The scientific names, codes, and common names for the species mentioned most often are presented in Table 1.

Table 1. Scientific and common names of plant species mentioned in this report.

Scientific name	Six-character code	Common name	Native/exotic
Agrostis gigantea	AGRGIG	giant bentgrass	Exotic
Alnus rubra	ALNRUB	red alder	Native
Carex obnupta	CAROBN	slough sedge	Native
Cirsium arvense	CIRARV	Canada thistle	Exotic
Ilex aquifolium	ILEAQU	English holly	Exotic
Phalaris arundinacea	PHAARU	reed canarygrass	Exotic
Picea sitchensis	PICSIT	Sitka spruce	Native
Polygonum cuspidatum	POLCUS	giant knotweed	Exotic
Polystichum munitum	POLMUN	swordfern	Native
Pteridium aquilinum	PTEAQU	bracken fern	Native
Rhamnus purshiana	RHAPUR	cascara	Native
Rubus discolor	RUBDIS	Himalayan blackberry	Exotic
Rubus laciniatus	RUBLAC	evergreen blackberry	Exotic
Salix sitchensis	SALSIT	Sitka willow	Native
Senecio jacobaea	SENJAC	tansy ragwort	Exotic

Background

The record of settlement, the period of occupation, and agricultural use of the homesteads has been assembled from primary documents and oral histories by Williams (1975) and Evans (1983). Description of vegetation composition of some of the larger remaining openings was carried out in the 1970s, 1980s, and 1990s by Williams (1975), del Moral (1985), and Riege (2000), respectively. The work from the 1980s posed several hypotheses to explain the "slow to non-existent succession" [to coniferous forest] at the former homesteads (del Moral 1985). These hypotheses were tested experimentally in the field by Riege (2000), and reported in the literature by Riege and del Moral (2004). The locations of the observational and experimental vegetation studies are shown in Table 2. Control of invasive, exotic plants has been carried out at several of the homestead locations since 2006.

Table 2. Homesteads included in previous observational and/or experimental studies.

Field Name	Reference Number[1]	Williams 1975	Del Moral 1985	Riege 2000	Riege and del Moral 2004
Olson #5	5			X	
Higley	10	X	X	X	
Dedman	19			X	
Streater	20	X	X	X	X
Gwin	21	X	X	X	X
Killea-Kelly	22	X	X	X	X
Barrington	23	X		X	
Kelly #25	25		X		
Andrews	34	X	X	X	

[1]From Williams 1975

History of Homesteading in Queets River Valley

Homesteading in the Queets Valley, under the provisions of the 1862 Homestead Act, began in 1890 with the promotion of a settlement called Evergreen. John Banta and S. Price Sharp, two land promoters from Tacoma, transported settlers to the Queets Valley and got them started for a fee of $50. (Williams 1975, Evans 1983). Homesteaders had to clear areas for farming and pasturage. Favored locations were recently burned areas and old river bottoms where the predominant *Alnus rubra* and *Acer circinatum* (vine maple) were relatively easy to remove (Williams 1975). Of six homesteads investigated in detail, Williams (1975) found only one that was cleared from virgin coniferous forest. For subsistence, the homesteaders grew vegetables (especially root crops), and planted fruit trees. They also planted ornamentals including *Ilex aquifolium* (Williams 1975). The bulk of the clearing was for hay and pasture to support cattle, the primary cash crop. Exotic plants introduced for hay and pasture included *Agrostis gigantea*, other cool-season grasses, and legumes (Williams 1975). There were approximately 64 homesteads in the Evergreen settlement at its peak. The community was active for approximately 50 years until President Franklin Roosevelt added the Queets river valley to Olympic National Park in 1940, an action that included the condemnation of

many homestead properties. Settlers were relocated and by 1953 all of the homesteads had been vacated (Williams, 1975, Evans 1983).

Previous Vegetation Studies

Survey of Abandoned Homestead Clearings (Williams 1975)

In 1975 Sallie Williams (University of Vermont, independent researcher) conducted an inventory of "all known and accessible homestead clearings" in the Queets River valley. She also collected detailed information regarding the agricultural practices and human use at six of the homestead sites, along with documenting then-current conditions at those sites (Williams, 1975). Her documentation included taking "a series of low-elevation, oblique aerial photographs…of the homestead clearings in February, 1975." Additionally, she drew vegetation cover maps for the six selected sites using both the aerial photographs and on-the-ground reconnaissance, determining the total acreage and percent cover for the major vegetation types.

Of the 64 homestead clearings Williams identified based on interviews with homesteaders, she was able to locate 43 through use of aerial photographs taken in 1973. Of these 43 clearings, most (35) were between 0.5 and 9 acres with only one larger than 30 acres. She identified rapid growth of native vegetation and erosion due to movement of the river's channel as possible explanations for the disappearance of 21 of the 64 homestead clearings and the preponderance of relatively small openings among those that remained (Williams 1975). Williams created a numbering system for the 43 clearings that serves to organize results from subsequent work, including this study. The clearings are numbered sequentially, starting with the farthest downstream homestead.

Williams reported the "major vegetation types" present in each of the six clearings selected for detailed study, though how these were measured is not described and abundance is not, strictly speaking, reported for individual species. In any case, among invasive, exotic species, *Rubus laciniatus* is reported as a major vegetation type for five of the six fields. She reported *Cirsium arvense* as a major vegetation type at one clearing, though it was only found at that clearing. *Ilex aquifolium* was present at three clearings; *Rubus discolor* was present at one clearing (Williams 1975). Williams also reported that *Phalaris canariensis* was among pasture grasses planted in one of the clearings; in summarizing Williams' work, del Moral (1985) evidently concluded that it was in fact *Phalaris arundinacea* that was present in this field.

Succession on Abandoned Homesteads (del Moral 1985)

Under contract to the Park, Roger del Moral of the University of Washington "surveyed six old homesteads to gather basic information about species composition and the extent of basic vegetation types," and produced a report in 1985. Five of the six homesteads had also been studied in detail by Williams. The methods for collecting vegetation data, including the year and season of observation, were not described in del Moral's report.

Del Moral reported both composition of dominant species within community types at each field, and a list of all vascular plant species within community types at each field. Among invasive, exotic species, *Rubus laciniatus* was reported as a dominant community type in four of the five fields also

studied by Williams, and present though not dominant at the fifth field. *Cirsium arvense* was reported as a dominant community type in three of the five fields also studied by Williams, and present though not dominant at one of the other two fields (del Moral 1985). Both *Ilex aquifolium* and *Rubus discolor* were present at two clearings; *Ilex* being restricted to the "homestead" habitat type (del Moral 1985).

Arrested Succession in Old Fields within a Temperate Rain Forest (Riege 2000, Riege and del Moral 2004)

The central question motivating Dennis Riege's Ph.D. dissertation (2000) was "why have trees failed to colonize most of the Queets fields?" Acknowledging that some tree recruitment had occurred, Riege re-stated this question as "how do environmental differences among old fields affect tree invasion?" Riege evaluated the time-course of invasion of several species, including *Cirsium arvense* and *Rubus laciniatus,* from aerial photographs, carried out descriptive studies of the relationship between vegetation composition and soil characteristics, and performed experimental studies of the effects of competition, facilitation, seed predation, and herbivory on tree regeneration. The results of three of the experiments, in addition to some of the observational results, were included in a later journal publication (Riege and del Moral 2004).

Reconstruction of the time-course of invasion of *Cirsium arvense* and *Rubus laciniatus* are most relevant to this report; the observational aspects of Riege's investigation were not designed or reported in a manner allowing comparison to our results. Riege observed dramatic expansion of *Cirsium arvense* in one of the fields studied by Williams (the only one within which Williams found the species). *Cirsium* was present as a small patch in 1939, the date of the earliest aerial photograph, and occupied three-quarters of the field by 1997. The expansion of *Cirsium* was fairly constant at 2 to 3 meters per year (Riege 2000). *Cirsium* was present at five other fields, four of which were studied by Williams. *Rubus laciniatus* was sparse prior to the 1971 photographs (Riege examined photographs from 1960 in addition to those from 1939). Subsequently, *Rubus* increased in numbers and/or sizes of patches in four fields (three of which were studied by Williams). In one field, the number of patches of *Rubus* decreased after 1975 (Riege 2000).

Control of Invasive Exotic Plant Species

The exotic plant management team (EPMT) for the North Coast-Cascades Network (NCCN) has been controlling invasive plants in the Queets valley since 2006. A total of 11.98 acres have been treated with herbicide between 2006 and 2013 targeting the following species: *Cirsium arvense*, *Cirsium vulgare*, *Digitalis purpurea*, *Ilex aquifolium*, *Rubus laciniatus* and *Senecio jacobea* (Table 3). Additionally, park staff occasionally mow the small field adjacent to the Queets ranger station (the Whittaker homestead).

Table 3. Acres treated with herbicide by the exotic plant management team at old homestead fields in the Queets river valley. The indicated areas represent infested (as opposed to gross) acreage.

	Field Name	Olson	Anderson	Higley	Gwin	Cowan	
	Reference Number	4	6	10	21	29	
Year	Species						TOTAL
2006	ILEAQU	-	-	0.10	-	-	
2009	RUBLAC	1.40	-	1.46	-	1.19	
	SENJAC	-	0.60	-	-	-	
2010	DIGPUR	-	0.33	-	-	-	
	RUBLAC	0.10	0.50	0.17	-	0.40	
	SENJAC	-	0.83	-	-	-	
2011	CIRVUL	0.01	-	-	-	-	
	DIGPUR	0.01	0.10	-	-	-	
	RUBLAC	0.12	0.32	0.32	-	-	
	SENJAC	0.12	0.33	-	-	-	
2012	RUBLAC	-	-	-	0.81	0.30	
2013	CIRARV	-	-	-	0.18	0.18	
	CIRVUL	-	0.06	-	-	-	
	DIGPUR	0.01	0.50	0.10	-	-	
	RUBLAC	0.07	0.17	0.20	1.50	0.15	
	SENJAC	0.07	-	0.10	-	-	
SPECIES TOTALS	CIRARV				0.18	0.18	0.36
	CIRVUL	0.01	0.06				0.07
	DIGPUR	0.02	0.93	0.10			1.05
	ILEAQU			0.10			0.10
	RUBLAC	1.69	0.99	2.15	2.31	2.04	9.18
	SENJAC	0.19	0.93	0.10			1.22
GRAND TOTALS		1.91	2.91	2.45	2.49	2.22	11.98

Methods

We made use of both aerial photography and other geographic data, and ground-based observation of vegetation. We carried out detailed observation of fields in 2009, 2010, and 2013, during the months of July and August. Incidental observations of invasive, exotic plants (or their absence), were recorded during various projects between 2007 and 2013.

Preliminary geographic analysis

The first step in identifying and describing the persistent clearings was to convert the maps created by Williams (1975) into a data layer within GIS. Williams (1975) produced maps and calculated the approximate acreage of all 43 clearings using 1973 orthophoto maps and a dot grid. We rendered Williams' field boundaries in GIS using landmarks (mostly trees and water features) that were visible in Williams' sketch maps and oblique aerial photographs. The boundaries were drawn against a background of the 1990-94 black and white orthophotos, 2002 hi-resolution aerial photos, and the 2006 color orthophotos. In some cases the acreages from the GIS renderings differed significantly from Williams'. In most such cases, the GIS acreages were used, unless there were compelling reasons to use Williams' acreage instead. The most current aerial photographs at the time of the preliminary analysis were from 2006. We used these photographs to establish current conditions as the basis for field sampling.

Delineation of clearings and vegetation patches in the field

We visited all 18 homesteads with openings determined to occupy at least one acre in 2006. We made the judgment that openings smaller than one acre have a high probability of colonization by native tree species, and so are unlikely to require action to control invasive plants. Three of the homestead sites with openings of at least an acre (Beard, Killea-Kelly, and Gwin) have two fields. The two fields at Beard and Killea-Kelly were combined in analysis due to their similarity. The Gwin fields were treated separately due to the heterogeneity of their past and present conditions. Thus we present results for 19 fields, representing 18 homesteads.

We mapped current field boundaries and interior vegetation polygons using a Thales Mobile Mapper GPS receiver and datalogger with the data collected in post-processing mode. Points were occupied for a minimum of three minutes. The field boundary was identified as the continuous drip line of the trees constituting the surrounding forest. Any saplings becoming established within the fields were ignored. Small undulations of the field boundaries were also ignored. GPS points were recorded in the field such that they could be connected with straight lines to form a polygon approximating the field perimeter (see Appendix 1). Vegetation patch boundaries were delineated subjectively based on changes in plant species composition. The planned minimum size for vegetation patches was 0.2 ha (0.5 ac), though in practice we did record some smaller patches. All the area with each surveyed field was included in a mapped patch. Within each patch we recorded the patch type labeled for the dominant plant species, mostly following the system employed by Riege (2000); and the cover of selected vascular plant species, in broad cover-classes. The patch types recognized by Riege (2000) were *Agrostis gigantea*, *Anthoxanthum odoratum*, *Cirsium arvense*, *Rubus laciniatus*, *Pteridium aquilinum*, *Carex obnupta*, and *Picea sitchensis*. We added *Rubus discolor* to the list. We estimated

percent cover in each polygon for several invasive, exotic plant species that are likely to be subject to control, and several native plant species which can dominate patches and hence inhibit spread of exotic plants. The invasive, exotic plant species were *Cirsium arvense*, *Ilex aquifolium, Phalaris arundinacea*, the Japanese knotweed group (*Polygonum cuspidatum, P. sachalinense*, and *P. x bohemica*)(Heutte et al. 2005), *Rubus discolor, Rubus laciniatus*, and *Senecio jacobaea*. We did not include exotic grasses (e.g., *Agrostis gigantea*) on the list both because we judged that they were unlikely to spread from the former homesteads and because no management goals for the former homesteads (e.g., conversion to forest, a likely means of controlling the grasses) have been identified. The native plant species were *Alnus rubra, Carex obnupta, Picea sitchensis, Polystichum munitum, Pteridium aquilinum*, *Rhamnus purshiana*, and *Salix sitchensis*. We walked the perimeter and as much of the interior of the polygon as necessary to assess patch type and assign cover-class for the selected vascular plant species. We recorded cover as indicated in Table 4. We estimated the area occupied by invasive exotic species within vegetation patches by multiplying the midpoint of the cover class (Table 4) by the mapped area of the patch.

Table 4. Cover classes used to record selected plant species in vegetation polygons.

Cover class	Range of cover values	Mid-point of cover values
1	Present to 1%	0.5%
2	2-5%	3.5%
3	6-25%	15.5%
4	26-50%	38%
5	51-75%	63%
6	76-100%	88%

Assessment of causes of decrease in clearing size

After determining field boundaries on the ground, we examined aerial photographs to determine the number of acres lost to river between 1973 and 2009-2013. Any remaining decrease in area was attributed to the growth of forest vegetation. Both the overall reduction in field size (including loss to the river) and the reduction in field size due to forest growth (excluding loss to the river) were calculated.

Invasive plants in the watershed at large

Additional records of invasive, exotic plants were obtained from a survey of the Queets trail, incidental observations while in transit to former homestead locations, and data collected for vegetation inventory and monitoring projects of the North Coast and Cascades Network. The survey of the Queets trail was performed using GPS units loaded with a data dictionary designed specifically for the task. The data dictionary included pull-down menus for the identity of the invasive species, the size of the infested area, the phenological state of the plants, and the distance to clean water (i.e., low turbidity and tannin content, for planning logistics of herbicide application). The data dictionary also included text fields for recording invasive species not on the pull-down list, and for habitat characteristics. The pull-down list consisted of the highest-priority invasive plants species for the park (Table 5). Approximately 21 km of trail were surveyed starting at the trailhead ford and ending

approximately 1.5 km below Pelton Creek. Several of the vegetation inventory plots fell within homestead fields mapped for this project and were excluded from analysis to avoid double-counting.

Table 5. High-priority invasive, exotic plant species for Olympic National Park.

Scientific name	Common name
Bromus tectorum	Cheatgrass
Centaurea biebersteinii	spotted knapweed
Centaurea jacea	brown knapweed
Centaurea diffusa	tumble knapweed
Cirsium arvense	Canada thistle
Cytisus scoparius	Scot's broom
Geranium robertianum	Herb Robert
Hedera helix	English ivy
Hieracium aurantiacum	orange hawkweed
Hypericum perforatum	common St. John's-wort
Ilex aquifolium	English holly
Iris pseudacorus	yellow iris
Lathyrus latifolius	everlasting peavine
Lathyrus sylvestris	small everlasting peavine
Phalaris arundinacea	reed canarygrass
Polygonum cuspidatum	Japanese knotweed
Polygonum polystachyum	Himalayan knotweed
Polygonum sachalinense	giant knotweed
Polygonum x bohemicum	Bohemian knotweed
Potentilla recta	sulphur cinquefoil
Prunus laurocerasus	laurel cherry
Rubus discolor	Himalayan blackberry
Rubus laciniatus	evergreen blackberry
Senecio jacobaea	tansy ragwort

Results

Persistence of Homestead Clearings

The attrition of homestead clearings observed by Williams in the 1973 aerial photographs has continued in the subsequent 33 years (Figure 2). Of the 43 clearings apparent in 1973, by 2006 14 had disappeared either due to growth of forest (10) or movement of the river (4). An additional 11 clearings were still apparent but smaller than our lower limit of one acre for field surveys (Figure 2). In the 20 years between the departure of the last homesteaders and Williams' investigation, nearly one-third of the homestead clearings disappeared. By 2006, 53 years after the departure of the last homesteaders, over half (54%) of the homestead clearings no longer existed. An additional 17% of the homesteads that Williams identified were represented by openings of less than one acre (Figure 2). The remaining openings of at least one acre span a considerable length of the river, from near the park boundary to several miles upstream of the end of the road (see Figure 10).

Nearly all of the 21 fields that were either too small for vegetation observation or were not apparent on aerial photography due to growth of forest canopy occupied four acres or less in 1973. One exception was field number 42 (Kilkelly) which was eight acres in 1973. The field is outside the park boundary and may have been eroded by Sams River or disturbed by logging activity.

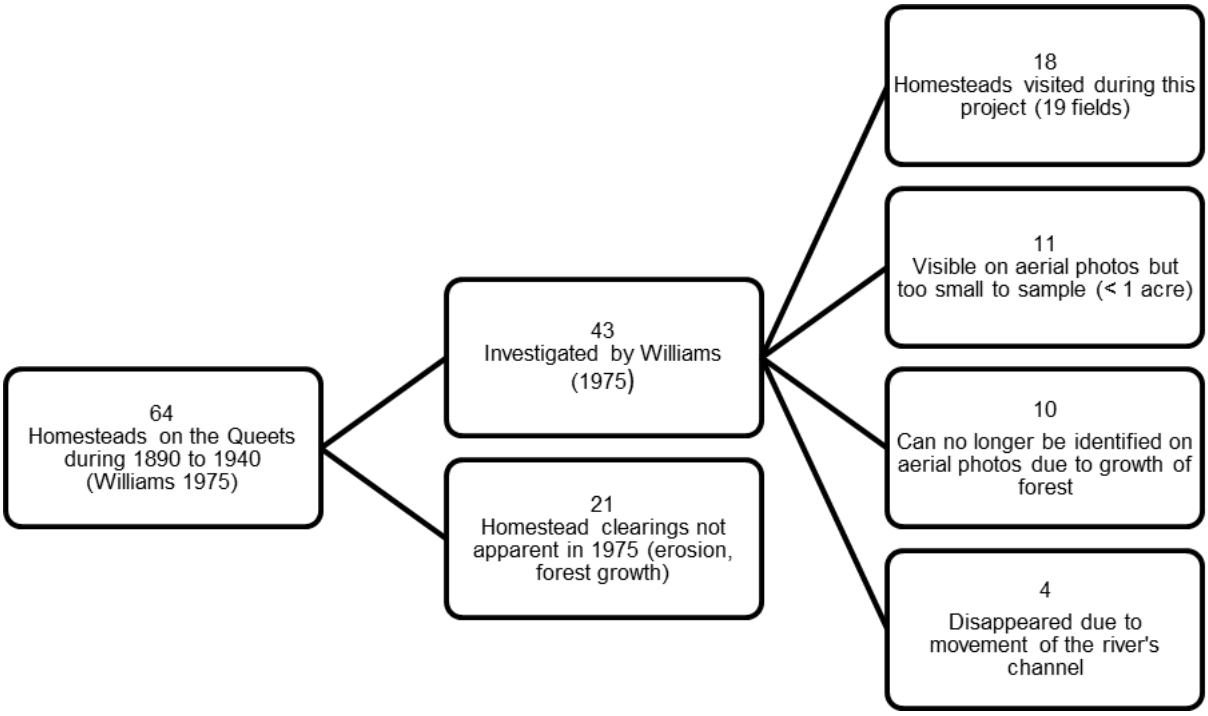

Figure 2. Attrition of homestead clearings in the Queets river valley.

Changes in Areal Extent of Clearings

The total area covered by the 19 fields we investigated decreased from 226.0 to 89.4 acres (60%) between 1973 and 2009-13 (Table 6). Most of the decrease in the size of the clearings has been due to development of forest canopy; the 50% reduction due to forest growth over all the fields we studied accounts for 113 acres, versus 21.4 acres lost due to changes in the location of the river (Table 6). The decrease in clearing size due to forest growth occurred on all the fields we studied, and amounted to more than one-quarter of the size of the clearings in 1973 in all but three of the fields. Five of the fields lost area to the Queets River since 1973, ranging from 0.9 to 8.5 acres. Erosion to date has been minimal at the McKinnon field (6% of the 1973 area), but is extensive at the Barrington (42%) and Olson #5 (72%) fields (Figure 3).

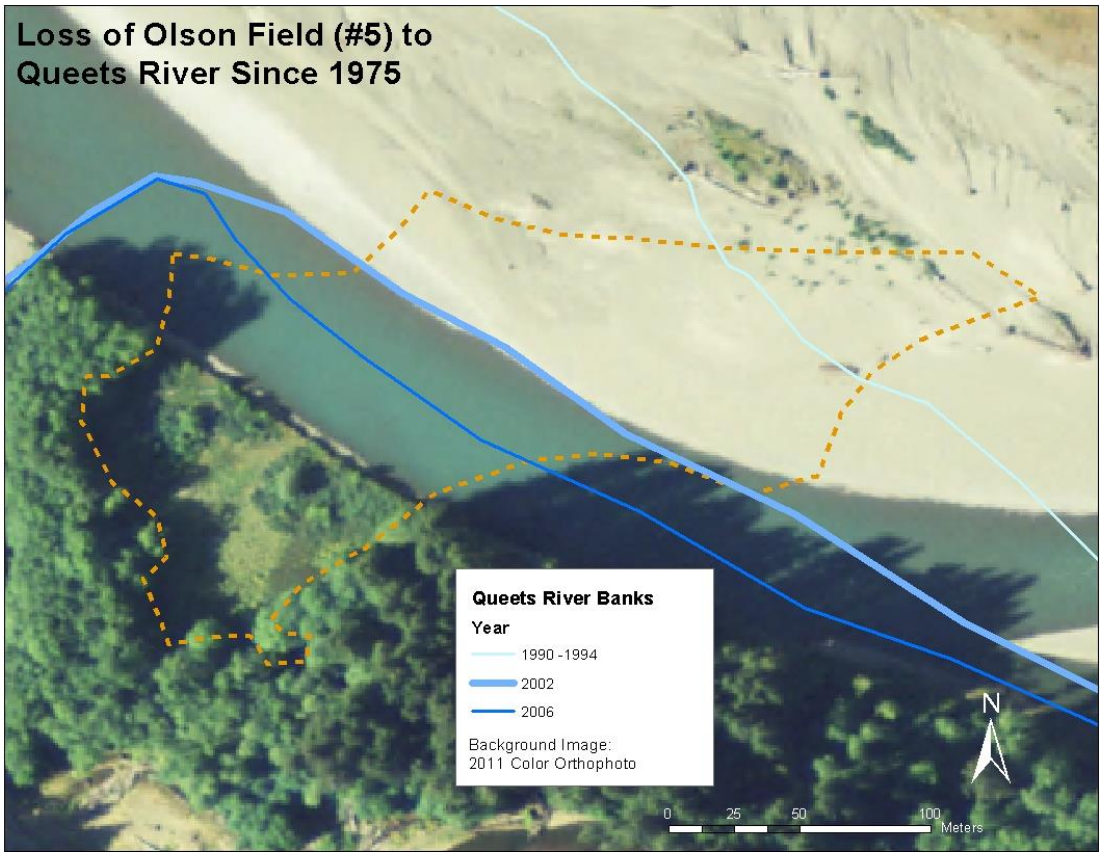

Figure 3. Example of field being lost to erosion by the Queets River. The Olson field (#5) has lost approximately 72% of its former area between 1973 and 2013. The dashed line represents the approximate field perimeter in 1973.

Table 6. Changes in area for homestead fields that were visited during this project, including reduction in size due to river erosion and forest growth.

Field Name	Reference Number	Williams Acreage (from report)	Tetreau GIS Interpretation of Williams Acreage	Current (2009-13) Acreage	Overall % reduction	Acres lost to river since 1973	% reduction due to forest growth
McKinnon	1	15.0	15.0	9.0	40%	0.9	35%
Olson #4	4	4.0	4.0	0.8	80%	0.0	80%
Olson#5	5	8.0	8.0	1.8	78%	5.8	6%
Anderson	6	11.0	11.0	1.5	86%	3.0[1]	59%
Higley	10	21.0	14.0	7.1	49%	0.0	49%
Streater #17	17	4.5	5.0	0.6	89%	0.0	89%
Beard	18	1.5	3.3	1.0	69%	0.0	69%
Dedman	19	21.0	21.0	4.9	77%	0.0	77%
Streater #20	20	23.0	27.9	17.0	39%	1.8	32%
Gwin SE	21	18.0[2]	30.5	7.1	77%	0.0	77%
Gwin SW	21	18.0[2]	15.9	5.3	67%	8.5	13%
Killea-Kelly	22	11.0	12.5	3.2	74%	0.0	74%
Barrington	23	7.0	10.5	4.0	62%	4.4	20%
North #27	27	6.5	8.9	4.9	45%	0.0	45%
North #28	28	3.5	3.5	0.6	83%	0.0	83%
Cowan	29	5.5	6.0	4.1	31%	0.0	31%
Whitaker	30	4.0	4.0	1.4	65%	0.0	65%
Andrews	34	21.0	21.0	13.6	35%	0.0	35%
Smith	39	3.5	4.0	1.5	62%	0.0	62%
Totals		207.0	226.0	89.4	60%	21.4[3]	50%

[1]This acreage is being used as an NPS maintenance boneyard and was not lost to the river.

[2]Williams (1975) reported one value for acreage of the "South" field at the Gwin homestead.

[3]Does not include the 2.97 acres being used as an NPS maintenance boneyard.

There is a generally inverse relationship between the size of the fields in 1973 and the subsequent reduction in size due to forest growth: the smaller clearings have tended to have a proportionally greater reduction in size than the larger clearings (Figure 4). Clearings that were less than 5 acres in 1973 are mostly gone now, with the exceptions of the Beard field which has gone from approximately 3 acres to 1 acre and the Smith field from 4 acres to 1 acre. There were two large fields with large decreases in area, in contrast to the general trend: Gwin SE, which started out as the largest clearing and has decreased in size by 77%; and Dedman, which has also lost 77% of its acreage to forest, despite having occupied 21 acres in 1973.

For two of the larger fields it is possible to reconstruct the entire trajectory of field size since the cessation of agricultural use. According to Williams (1975), the larger Streater field was originally

30 acres, and was occupied until 1920; Andrews field was also originally 30 acres and was occupied until 1944. Streater field decreased in size 7% between 1920 and 1973 (i.e., 30 acres to 27.9 acres, Table 6). It then decreased 39% between 1973 and 2010 (the year of our measurement). Andrews field decreased in size by 30% between 1944 and 1973. It then decreased by 35% between 1973 and 2009.

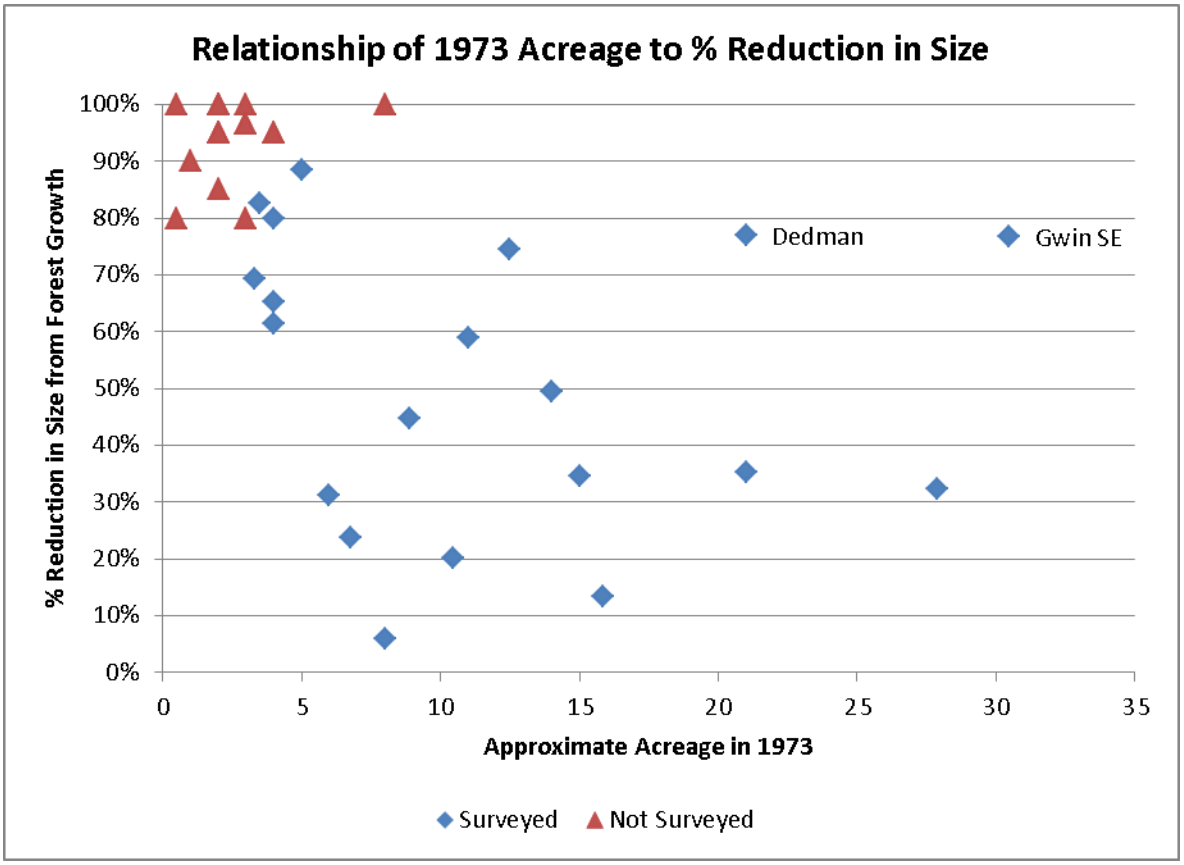

Figure 4. Plot of approximate field size in 1973 versus the percent reduction in field size from 1973 to present due to forest growth. "Not Surveyed" indicates sites that were not included in the field visits during this project.

Plant Species Composition of the Persistent Clearings

Summary of Vegetation Patch Types

We mapped a total of 52 vegetation patches within the 19 fields that we visited (Figure 5). *Agrostis gigantea* (Figure 6) was the most common and extensive patch type, accounting for 22 of the 52 patches (42%), and 55.7 of the 89.4 acres that were mapped (62%). Patches dominated by *Carex obnupta* (Figure 7) were also common and extensive, accounting for 11 patches (21%), and 11.5 acres (13%). Patches dominated by *Rubus laciniatus* (Figure 8) and *Pteridium aquilinum* (Figure 9) were reasonably common (both accounting for 12% of patches), with *Rubus* patches slightly more extensive than *Pteridium* patches (10% and 8% of total area, respectively). There were multiple patches of both *Cirsium arvense* and *Picea sitchensis*, and one patch of *Rubus discolor*. Though we

observed *Anthoxanthum odoratum* in the fields, we did not encounter any patches dominated by the species that were large enough to map.

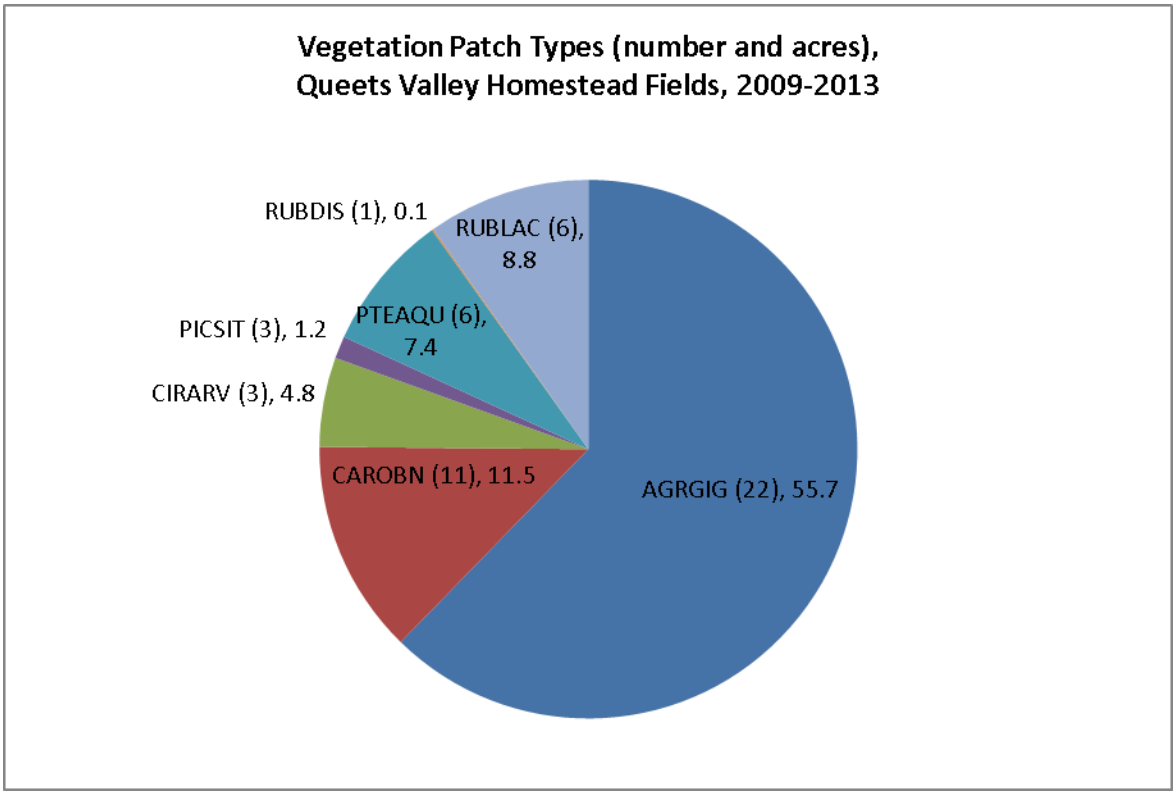

Figure 5. Number and total acres of vegetation patch types in Queets valley homestead fields that were mapped between 2009 and 2013.

Figure 6. Vegetation patch dominated by *Agrostis gigantea*, Andrews field, August 2009.

Figure 7. Vegetation patch dominated by *Carex obnupta*, Olson #5 field, August 2013. Note the presence of *Senecio jacobaea* in foreground and background.

Figure 8. Vegetation patch dominated by *Rubus laciniatus*, Olson #5 field, August 2013. Note the *Alnus rubra* emerging through the *Rubus*.

Figure 9. Vegetation patch dominated by *Pteridium aquilinum*, Killea-Kelly field, August 2013.

Invasive, Exotic Plants by Patch Type

The targeted invasive, exotic plant species occurred in all patch types, whether dominated by native or exotic species (Table 7). Three species were especially common: *Rubus laciniatus*, *Cirsium arvense*, and *Senecio jacobaea*. *Rubus laciniatus* was present in at least two-thirds of each of the patch types (with the exception of the one patch dominated by *Rubus discolor*), and was present in 87% of all patches. *Cirsium* was common in all patch types dominated by graminoids or forbs, as well as patches dominated by *Rubus laciniatus*. It occurred in almost two-thirds of all patches. *Senecio* was most common in patches dominated by *Rubus laciniatus, Agrostis gigantea, or Pteridium aquilinum*; it occurred in just under half of patches (Table 7). Other than in the types they dominated, the invasive, exotic species were relatively low in abundance in most patches, as indicated by median cover-class values mostly of 1 or 2. The *Picea sitchensis* patch type was notable for the occurrence of only one of the targeted invasive, exotic plant species (Table 7).

Potentially-dominant, Native Plants by Patch Type

The potentially-dominant, native plant species occurred in all patch types, whether dominated by native or exotic species (Table 8). Three species were especially common in patch types dominated by exotic species: *Carex obnupta*, *Pteridium aquilinum*, and *Alnus rubra*. *Carex* was present in at least two-thirds of the patches dominated by *Agrostis gigantea* or *Cirsium arvense*, and was present in half of the patches dominated by *Rubus laciniatus*. *Pteridium* was present in over half of the patches dominated by *Agrostis gigantea* or *Cirsium arvense*, but was not common in patches dominated by *Rubus laciniatus*. *Alnus* was present in all of the patches dominated by *Rubus laciniatus* and over half of the patches dominated by *Agrostis gigantea*. Other than in the types they dominated, in most patches the potentially-dominant, native species were relatively low in abundance, as indicated by median cover-class values between 1 and 2 (Table 8).

Table 7. Frequency and cover of invasive, exotic plant species by vegetation patch type[1].

Patch Type	AGRGIG		CAROBN		CIRARV		PICSIT		PTEAQU		RUBLAC		All types	
N	22		11		3		3		6		6		52	
Species	%[2]	Cover[3]	%[2]	Cover[3]	%[2]	Cover[3]	%[2]	Cover[3]	%[2]	Cover[3]	%[2]	Cover[3]	%[2]	Cover[3]
CIRARV	64	2	82	1	100	5	0	n/a	33	1	100	1	65	1
ILEAQU	9	1.5	0	n/a	0	n/a	0	n/a	17	3	0	n/a	6	2
PHAARU	0	n/a	0	n/a	33	1	0	n/a	0	n/a	0	n/a	2	1
POLCUS	5	1	0	n/a	0	n/a	0	n/a	17	1	0	n/a	4	1
RUBDIS	9	1.5	9	1	33	1	0	n/a	17	2	0	n/a	12	1.5
RUBLAC	91	1	91	1	67	2	100	1	67	1.5	100	6.0	87	1
SENJAC	59	1	27	1	0	n/a	0	n/a	50	1	67	1	44	1

[1]The one patch dominated by *Rubus discolor* is not shown; the only targeted invasive, exotic species present was *Rubus discolor*, with a cover class of 5.

[2]Frequency (i.e., the percentage of patches of the indicated type in which the species occurred).

[3]Median cover class for the combination of patch type and species.

Table 8. Frequency and cover of potentially-dominant, native plant species by vegetation patch type[1].

Patch Type	AGRGIG		CAROBN		CIRARV		PICSIT		PTEAQU		RUBLAC		All types	
N	22		11		3		3		6		6		52	
Species	%[2]	Cover[3]	%[2]	Cover[3]	%[2]	Cover[3]	%[2]	Cover[3]	%[2]	Cover[3]	%[2]	Cover[3]	%[2]	Cover[3]
ALNRUB	64	1	27	2.0	33	1	67	1.5	33	1.5	100	2	56	1
CAROBN	77	2	100	6.0	67	1.5	33	1	83	2	50	1	75	2
PICSIT	68	1	36	1.5	33	1	100	6	83	1	17	1	56	1
POLMUN	55	1	64	1	33	1	67	1	17	1	n/a	0	44	1
PTEAQU	64	1.5	64	2	67	2	100	1	100	5	17	2	63	2
RHAPUR	45	1	73	2	33	1	67	1	83	1	17	1	52	1
SALSIT	9	1	n/a	0	n/a	0	n/a	0	n/a	0	33	1	8	1

[1]The one patch dominated by *Rubus discolor* is not shown; the only potentially-dominant, native plant species present was *Alnus rubra*, with a cover class of 1.

[2]Frequency (i.e., the percentage of patches of the indicated type in which the species occurred).

[3]Median cover class for the combination of patch type and species.

Distribution of Invasive, Exotic Plants among Fields

The area occupied by the targeted invasive, exotic plant species is concentrated within several of the larger remaining openings (Table 9, Figure 10). Almost 90% of the estimated area for the invasive plants occurred within the five homesteads with the largest persistent fields. These fields occur along nearly the entire length of the Queets valley with former homesteads, from McKinnon field near the park boundary, to Andrews field in the wilderness beyond the end of the Queets road (Table 9, Figure 10). The larger remaining fields contrast with one another with respect to the ratio of estimated area of invasive plants to entire field area. For the largest field (Streater), this ratio is less than 0.1 (i.e., the sum of estimated areas occupied by the invasive species is less than 10% of the area of the field), whereas the ratio is greater than 0.3 for the next-largest field (Andrews). The ratio exceeds 1.0 for Gwin NW, where *Rubus laciniatus* covered nearly the entire area (cover class 6), and *Cirsium arvense* was also present (cover class 3). In most fields, *Rubus laciniatus* had the largest estimated area or was tied with another species. *Cirsium arvense* had the largest estimated area or was tied with another species in more than one-third of the fields. *Senecio jacobaea* was tied with other species for the largest estimated area in two fields, both in the downstream half of the study area. Over all the fields, the estimated area occupied by the targeted invasive plant species was 21 acres; *Rubus laciniatus* had the largest estimated area (Table 9). *Cirsium arvense* had nearly as large an estimated acreage as *Rubus laciniatus*. Together they accounted for more than 90% of the estimated acreage of targeted invasive, exotic plants.

Table 9. Estimated acreage of targeted invasive, exotic plants within fields.

Field Name	Reference Number	Field Area (acres)	Sum of estimated acreage of invasive plants	Invasive species with largest estimated area
McKinnon	1	9.0	5.26	RUBLAC
Olson	4	0.8	0.01	RUBLAC, SENJAC
Olson	5	1.8	0.74	RUBLAC
Anderson	6	1.5	0.02	RUBLAC
Higley	10	7.1	1.96	CIRARV
Streater (small)	17	0.6	0.11	ILEAQU
Beard	18	1.0	0.06	CIRARV
Dedman	19	4.9	0.07	CIRARV, RUBLAC, SENJAC
Streater	20	17.0	1.21	CIRARV
Gwin SE	21	7.1	0.22	RUBLAC
Gwin NW	21	5.3	5.45[1]	RUBLAC
Killea-Kelley	22	3.2	0.13	RUBLAC
Barrington	23	4.0	0.20	RUBLAC
North (south)	27	4.9	0.97	RUBLAC
North (north)	28	0.6	0.10	RUBLAC
Cowan	29	4.1	0.46	CIRARV
Whittaker	30	1.4	0.01	RUBLAC
Andrews	34	13.6	4.26	CIRARV
Smith	39	1.5	0.02	CIRARV, RUBLAC
All fields		89.4	21.20	RUBLAC

[1]This acreage exceeds the field area due to the presence and high abundance of two invasive plant species.

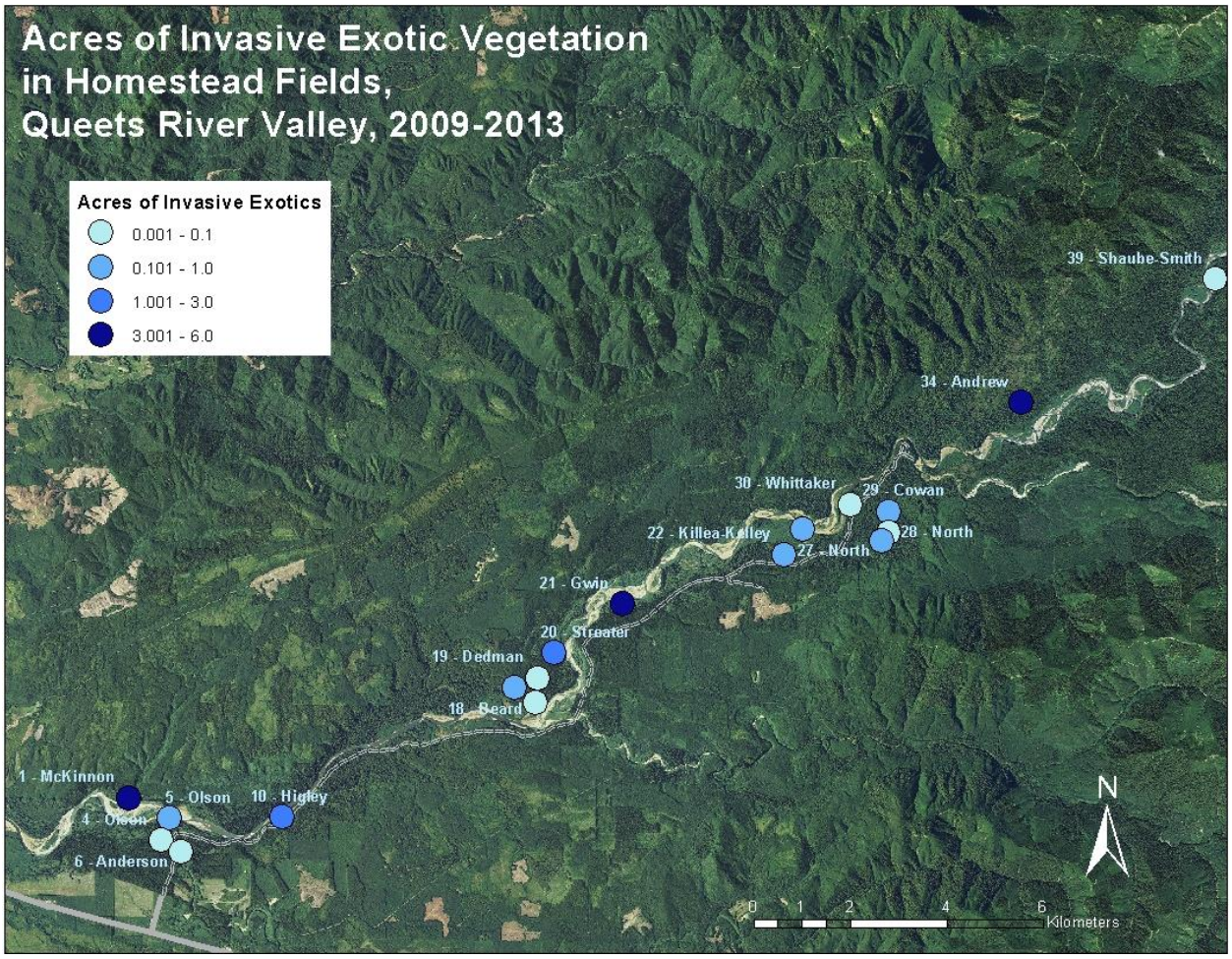

Figure 10. Estimated acreage of invasive exotic plant species per homestead field.

The three most abundant species of invasive, exotic plants had contrasting patterns of distribution along the length of the Queets River with remaining homestead openings (Figure 11). *Cirsium arvense* was abundant to dominant in patches (i.e., cover-class values between 3 and 6) over the entire length of the river with homesteads except for the homestead farthest upstream. *Rubus laciniatus* was abundant to dominant in patches over nearly as much of the river as *Cirsium*, with low cover values in only the two homesteads farthest upstream. *Senecio jacobaea* was not observed at three homesteads farthest upstream, and was abundant only at the downstream end of the study area (Figure 11).

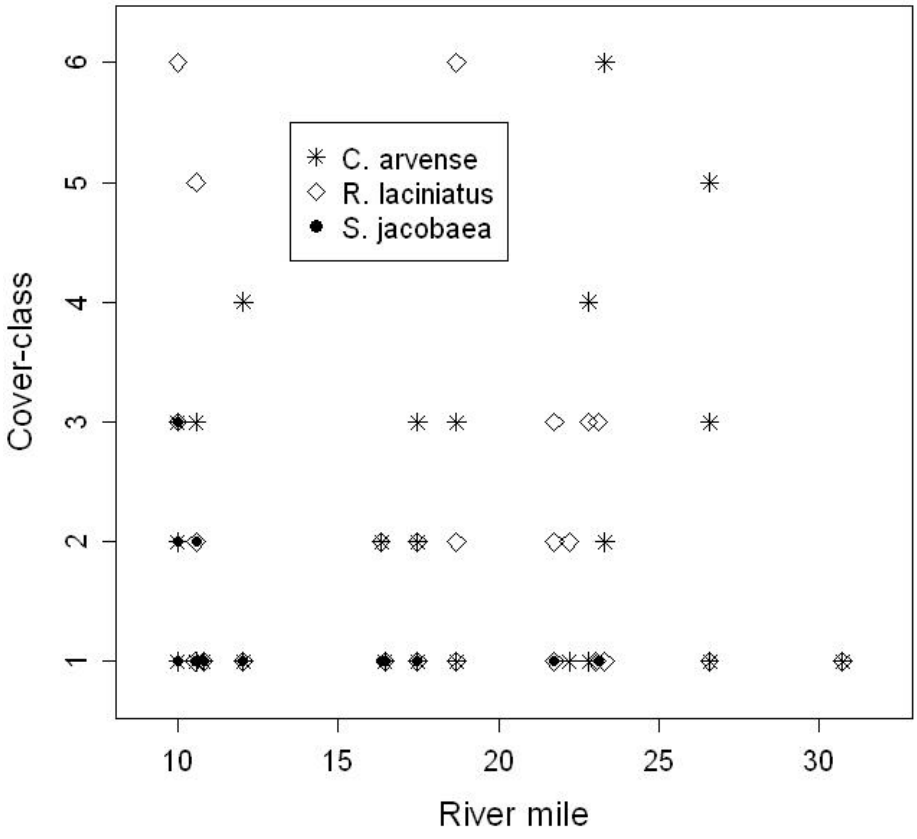

Figure 11. Distribution and abundance of the most abundant invasive, exotic plant species within mapped vegetation patches, as a function of distance upstream from the mouth of the Queets River.

Invasive, Exotic Plants Elsewhere in the Watershed

The survey of the Queets River trail and incidental observations from this and other studies indicate that the targeted invasive, exotic plant species have spread in the watershed beyond the end of the road, and beyond the farthest upstream homestead (Figure 12). Of the 120 observations of these species we assembled for the portion of the watershed beyond the end of the road, most were *Rubus laciniatus* (69%), followed by *Rubus discolor* (18%), and *Cirsium arvense* (12%). There was one observation of *Senecio jacobaea*, consisting of fewer than 11 plants.

We detected *Rubus laciniatus* farther upstream than any of the other targeted invasive species. The farthest upstream point for the species was near river mile 36, more than five miles above the last homestead field we visited. The farthest upstream point for *Cirsium arvense* was between river miles 34 and 35. The farthest upstream detection of *Rubus discolor* was less than one mile above the last homestead field we visited. However, that point was five miles above Andrews field, the farthest upstream that we observed *Rubus discolor* at any of the homestead fields.

The combined distribution of the *Rubus* species along the trail was patchy, with several very large patches and many significant stretches that lacked either species. The largest patches of *Rubus* were located along the lower portion of the trail; patches diminished in size and frequency with distance upriver. Very little *Rubus* was found from 5.2 to 11 km along the trail; the frequency increased past that point, although the subsequent patches were generally small (Figure 12).

The *Rubus* species tended to occur in different habitats from those within which we observed *Cirsium arvense*. The *Rubus* species were generally in somewhat open areas within forest, especially in the vicinity of old homestead sites. We typically found *Cirsium* nearer the river, either in sandy or gravelly areas of recent disturbance, or on alder flats that presumably had been subject to somewhat less-recent disturbance.

Surveyed areas where none of the targeted invasive plants species were detected included the upper 5 km of the Queets Trail that we surveyed, and several point locations both close to the river and up to one mile away from the river (Figure 12).

From the park boundary upstream to the end of the road, we observed *Cirsium arvense*, *Ilex aquifolium*, *Rubus discolor*, *Rubus laciniatus*, and *Senecio jacobaea* at scattered locations. We also documented locations where none of these species occurred, from nearly adjacent to the river to over one-half mile away from the river (Figure 12).

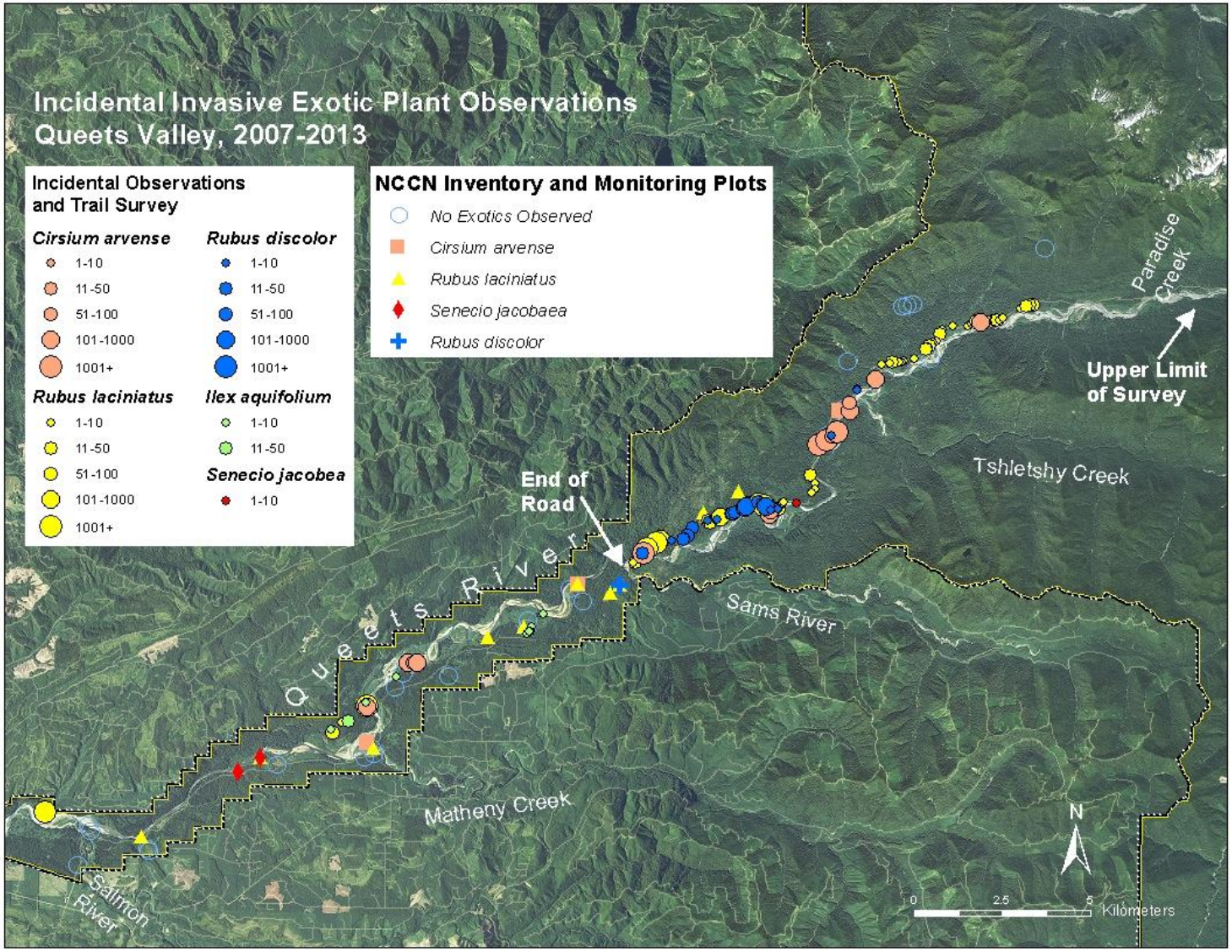

Figure 12. Observations of selected invasive exotic species in the Queets Valley at I&M vegetation mapping and forest monitoring plots, and along the Queets River trail. Also included are vegetation mapping and forest monitoring plots where data were collected but those species were not observed. The park boundary and the surrounding network of roads are also displayed.

Discussion

Distribution of invasive exotic plants in the Queets watershed

Invasive, exotic plants are present in the Queets watershed within Olympic National Park, at the former homestead sites and elsewhere, from the downstream end of the river within the park to several miles inside the wilderness. Invasive species likely to be subject to control efforts occupy an estimated 24% of the 89 acres of openings remaining from the homesteading era. The invasive species in the watershed contrast with one another with respect to mode of introduction, timing of spread, and current extent. These differences may help frame management responses.

Three of the invasive, exotic species likely to be subject to control efforts were brought to the homesteads intentionally for food, forage, or decoration. Two of these species (*Phalaris arundinacea*, and *Rubus discolor*) were planted in only one of the homesteads that Williams (1975) investigated. The other species (*Ilex aquifolium*) was planted at four of the five homesteads that Williams investigated. The geographic spread of these three species in the Queets watershed has been minimal to modest. We observed *Phalaris arundinacea* only once, in the same homestead field where it was planted. The spread of *Ilex aquifolium* that we observed was limited to the vicinity of former homesteads. *Rubus discolor* has spread more than the other two species, but it still only occurs in three homestead fields, is abundant in only the field where it was originally planted, and is less extensive and abundant in the rest of the watershed than *Rubus laciniatus*.

The three invasive, exotic plant species which are most extensive and abundant in the former homesteads evidently arrived on their own, either during or after the period of occupancy of the homesteads. Williams (1975) noted that in keeping their fields cleared, the homesteaders removed both non-native and native plant species. She reported that *Rubus laciniatus* had "spread extensively throughout the Queets Valley;" she listed the species as affecting three of the four homesteads for which she had information. She listed *Cirsium arvense* as affecting only one of the four homesteads. No mention of *Senecio jacobaea* appears in Williams' (1975) report. *Senecio jacobaea* was present, though evidently not abundant, in only one of the six fields del Moral (1985) observed in the mid-1980s.

Though it was present during the homesteading era, *Rubus laciniatus* did not attain widespread abundance until at least a decade after that era ended. According to Riege's (2000) analysis of aerial photographs for eight homesteads, the species began to increase in distribution and abundance between 1960 and 1971. *Cirsium arvense* appeared in fields other than the first field where it was observed a decade or more after *Rubus laciniatus* began to spread. Williams (1975) found it in one field whereas del Moral (1985) found it in four fields. It is worth noting that *Cirsium arvense* was spreading steadily within the field where it was first observed during the decades that it was not taking hold in the other fields (Riege 2000). *Senecio jacobaea* may still be in its initial phase of invasion into the watershed, as it is most abundant at the homestead farthest downstream (Figure 11). All three species are likely to continue to spread in the watershed in absence of control efforts, since abundance decreases with distance upstream (Figure 11, 12).

Change in spatial extent of homestead clearings

Change in the size of the clearings associated with the homesteads in the Queets valley has been evaluated twice in the 60 years since the cessation of occupation: after roughly two decades by Williams (1975) and after more than five decades in this study. At both points in time, there was a consistent decrease in size of the clearings. The one potential exception is Killea-Kelley field (number 22), which, according to Williams, did not appreciably decrease in size between cessation of occupation and 1973. A large fraction of the homestead clearings have decreased in size so much that they have disappeared (over half up to present). In the interval since Williams's study, smaller residual clearings have been more likely to decrease dramatically in size: all of the 16 clearings that were 5 acres or less in the 1970s decreased by 50% or more while only six of the 15 larger clearings decreased by that proportion (Figure 4). The area occupied by residual clearings still at least one acre in size decreased by almost two-thirds (60%) between 1973 and present (Table 6).

While many clearings have disappeared, and all are decreasing in size, several large clearings remain. The three largest clearings decreased by a similar proportion since the 1970s (i.e., McKinnon, Streater, and Andrews, 40%, 39%, and 35%, respectively), so it is appropriate to consider them as a group in order to project when they might decline to a size at which eventual disappearance would be likely (i.e., 5 acres). Assuming that the annual percentage decrease in size for each field remained constant, it is possible to calculate an annual rate of decrease for each field (see Sheil et al. 1995). For the three largest clearings, this estimated annual rate of decrease in size varies little (1.2% to 1.3%). Given that the fields currently vary in size by almost a factor of two (from McKinnon field at 9 acres to Streater field at 17 acres), the projected number of years to reach 5 acres also varies, from 46 years for McKinnon to 91 years for Streater. We observed that most fields 5 acres or smaller mostly disappeared in the 33 years between 1973 and 2006. So if recent trends continue, we can expect the three largest fields to persist for roughly another 80 to 120 years.

Two processes have caused the decrease in size and disappearance of homestead clearings: growth of forest and movement of the Queets River. We are able to compare the magnitude of the two processes in the interval since 1973. Forest growth was ubiquitous, contributing to decrease in size of all the homestead clearings we measured; summed over all the clearings, forest growth accounted for four times the decrease of area as that attributed to movement of the river. However, the effect of the river was concentrated on a limited number of clearings. In three of the five clearings where we observed loss of area due to the river, it was the predominant cause, accounting for up to 92% of the area lost.

Expansion of forest into the clearings can be conceived as either occurring through individual invasion into the matrix of the clearing, or the incremental spread from the edge of the surrounding forest (Riege 2000). We observed some evidence of tree invasion into the matrix of clearings, including patches dominated by *Picea sitchensis* and occurrence of the species in other patch types. The three *Picea* patches we identified were in the two largest fields; all occupied about 0.4 acres. *Picea* occurred in just under half of the patches dominated by other species, but its occurrence was not evenly distributed between patch types. It occurred in most of the patches dominated by *Agrostis gigantea* and *Pteridium aquilinum* and was uncommon in the other patch types. Where it occurred, it

was generally not abundant (i.e., median cover value of 1 in patches dominated by exotic species, Table 8). Thus, as Riege (2000) observed, invasion by Picea is occurring, but so slowly that conversion to forest is unlikely to occur any time soon. At present, spread from forest edges is evidently a much more significant process than tree invasion. Species composition of the forest re-occupying the former clearings was beyond the scope of this study but may be of sufficient interest to park managers to warrant investigation.

The portion of the Queets valley directly subject to the river can be divided into several types of landforms, varying in vegetation composition and frequency of disturbance (i.e., removal by the river; Latterell et al. 2006). Among other types, Latterell et al. (2006) contrasted transitional and mature fluvial terraces. Transitional fluvial terraces are characterized by a mix of deciduous and coniferous trees less than 100 years old, while vegetation on mature fluvial terraces consists of coniferous forests 100 to 300 years old. The erosion rate of transitional terraces is six times greater than that for mature terraces, such that the half-life (time for the river to remove half the existing area) for transitional terraces is 62 years, versus 401 years for mature terraces (Latterell et al. 2006). The three largest remaining fields contrast with respect to both landform as indicated from surrounding vegetation, and distance to the river (both interpreted from 2011 aerial photographs and field observations). The McKinnon field has transitional fluvial terrace on two sides, a conifer-covered hillslope on a third side, and adjoins the river on the fourth side. The Streater field has transitional fluvial terrace on one side and mature fluvial terrace on the other three sides. At its closest point, the river is just over 100 feet distant. The Andrews field has mature fluvial terrace on all four sides. At its closest point, the river is over 900 feet distant. Thus it seems likely in the next few decades that the McKinnon field could lose considerable area to the river, the Streater field might lose more area along one margin, and that any loss to the river is quite unlikely for the Andrews field.

Vegetation composition within fields

Assessment of changes over time in vegetation composition within the fields is complicated both by the lack of description of measurement methods in earlier work on entire fields (i.e., Williams 1975, del Moral 1985), the availability for our observation of only subsets of the areas observed earlier, due to forest growth and erosion by the river. However, the general features of the fields described by del Moral (1985) match the patch types we observed for all of the five fields in common with only relatively minor exceptions (Table 10). Del Moral (1985) stated that for the most part, the differences in vegetation composition between his work and Williams' (1975) were modest. So it appears that the general structure of the vegetation in the fields has not changed dramatically in almost four decades.

Table 10. Vegetation within fields in 1980s (del Moral 1985) and at present.

Field Name	Reference Number	Dominant and common vegetation types in 1980s (presumed descending order of abundance)	Patch types observed in current study (descending order of patch area)
Higley	10	AGRGIG	AGRGIG, CAROBN
Streater	20	AGRGIG, CAROBN, PTEAQU	AGRGIG, CAROBN, PTEAQU
Gwin	21	AGRGIG, PTEAQU, RUBLAC, CIRARV	RUBLAC, PTEAQU, AGRGIG, CAROBN
Killea-Kelley	22	AGRGIG, PTEAQU	AGRGIG, PTEAQU
Andrews	34	AGRGIG, CIRARV	AGRGIG, CIRARV, CAROBN, PICSIT, RUBDIS

Patches of *Carex obnupta* are one component of the vegetation of the fields which may have potential to increase in size and numbers over time. For example, del Moral (1985) reported *Carex obnupta* as absent from Andrews field (present only in the "woods" habitat). We recorded a patch 0.8 acres in size, and presence of the species in a patch dominated by *Agrostis gigantea*. We also found the species in two fields where it was not visible in the aerial photographs obtained by Williams (1975). In his analysis of aerial photographs, Riege (2000) observed that the species was first apparent at the Higley field in 1981. He also observed expansion of existing patches in several fields at rates up to 0.4 meters/year (Riege 2000). We encountered more patches of *Carex obnupta* than patches of any other native species. Both *Cirsium arvense* and *Rubus laciniatus* occurred in most *Carex obnupta* patches, but neither were abundant. *Senecio jacobaea* occurred in just over one-fourth of *Carex obnupta* patches, also at low abundance (Table 7).

Synthesis and Management Implications

Invasive, exotic plant species with the potential to disrupt native ecosystems have come to occupy former homesteads in the Queets valley, mostly since the end of the homesteading era. New invasive species are arriving at the homesteads, and some of the invasive species already present have spread to additional homesteads and elsewhere in the watershed. At the same time, expansion of forest and movement of the river's channel are eliminating the clearings, especially the smaller ones. At least several of the largest homestead clearings may persist for another century if current trends continue.

In addition to the effects of the invasive plants within the former homestead areas, it is worthwhile to consider the former homesteads as potential seed sources for other areas in the watershed. Patterns of spread of both *Cirsium arvense* and *Senecio jacobaea* make clear that areas other than the homesteads have served as seed sources in recent decades. Seed of *Cirsium arvense* can be dispersed by wind, animals, or water, with wind credited for longer-distance dispersal (Tilley 2010, Zouhar 2001). We have observed the species with mature inflorescences in the Queets valley as early as August; wind dispersal of seeds probably ceases with the onset of rains in October (Tilley 2010). On the west side of the Olympic Peninsula, prevailing winds in August and September are from the south and the west (data for Quillayute Airport and Hoquiam Airport, respectively, Western Regional Climate Center 2014). *Cirsium arvense* was first observed at one of the eastern-most homesteads. It later appeared in homesteads farther to the west, presumably due to dispersal from a source or sources upwind and therefore outside of the park. Similarly, *Senecio jacobaea*, another wind-

dispersed species (Wardle 1987), is currently most abundant to the west of the one homestead where it was observed in the 1980s. By contrast, *Rubus laciniatus* is primarily dispersed by animals and its fruits are consumed by a number of bird species (Tirmerstein 1987). Thus, the homesteads are likely to serve as sources of seed of *Cirsium arvense* and *Senecio jacobaea* for locations downwind (i.e., upstream), and of *Rubus laciniatus* in any direction within typical flight distances of birds such as American robins (*Turdus migratorius*) (Tirmerstein 1987).

Several lines of evidence suggest that at least *Cirsium arvense* and *Rubus laciniatus* are likely to continue to spread in the Queets watershed unless controlled. The abundance and/or continuity of occurrences decreases with distance upstream (Figure 12). Some of the occurrences farthest upstream were observed to be flowering. Throughout its range, the distribution of *Cirsium arvense* is limited in part by low temperatures, most likely due to winter temperatures and the length of the growing season (Tiley 2010). This may explain why we have found the species at elevations up to 1600 feet in the park, but no higher. The highest elevation we have documented in the Queets watershed is below 600 feet. A warming climate and an increased atmospheric concentration of CO_2 are likely to result in an expansion in range, more vigorous growth, and less susceptibility to the commonly-used herbicide glyphosate for *Cirsium arvense* (Tilley 2010).

Our observations, combined with results from previous studies of the homesteads, lead to potential focus areas for management, as well as several questions to pursue to enhance probability of success. Since the most abundant invasive plant species in the homesteads may be continuing to spread, populations farthest upstream should be a priority. The largest residual fields should receive greater emphasis in exotic plant control than the smaller ones, since they are likely to persist for many decades and home to the largest concentrations of invasive plants. Small populations of invasive, exotic plant species with especially great potential to disrupt native ecosystems (i.e., *Phalaris arundinacea*, *Polygonum cuspidatum*) should be eradicated before they spread. The incipient invasion of *Senecio jacobaea* is likely to benefit from a concerted control effort, inasmuch as it tends to disperse relatively short distances (Wardle 1987).

The effectiveness of invasive plant management in the Queets watershed will be enhanced by a more thorough understanding of current distribution in the portion of the watershed beyond the end of the road. We have demonstrated that *Rubus laciniatus* and *Cirsium arvense* are present in numerous locations in the wilderness portion of the Queets watershed, and we have identified the contrasting, typical habitats for the two species. A more thorough, statistically-based survey of forest openings (e.g., blow-down patches) and areas recently disturbed by the river would provide a solid foundation for control efforts. In addition, it may be appropriate to support research into how best to make use of native plant species (in addition to the obvious *Picea sitchensis*) that may be of high utility in restoration of the homestead fields. *Carex obnupta* stands out for its ability to colonize and spread within some of the former fields, and the relative scarcity of invasive plants within patches of the species, while *Alnus rubra* is notable for presence in all patches of either *Rubus laciniatus* or *R. discolor* that we encountered. It is also worth examining the understory vegetation at former openings that have returned to forest to confirm that invasive, exotic plants are scarce or absent.

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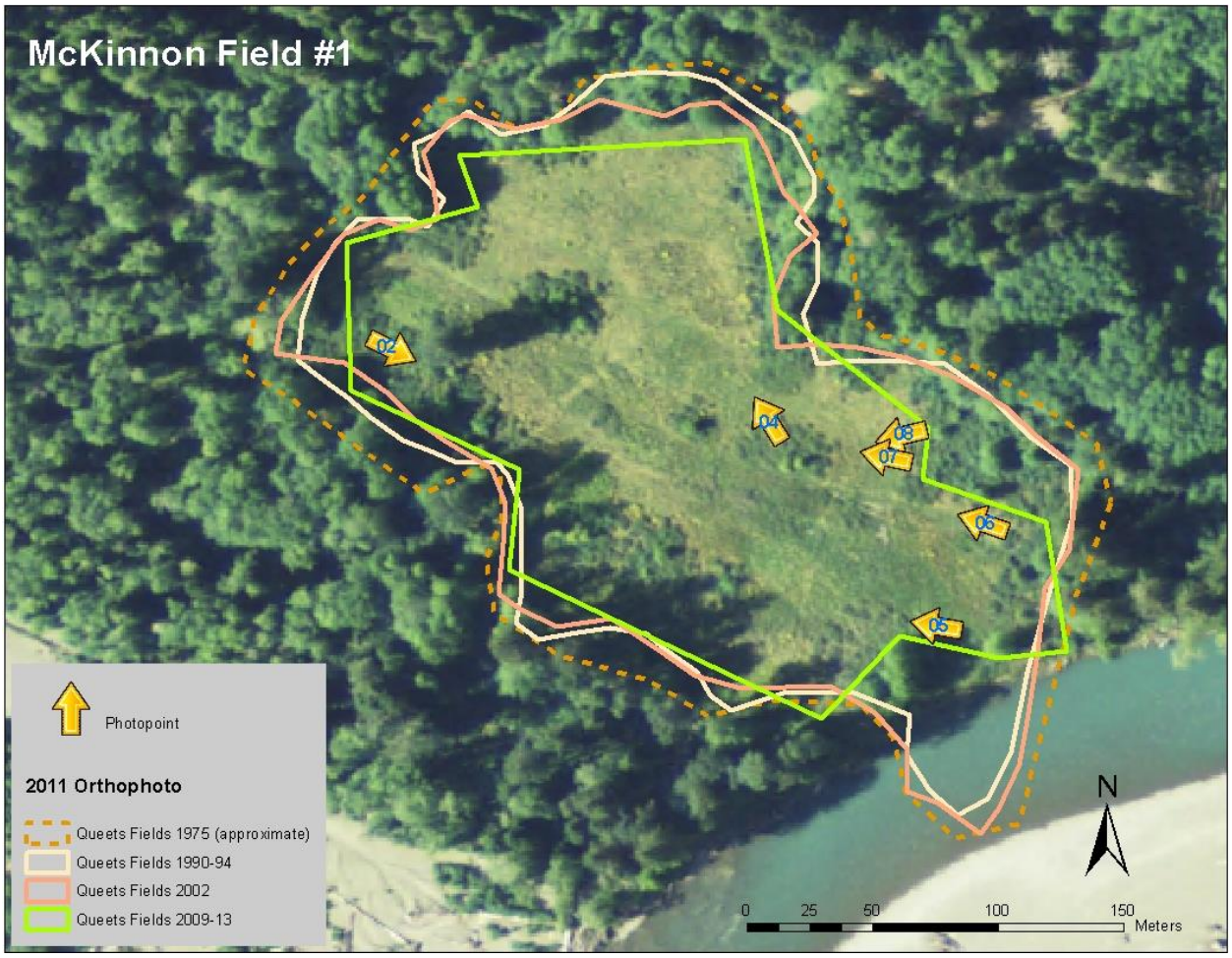
Appendix A: Detailed Field Descriptions

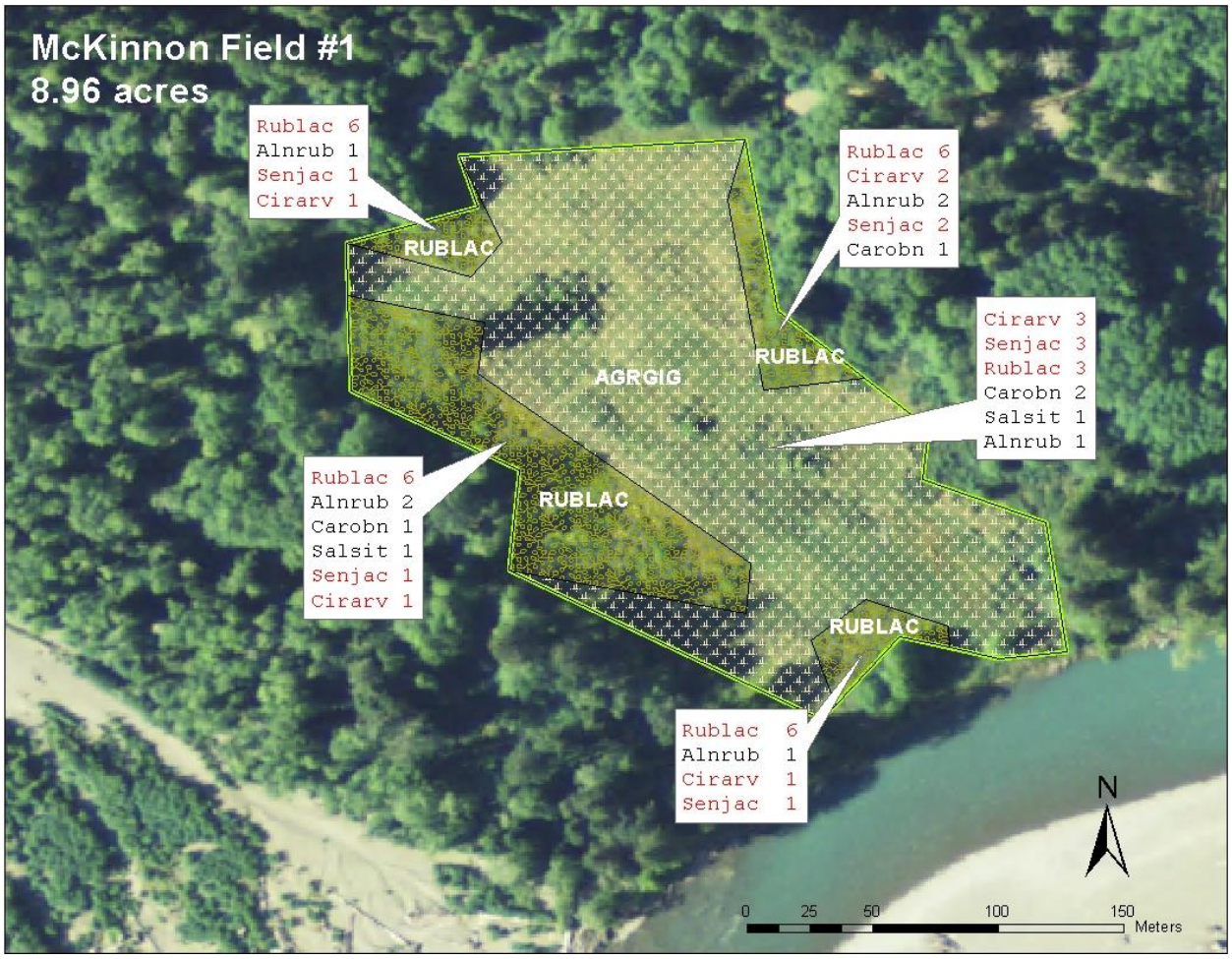
For each field there are two images: one depicting the field boundaries over time and the other depicting the current vegetation patch types within the field. For all images the background consists of orthophotography obtained in 2011. A brief narrative about the field and a general description of the current vegetation is also provided. For some fields a species list (not all-inclusive) is provided as well. The photo point arrows and numbers refer to digital photos that were taken during the 2009-13 field visits. Photo point details are included in a table at the end of this appendix.

McKinnon (#1)



Field Name	Williams Number	Williams Acreage (from report)	Tetreau GIS Interpretation of Williams Acreage	Current (2009-13) Acreage	Overall % reduction	Acres lost to river since 1975	% reduction by forest encroachment
McKinnon	1	15	15	8.96	40%	0.86	35%

The boundaries of the McKinnon field have not changed much since 1975; just a slow, steady encroachment around the perimeter. The river is just now starting to erode into the field.

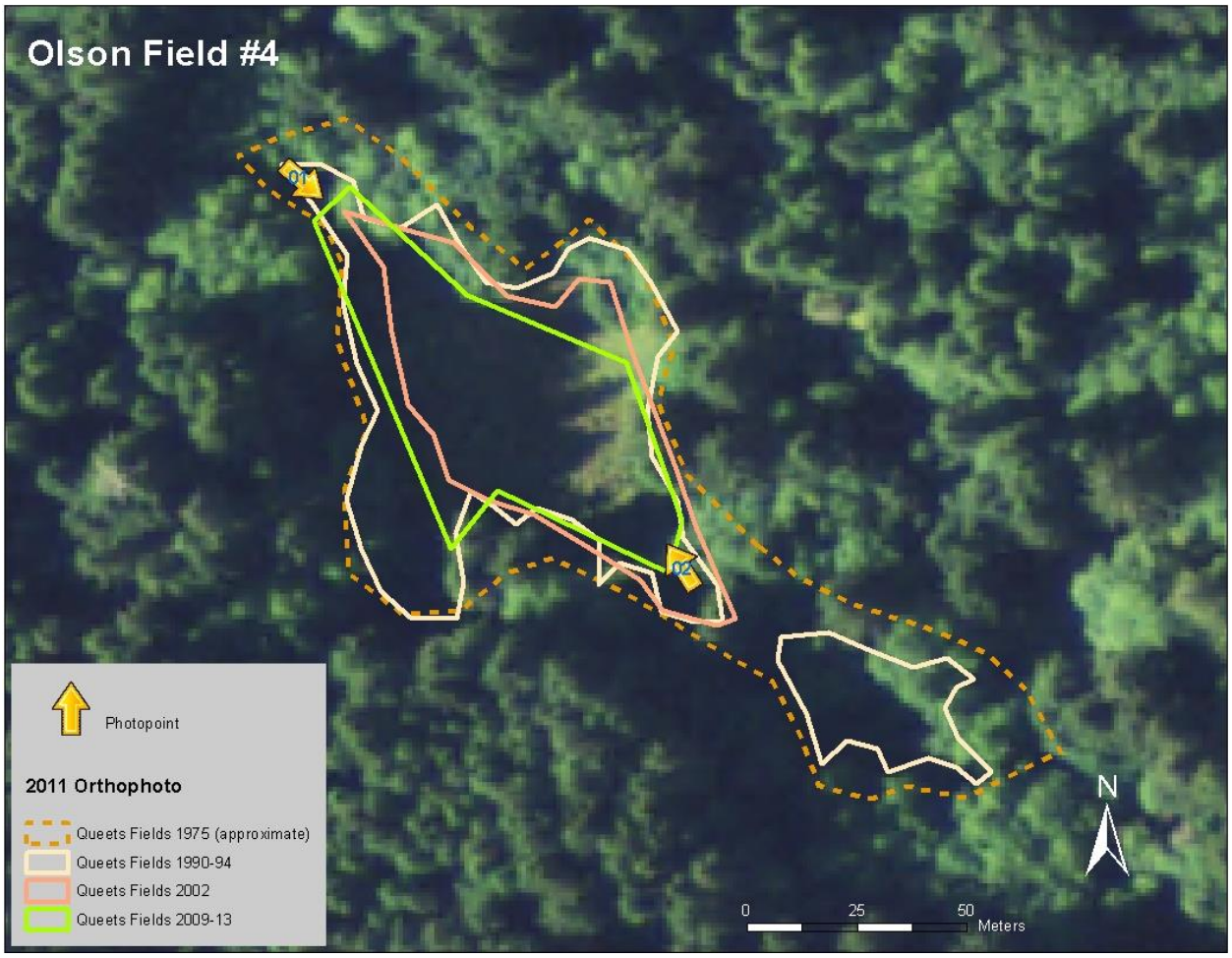


The southeast edge of the site fronts the Queets River. The field is dominated by *Rubus laciniatus*. Even the interior polygon of *Agrostis gigantea* harbors two islands of *Rubus laciniatus* that are each just a bit too small to be considered their own polygons. *Rubus laciniatus* also rings the entire margin of the site, extending under the bordering spruce and alder canopy. *Cirsium arvense* is common throughout, often in dense patches. *Senecio jacobaea* is spotty and not dense, but it too is distributed throughout. There were no cinnabar moth (*Tyria jacobaeae*) larvae found on the *Senecio jacobaea* but they are prevalent across the river at the Olson #5 site. There are no ornamental or holly plants. Woody plants occur more frequently on this site than typical fields. A unique feature of this field is how alders are advancing ahead of the spruce to invade in a more or less uniform band around the perimeter.

Species List

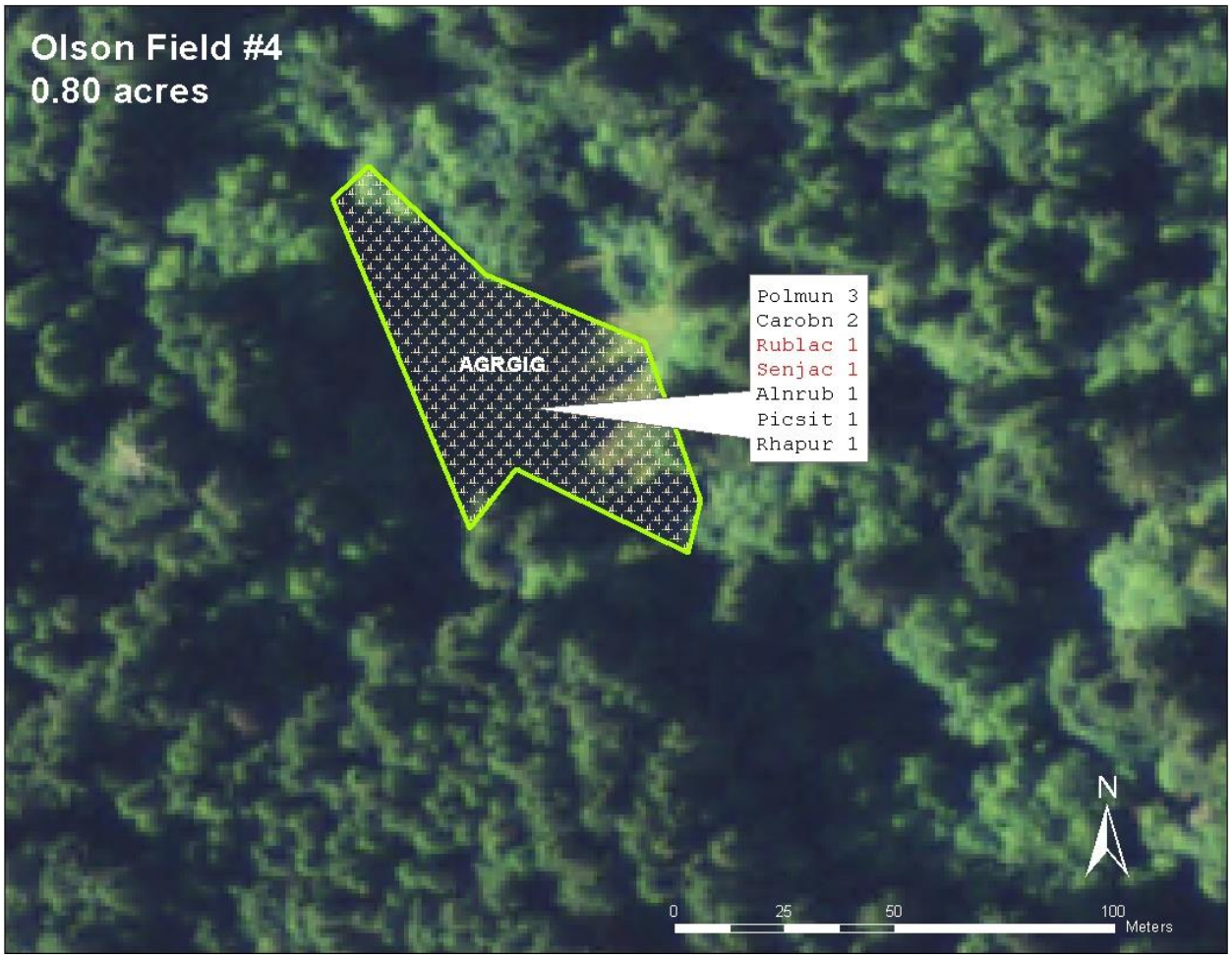
Acer circinatum
Agrostis gigantea
Alnus rubra
Anthoxanthum odoratum
Cirsium arvense
Digitalis purpurea
Elymus glaucus
Holcus lanatus
Hypochaeris radicata
Juncus effuses
Oemleria cerasiformis
Picea sitchensis
Polystichum munitum
Populus balsamifera
Ranunculus repens
Rosa nutkana
Rubus laciniatus
R. spectabilis
R. ursinus
Rumex acetosella
R. crispus
Salix sitchensis
Sambucus racemosa
Scirpus microcarpus
Senecio jacobaea
Stachys cooleyae
Symphoricarpos albus
Trifolium repens

Olson (#4)



Field Name	Williams Number	Williams Acreage (from report)	Tetreau GIS Interpretation of Williams Acreage	Current (2009-13) Acreage	Overall % reduction	Acres lost to river since 1975	% reduction by forest encroachment
Olson #4	4	4	4	0.8	80%	0.00	80%

This small field has lost most of its acreage on the southeast end which is now a deciduous woodland environment with an overstory of mostly *Alnus rubra*.

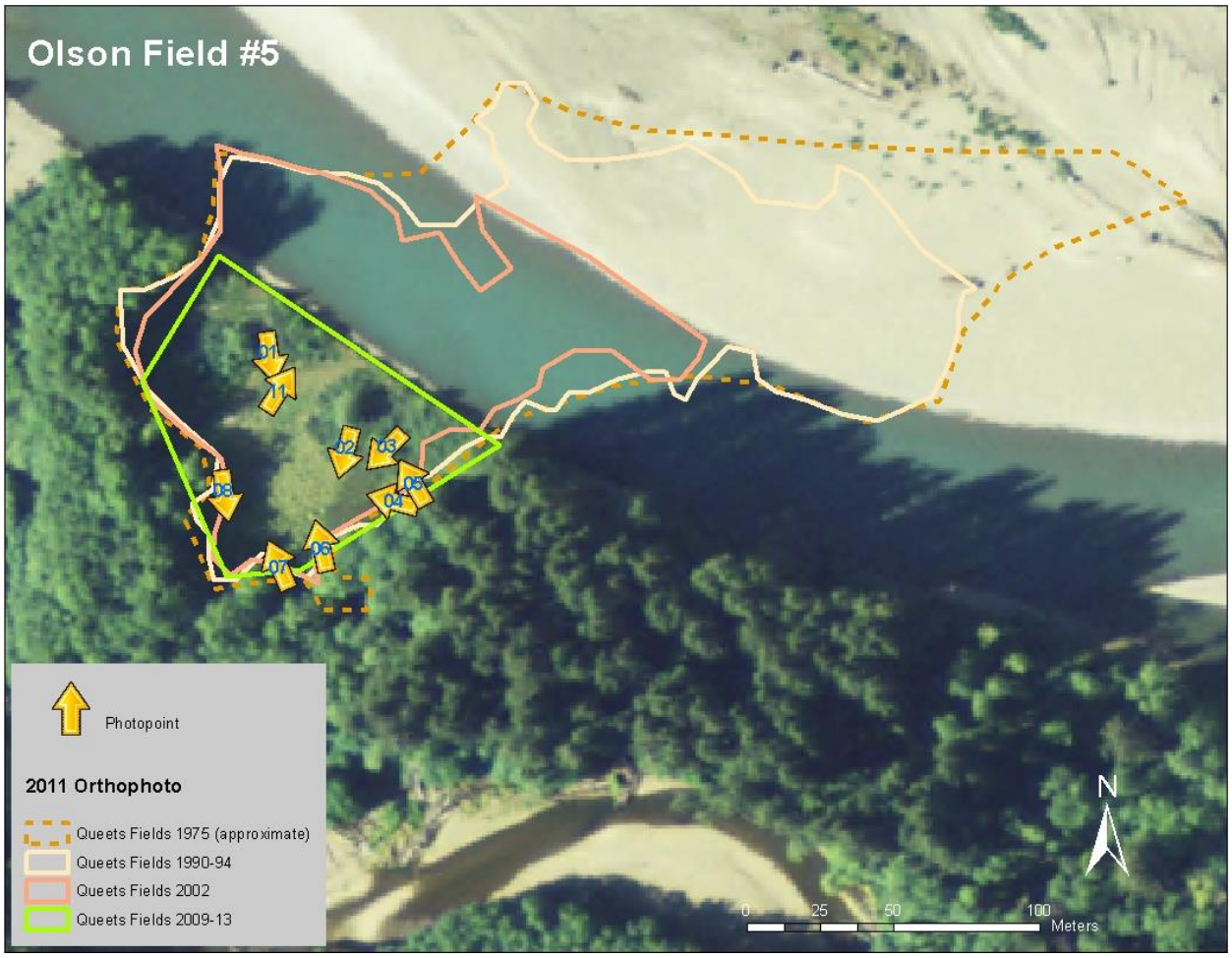


The field is one polygon of *Agrostis gigantea* and associates. Interspersed are small patches of *Polystichum munitum* and *Carex obnupta*. Elk browsing is especially evident on the *Polystichum munitum*. The field perimeter is defined by *Picea sitchensis*, *Alnus rubra* and *Acer macrophyllum* with some *Acer circinatum*. As delineated, the field shape is simplified, omitting small bays of *Agrostis* that are fringed with overhanging branches; these bays are well along to forest conversion. Woody plants found sporadically in the field consist of *Picea sitchensis*, *Alnus rubra* and *Rhamnus purshiana*.

Species List

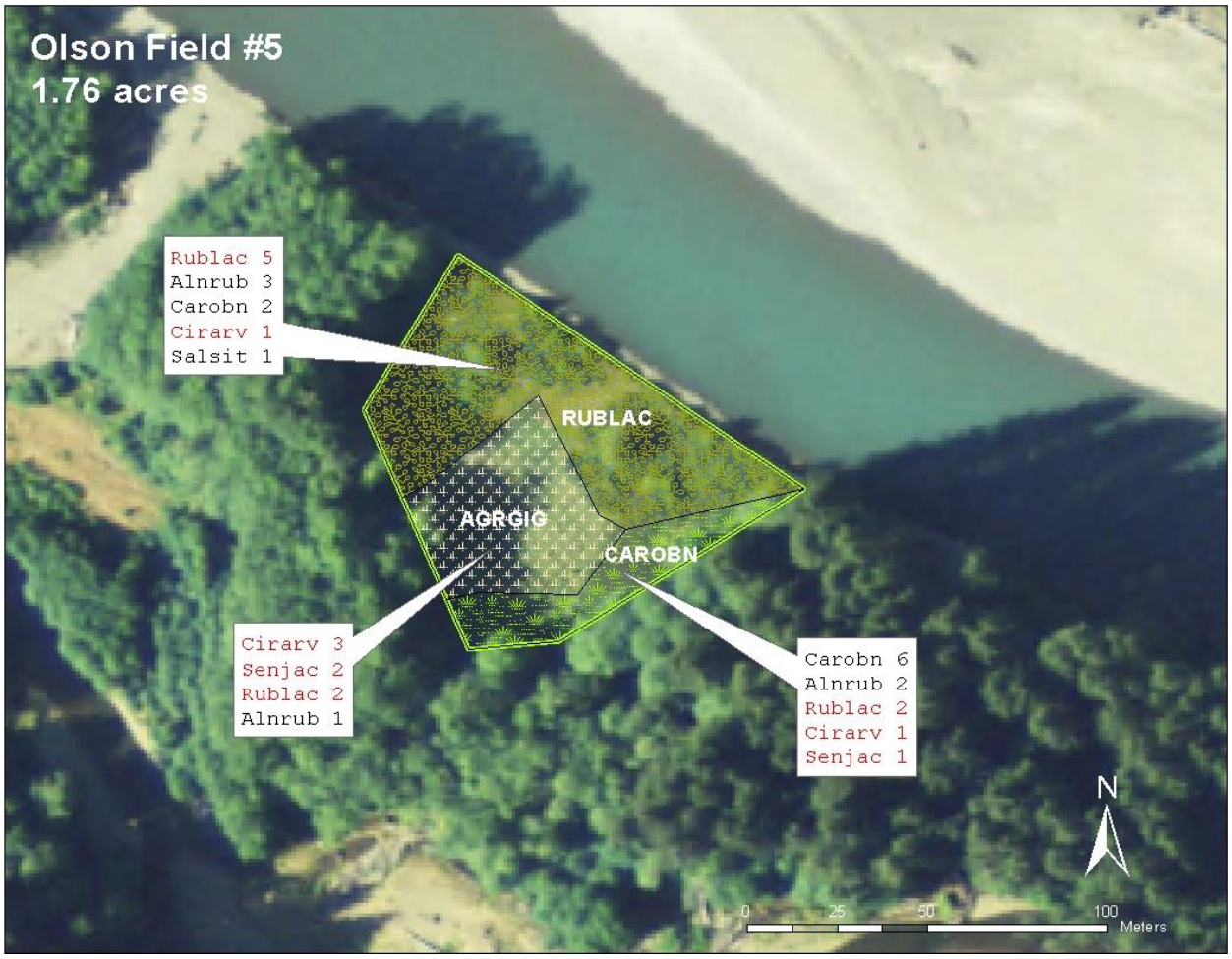
Agrostis gigantea
Anthoxanthum odoratum
Carex obnupta
Claytonia siberica
Digitalis purpurea
Galium triflorum
Holcus lanatus
Hypochaeris radicata
Juncus effusus
Moehringia macrophylla
Oxalis oregana
Prunella vulgaris
Ranunculus repens
Rubus laciniatus
R. spectabilis
R. ursinus
Rumex occidentalis
Scirpus microcarpus
Senecio jacobaea
Stachys cooleyae
Trifolium repens

Olson (#5)



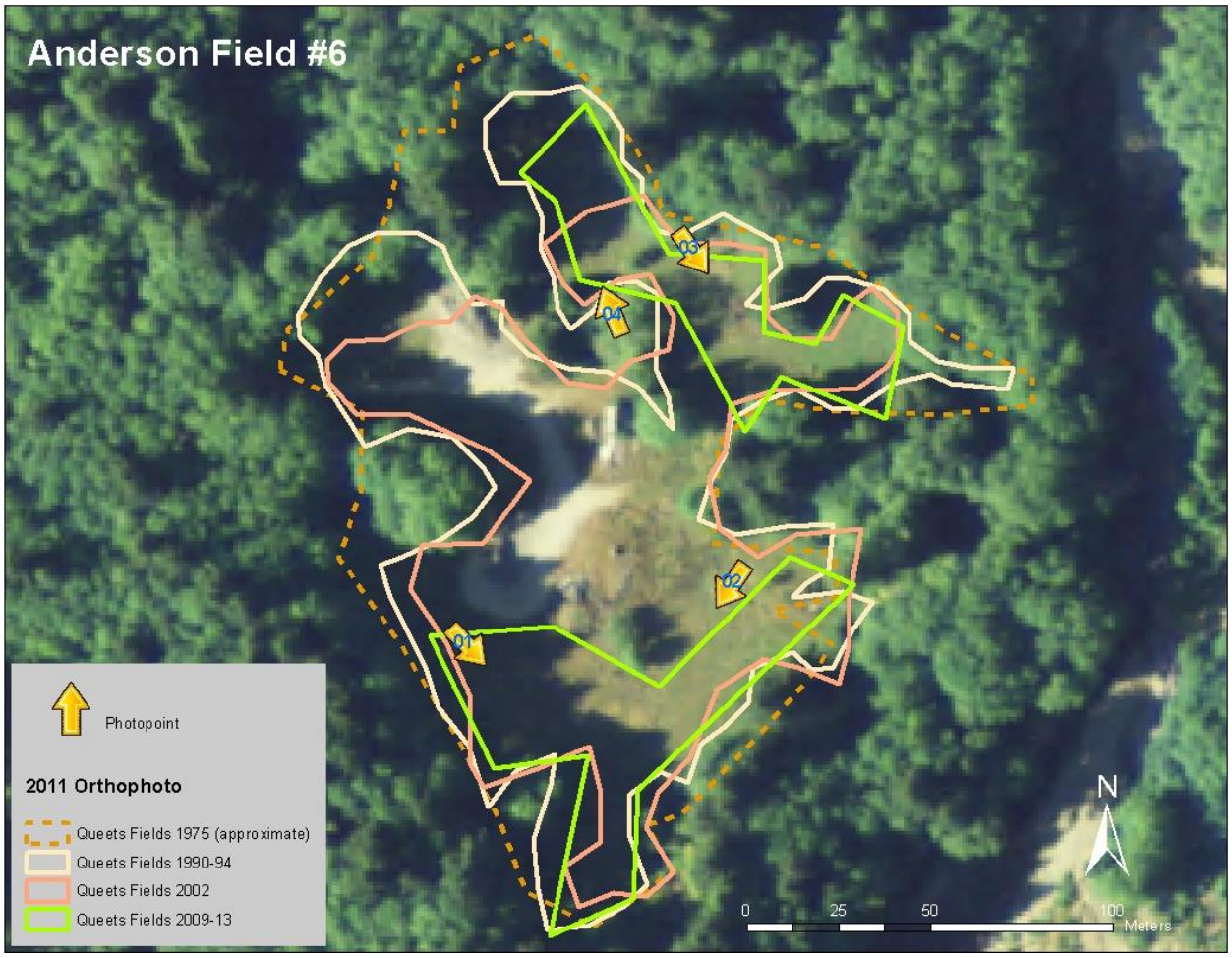
Field Name	Williams Number	Williams Acreage (from report)	Tetreau GIS Interpretation of Williams Acreage	Current (2009-13) Acreage	Overall % reduction	Acres lost to river since 1975	% reduction by forest encroachment
Olson#5	5	8	8	1.76	78%	5.77	6%

Approximately 72% of this field has been lost to the river since 1975, and it is currently on the outside of a bend. There has been very little forest encroachment into what is left of the field.



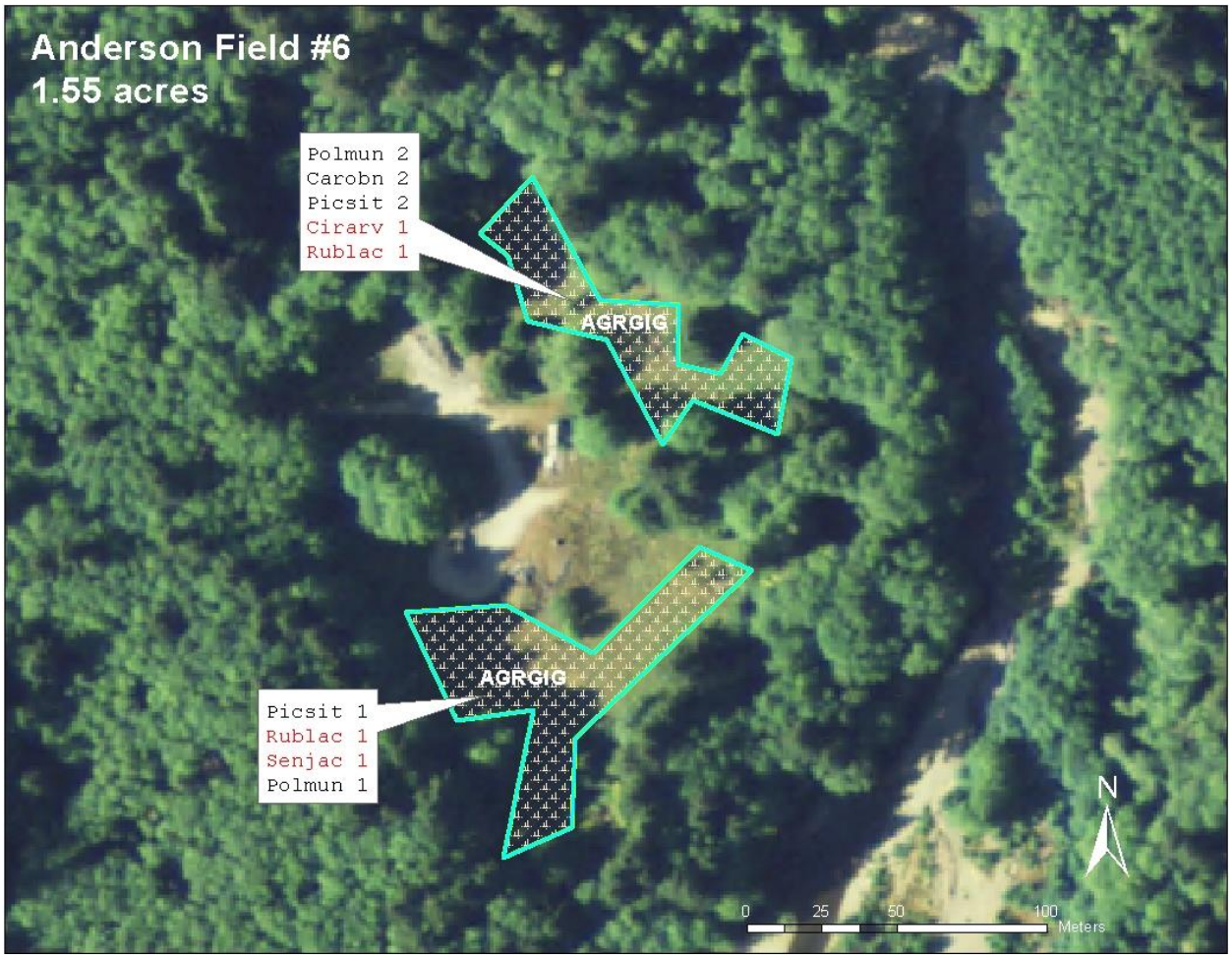
An active bluff face fronts the river along the field's northeastern edge. The remaining field perimeter is defined by *Alnus rubra*. The field is divided into three polygons. The eastern and northern portions are dominated by *Rubus laciniatus*. The southern boundary is dominated by *Carex obnupta*. Most of the center of the field and then to the western edge is dominated by *Agrostis gigantea* and its usual associates. *Cirsium arvense* is spread throughout the field but is most abundant in the *Agrostis* polygon. *Senecio jacobaea* is intermixed in the *Agrostis* and *Carex* polygons. Cinnabar moth larvae are abundant and are controlling many of the *Senecio jacobaea*. *Rubus laciniatus* is found throughout the field. *Alnus rubra* and *Salix sitchensis* are located within the *Rubus laciniatus* polygon as are some small *Agrostis* patches.

Anderson (#6)



Field Name	Williams Number	Williams Acreage (from report)	Tetreau GIS Interpretation of Williams Acreage	Current (2009-13) Acreage	Overall % reduction	Acres being used as maintenance boneyard	% reduction by forest encroachment
Anderson	6	11	11	1.54	86%	2.97	81%

Almost three acres of this former homestead field is currently being used as a maintenance boneyard for the park. When mapping the current field boundaries we avoided any areas that appeared to have been disturbed by maintenance activities. Forest encroachment appears to be slowly occurring around the entire perimeter.

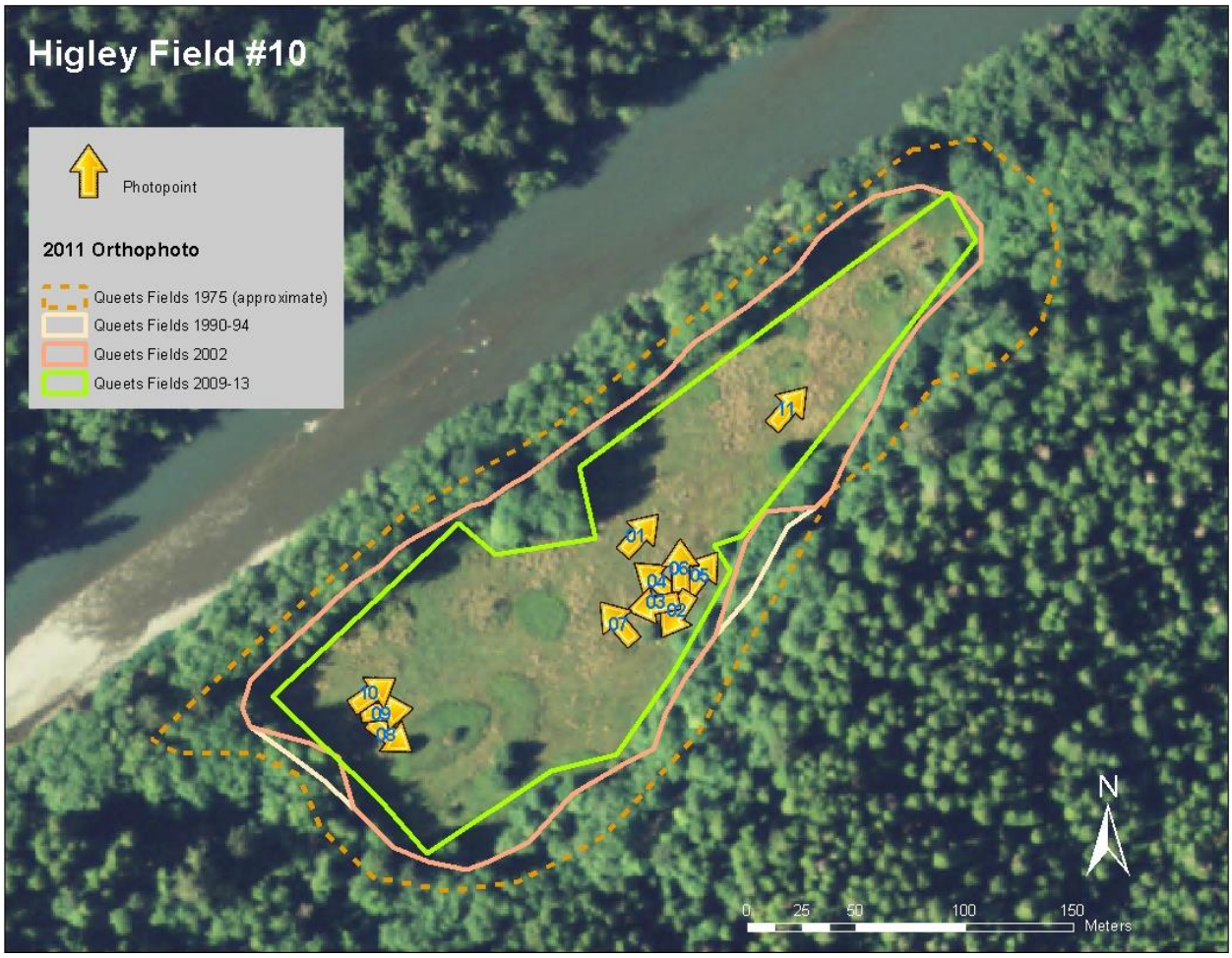


A portion of this field (not included in the survey) serves as an NPS maintenance boneyard. This field is separated into two distinct sections by a stand of *Alnus rubra*, *Picea sitchensis* and *Acer circinatum*. This same species mix is found all along the field perimeter. Each section of the field is comprised of one polygon, both of which are dominated by *Agrostis gigantea*. The northern polygon contains patches of *Polystichum munitum*, *Carex obnupta* and *Picea sitchensis*. Only two plants of *Cirsium arvense* were found. The few *Senecio jacobaea*, *Cirsium vulgare* and *Rubus laciniatus* present had recently been sprayed. The convoluted field perimeter is due to the incursion of *Picea sitchensis*, *Alnus rubra* and *Acer circinatum*. The southern polygon has a similar low occurrence of *Rubus laciniatus*, and *Cirsium arvense* was absent. There appears to be less elk use here than in other fields surveyed.

Species List

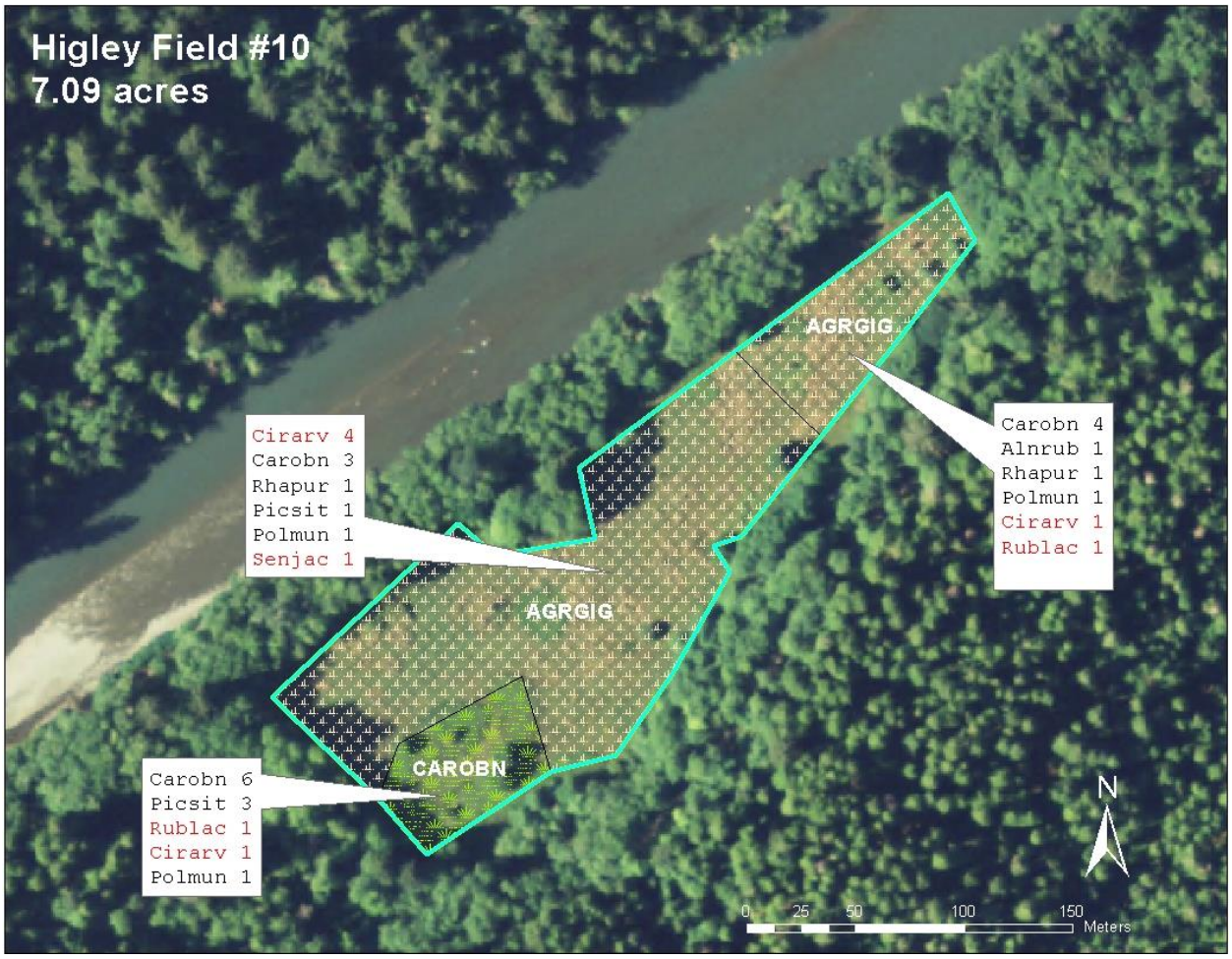
Acer circinatum
Agrostis gigantea
Anthoxanthum odoratum
Athyrium filix-femina
Carex sp.
Cirsium arvense
C. vulgare
Digitalis purpurea
Galium triflorum
Holcus lanatus
Hypochaeris radicata
Juncus balticus
J. effusus
Picea sitchensis
Polypodium glycyrrhiza
Polystichum munitum
Prunella vulgaris
Ranunculus repens
Rubus laciniatus
R. spectabilis
R. ursinus
Rumex acetosella
R. occidentalis
Sambucus racemosa
Scirpus microcarpus
Senecio jacobaea
Trifolium repens

Higley (#10)



Field Name	Williams Number	Williams Acreage (from report)	Tetreau GIS Interpretation of Williams Acreage	Current (2009-13) Acreage	Overall % reduction	Acres lost to river since 1975	% reduction by forest encroachment
Higley	10	21	14	7.09	49%	0.00	49%

Also known as the Donaldson homestead, this field is located along a seemingly stable, straight stretch of river, thus although it is close to the bank it has not lost any acreage to erosion. The homestead was occupied for 55 years (1889 to 1944), the longest of any of major Queets homesteads. This is a prominent and easily-accessible field and has been included in several surveys and studies. Williams, Riege and del Moral all looked carefully at this site, and it has been surveyed by cultural resource personnel as well. The old house site is very apparent and is surrounded by a variety of fruit trees and ornamental species, including a coast redwood tree. Forest encroachment has been uniformly slow around the entire perimeter.



The forest bordering the field is composed of *Alnus rubra*, *Acer macrophyllum* and *Picea sitchensis*. Young, vigorous (height about 25') *Picea sitchensis* are along portions of the perimeter and within the *Carex obnupta* polygon. Dense *Carex obnupta* is toward the middle of the field and reaches down to the southern edge. It is also found throughout the site in the *Agrostis* dominated type with greater densities toward the east. The height of the *Carex obnupta* varies from two feet to four feet and appears to reflect a moisture gradient. *Agrostis gigantea* and its usual associates (see species list) dominate the majority of the field. The *Agrostis* dominated polygons represent a mixture of primarily exotic grasses and forbs. *Cirsium arvense* occurs throughout, being more abundant on the western side. *Senecio jacobaea* is just beginning to establish itself here. A small number of cinnabar moth larvae were on some of the *Senecio jacobaea*.

Species List

Agrostis gigantea
Anthoxanthum odoratum
Athyrium filix-femina
Carex obnupta
Cirsium arvense
C. vulgare
Digitalis purpurea
Galium triflorum
Holcus lanatus
Hypochaeris radicata
Lotus pedunculatus
Mimulus guttatus
Polystichum munitum
Ranunculus repens
Rhamnus purshiana
Rubus laciniatus
R. spectabilis
R. ursinus
Sambucus racemosa
Senecio jacobaea
Stachys cooleyae
Tolmiea menziesii
Trifolium repens

Streater (#17)

The past boundaries of this small field were not mapped due to inadequate photographs.

Field Name	Williams Number	Williams Acreage (from report)	Tetreau GIS Interpretation of Williams Acreage	Current (2009-13) Acreage	Overall % reduction	Acres lost to river since 1975	% reduction by forest encroachment
Streater #17	17	4.5	5	0.57	89%	0.00	89%

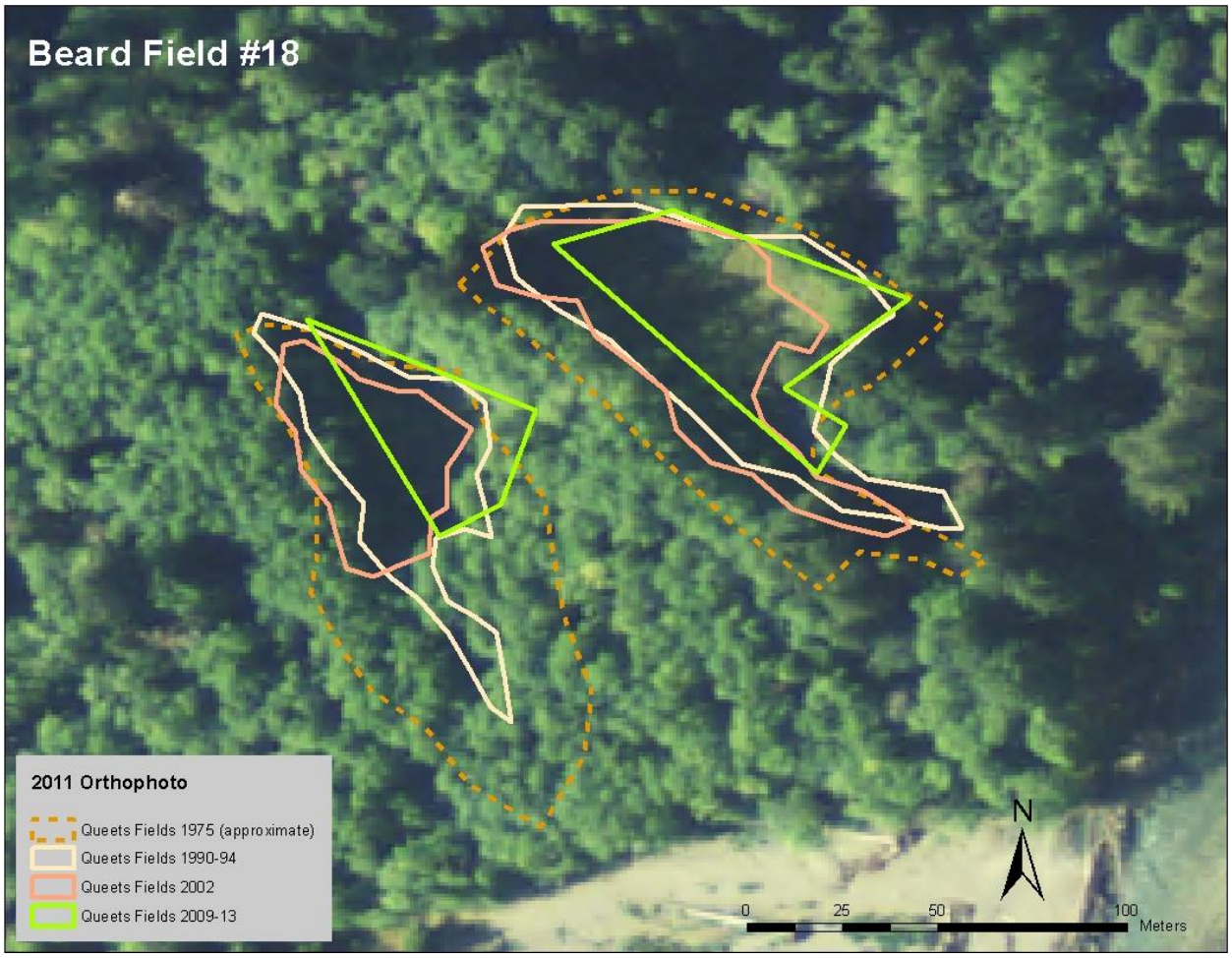
This small field remnant is being swallowed up by the forest and is currently dominated by *Pteridium aquilinum* and a large tangle of *Ilex aquifolia*. Tucked in the forest, it is difficult to find.

There is a large tangle in the center of *Ilex aquifolia* with *Malus fusca* and *Rhamnus pursiana*. Additional *Ilex* is scattered all around the perimeter of the field, along with mature *Picea sitchensis*, *Alnus rubra* and *Rhamnus purshiana.* Within the field, *Pteridum aquilinum* is dominant.

Species List

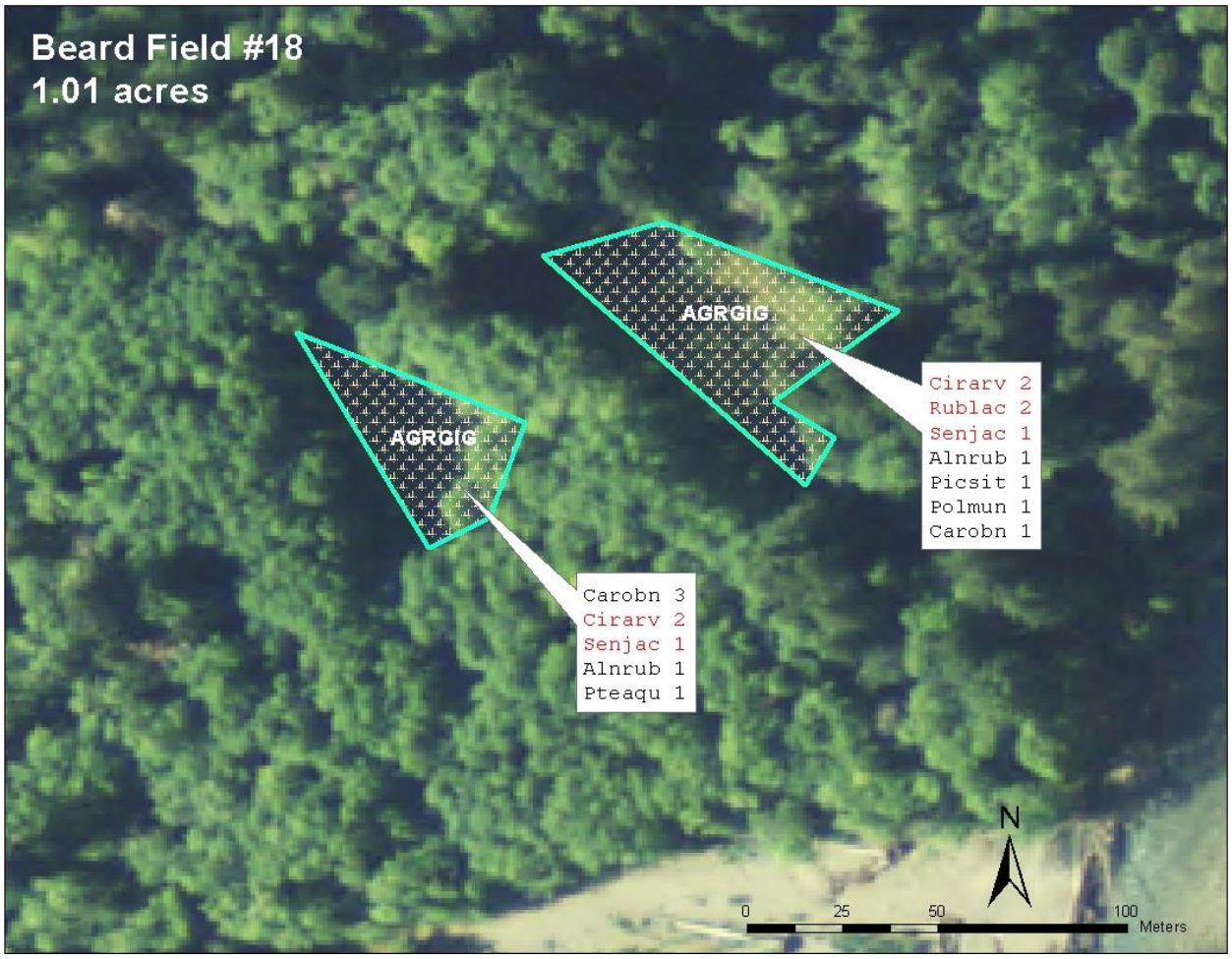
Agrostis gigantea
Anthoxanthum odoratum
Carex obnupta
Cerstium sp.
C. vulgare
Galium sp.
Holcus lanatus
Hypochaeris glabra
Polmonium munitum
Polystichum munitum
Prunella vulgaris
Ranunculus repens
Rhamnus purshiana
Rubus laciniatus
R. spectabilis
R. ursinus
Rumex acetosella
Sambucus racemosa
Stachys cooleyae
Trifolium repens

Beard (#18)



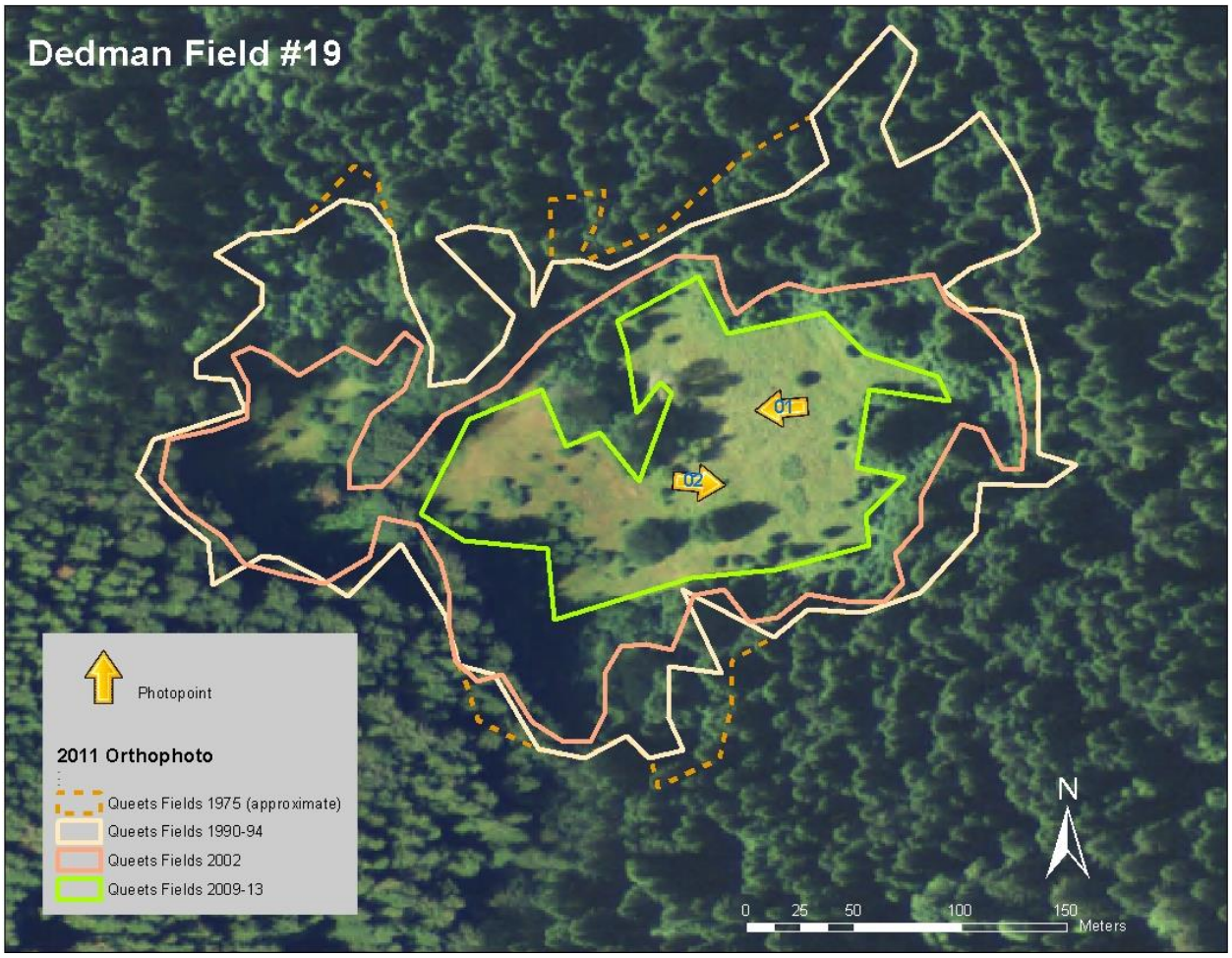
Field Name	Williams Number	Williams Acreage (from report)	Tetreau GIS Interpretation of Williams Acreage	Current (2009-13) Acreage	Overall % reduction	Acres lost to river since 1975	% reduction by forest encroachment
Beard	18	1.5	3.3	1.01	69%	0.00	69%

These two small fields have lost most of their acreage on the southern end where the field has been overtopped by *Alnus rubra* forming an open deciduous woodland environment, similar to the southeast end of Olson #4. The GPS positions from our survey appear to the shifted noticeably to the northeast as can be seen in the figure above.



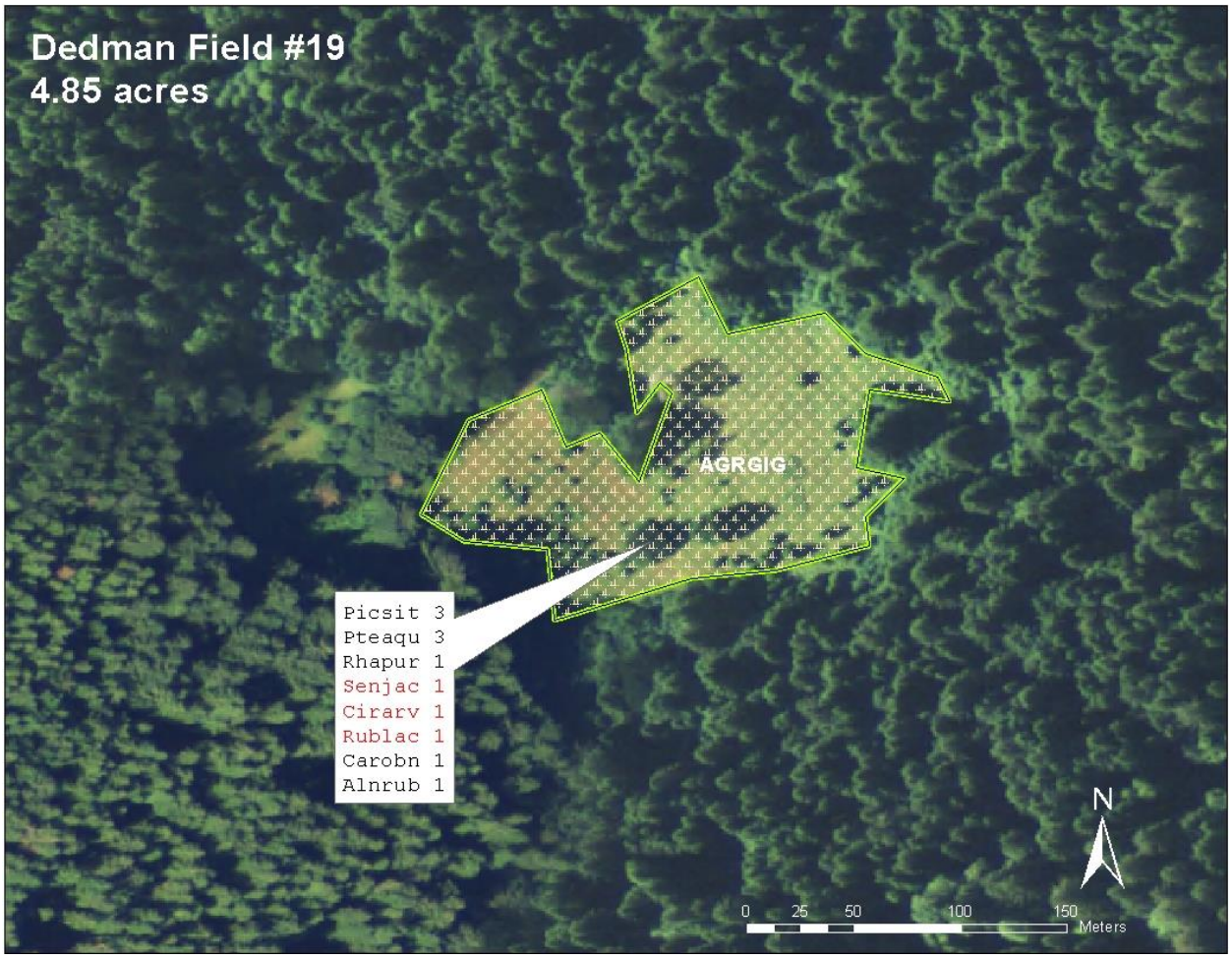
The perimeters consist of mature *Alnus rubra* with young ones also, a few mature *Picea sitchensis* with young ones 10' to 50', and a couple of mature *Acer macrophyllum* and *Acer circinatum*. The *Agrostis* dominated fields are composed of the usual suspects. *Agrostis gigantea* and *Anthoxanthum odoratum* dominate, with patches of *Holcus lanatus*. *Cirsium arvense* is distributed throughout both fields, while *Rubus laciniatus* occurs only in the eastern one where it is associated with a patch of *Carex obnupta* (approx. 50' x 60'). Other species include *Trifolium repens*, *Cerastium* sp., *Hypochaeris glabra*, *Prunella vulgaris*, *Lotus corniculatus*, *Ranunculus repens*, *Juncus effusus* and *Rumex acetosella*.

Dedman (#19)



Field Name	Williams Number	Williams Acreage (from report)	Tetreau GIS Interpretation of Williams Acreage	Current (2009-13) Acreage	Overall % reduction	Acres lost to river since 1975	% reduction by forest encroachment
Dedman	19	21	21	4.85	77%	0.00	77%

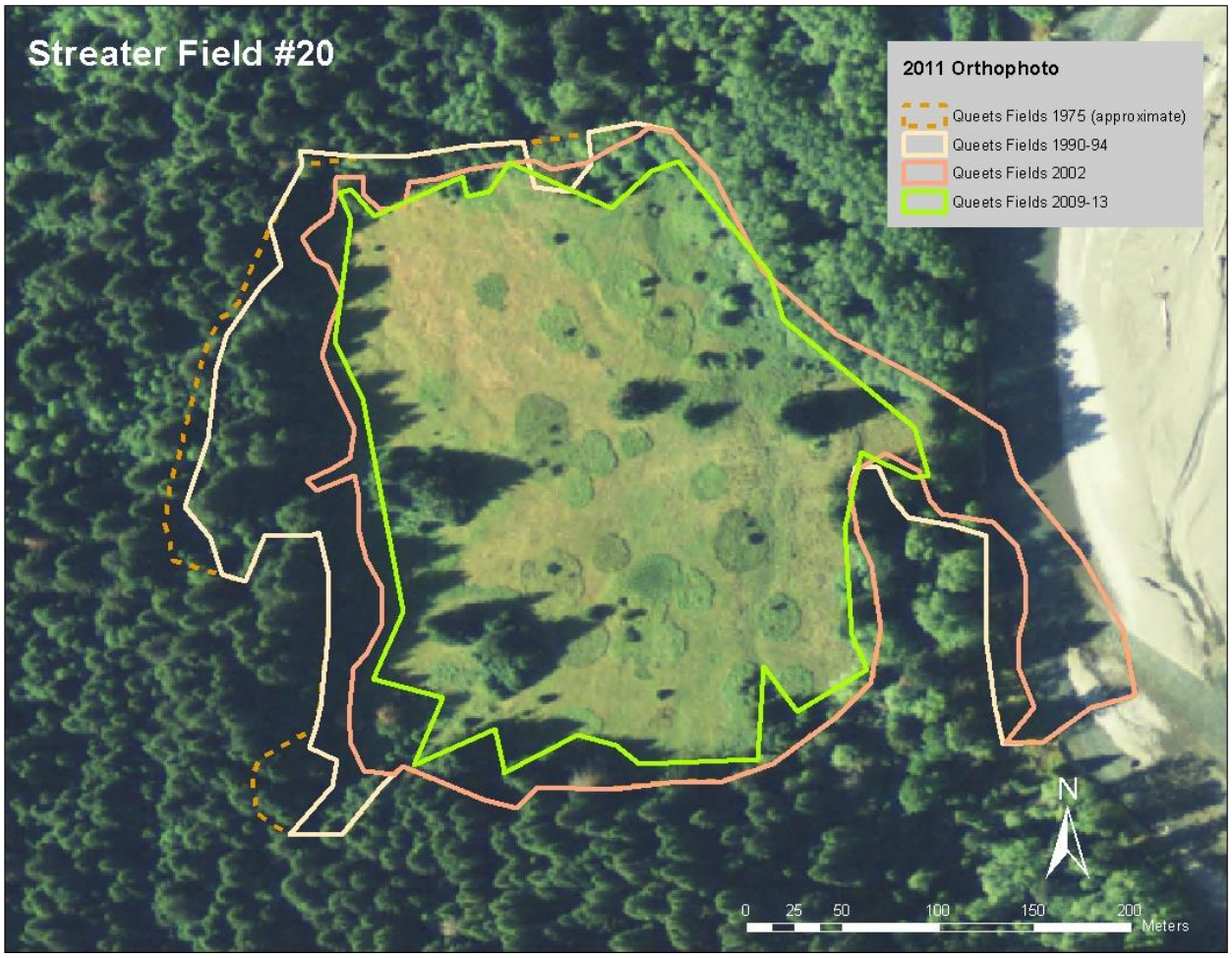
This is one of the unique fields that started out large but has had substantial forest encroachment since 1975 losing 77% of its acreage to the invading spruce forest. There is still a small open area at the western end but it is cut off from the main field and was too small to map as an individual field. Unfortunately there is not much information regarding the history of this field in Williams' research materials that is helpful in determining why so much forest encroachment has occurred here as compared to most other fields. There are nine heritage fruit trees in the field including apple, cherry and pear. Access to the field is easy when approaching from Streater #20.



The western-most lobe of the former field has been completely cut off by *Picea sitchensis* and was not included a part of the field in our mapping.

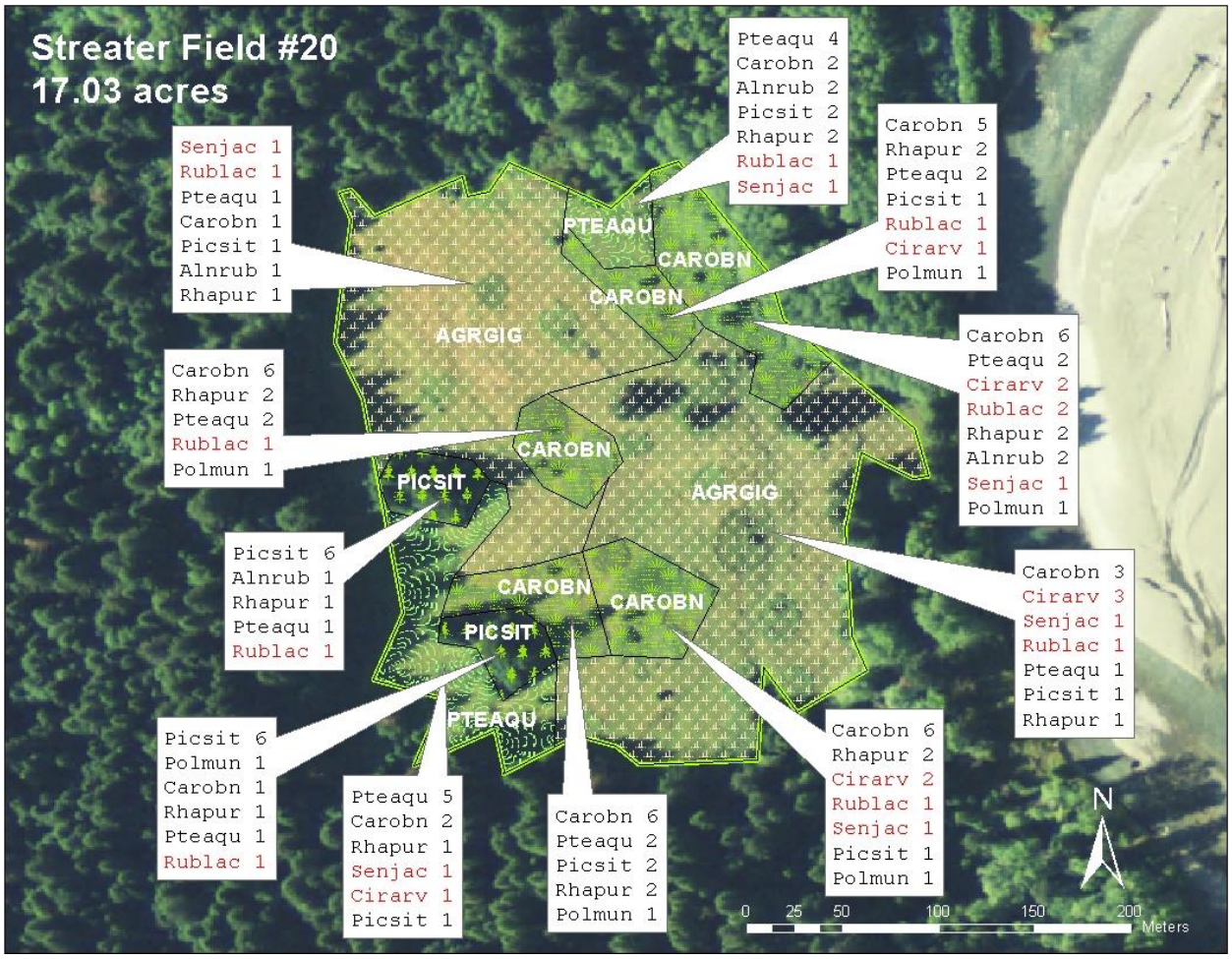
The southwest portion of the field has a perimeter mature and young *Picea sitchensis* (20'-40' tall young trees). *Rhamnus purshiana* occurs all along the perimeter and is invading the open area which is dominated by *Pteridium aquilinum* (5'-6' tall) with *Agrostis gigantea* under that, along with *Ranunculus repens*. To the northeast, *Pteridium aquilinum* is invading the grass but the grass dominates the center; *Pteridium* is mostly on the margins and around invading *Picea sitchensis*. There is one small patch (30'x20') of *Carex obnupta* which harbors two individuals of *Rubus laciniatus*. The overall perimeter is young, dense *Picea sitchensis* 1'-25' tall (with some *Tsuga heterophylla*), along with *Rhamnus purshiana*.

Streater (#20)



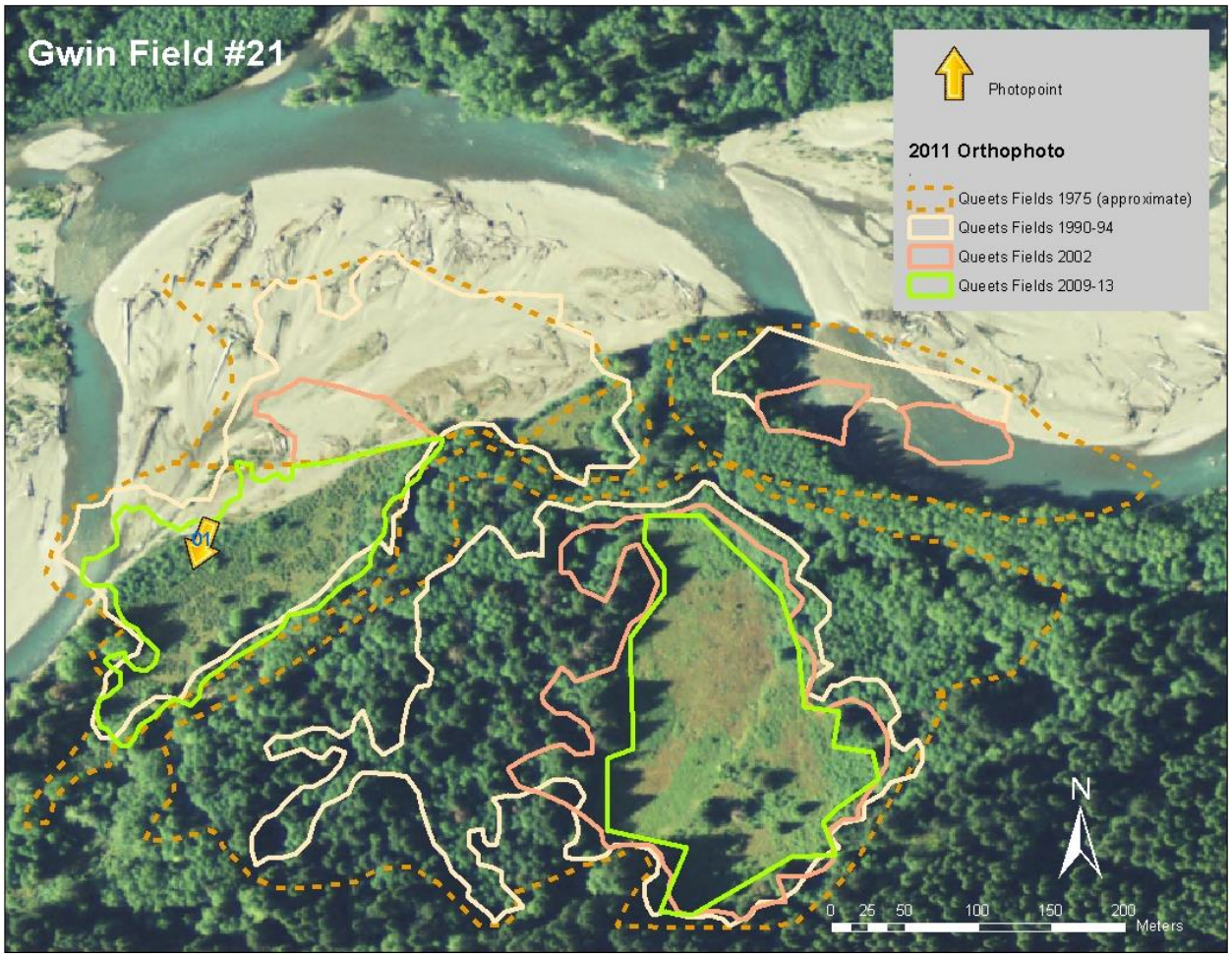
Field Name	Williams Number	Williams Acreage (from report)	Tetreau GIS Interpretation of Williams Acreage	Current (2009-13) Acreage	Overall % reduction	Acres lost to river since 1975	% reduction by forest encroachment
Streater #20	20	23	27.9	17.03	39%	1.83	32%

This is currently the largest of the remaining homestead fields. It is well-known to park managers and many members of the public. It was occupied for 29 years (1891 to 1920) and held a prominent place in Queets history as the location of "Streater's Crossing". A family cemetery located in the field is apparently still maintained by Streater descendants. Riege and del Moral both used this field as a study site as the forest encroachment here has been limited primarily to a modest amount along the western boundary. The patches of sedge within the field have expanded notably since 1975.



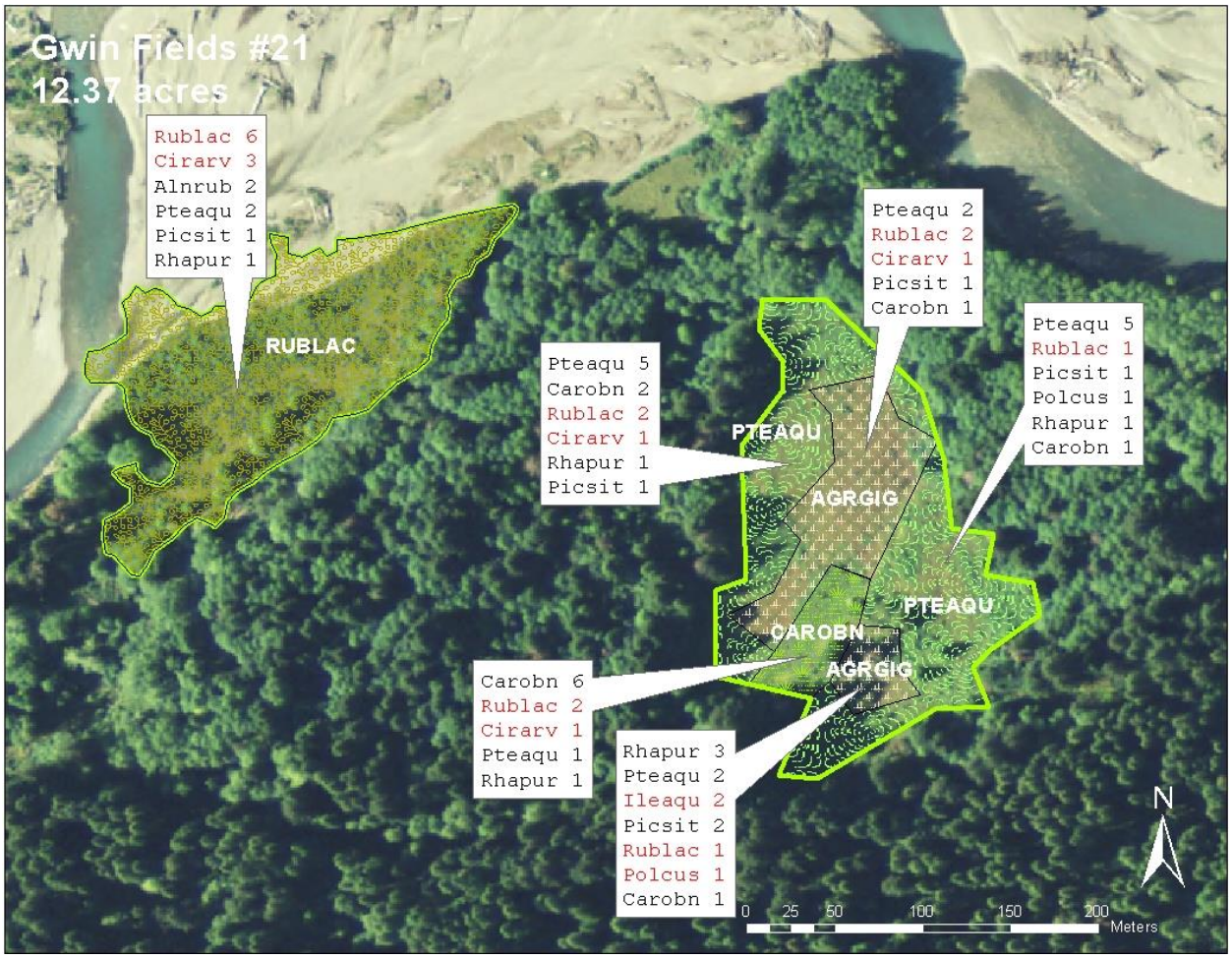
(No overall vegetation narrative recorded.)

Gwin (#21)



Field Name	Williams Number	Williams Acreage (from report)	Tetreau GIS Interpretation of Williams Acreage	Current (2009-13) Acreage	Overall % reduction	Acres lost to river since 1975	% reduction by forest encroachment
Gwin SE	21	ND	30.47	7.1	77%	0.00	77%
Gwin SW	21	ND	15.86	5.27	67%	8.48	13%

There were originally three fields here, and now there is only one-and-a-third. This homestead had the second-longest occupancy at 54 years (1890 to 1944) and was also a prominent place in the history of the Queets valley. The northeast field has been almost entirely washed away by the river, and what is left has complete canopy closure of mature alder. Much of the southwestern (or western) field has also been lost to the river, and what is left is a dense thicket of *Rubus laciniatus* (we were not able to map it with the GPS and thus had to rely on the orthophotos in the GIS). The southeastern (or southern) field is similar the Dedman field in that there has been extensive forest encroachment since 1975. Williams provided more details about the history of this site indicating that the encroachment has occurred primarily in areas that were never completely cleared or cultivated. A small orchard of apple trees still exists near the former house site.



The southeast field is divided into an upper and a lower terrace. The upper terrace was the site of the homestead buildings and small orchard. The perimeter is primarily *Pteridium aquilinum*, with grasses dominating the core of the field. There are small patches of *Carex obnupta*, and trees are starting to invade (mostly *Rhamnus* and some *Picea*). There is evidence of some burrowing animals, and elk droppings are very infrequent. Holly is present in forest on the south side of the upper terrace, and also under the *Picea* on the lower terrace. We also noted a few mature *Picea* nearby that are dead or dying.

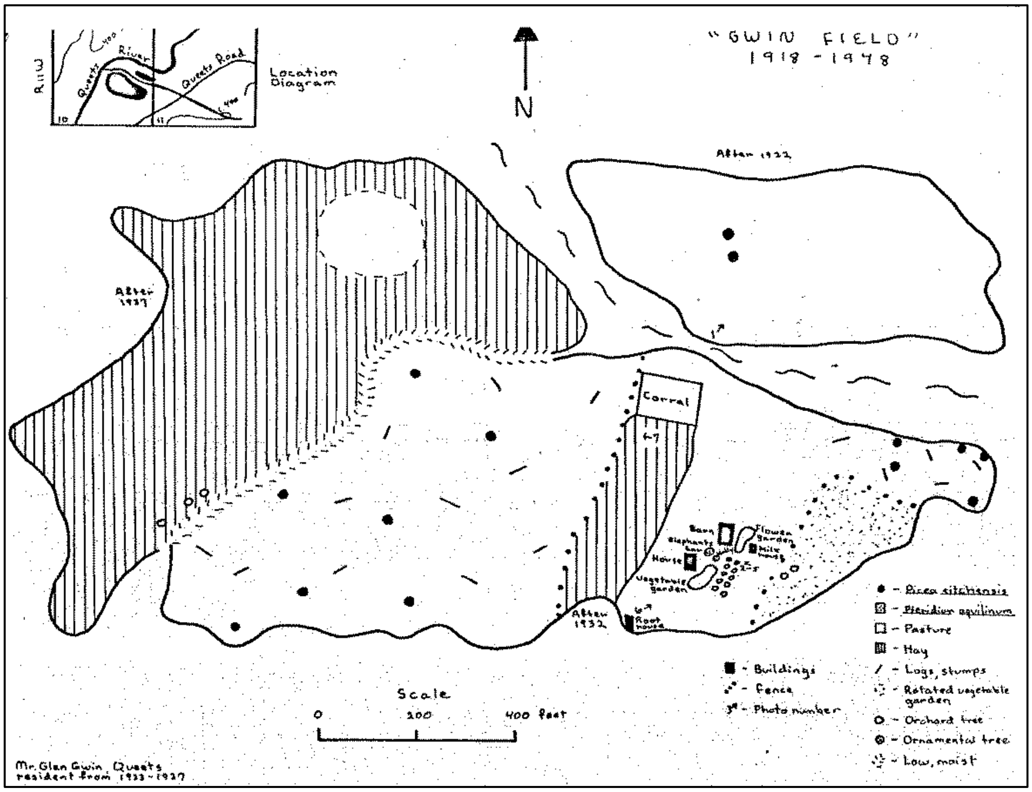
Gwin SE Field, Forest Encroachment

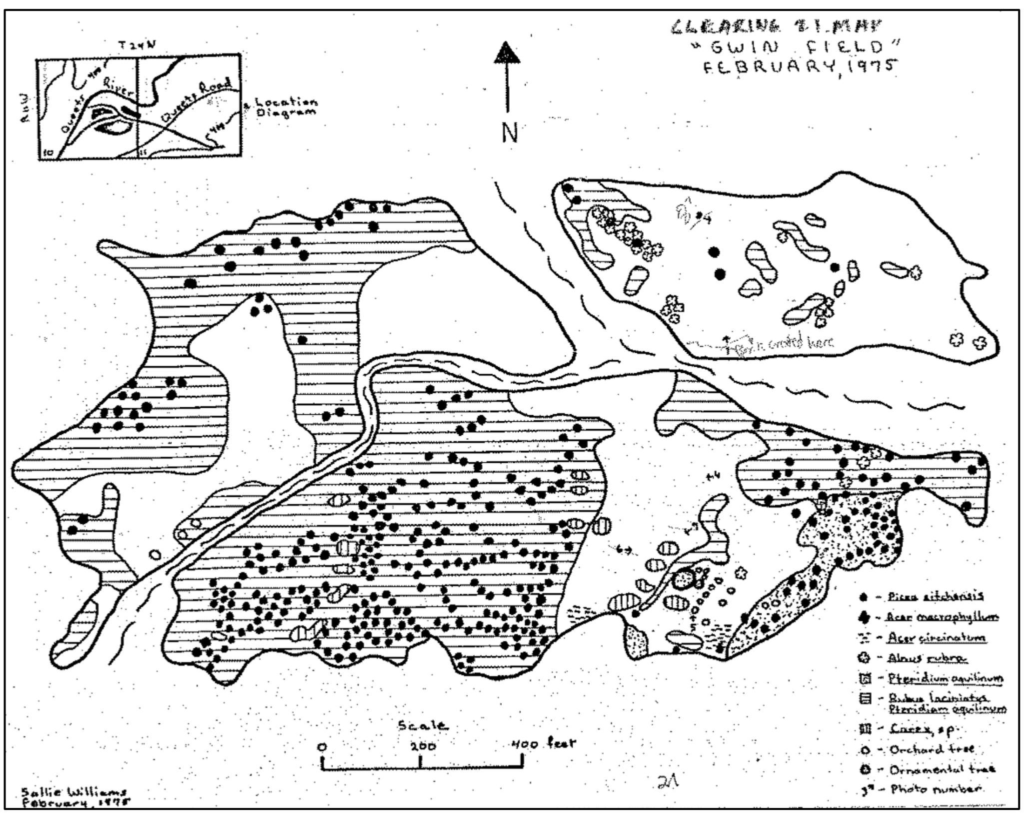
The southeast field of the Gwin homestead warrants additional discussion due to the extensive forest encroachment that has occurred since 1975. The greatest loss of field acreage has occurred where numerous young *Picea sitchensis* were visible in Williams' 1975 oblique aerial photos (see photo pair below).

2011 orthophoto

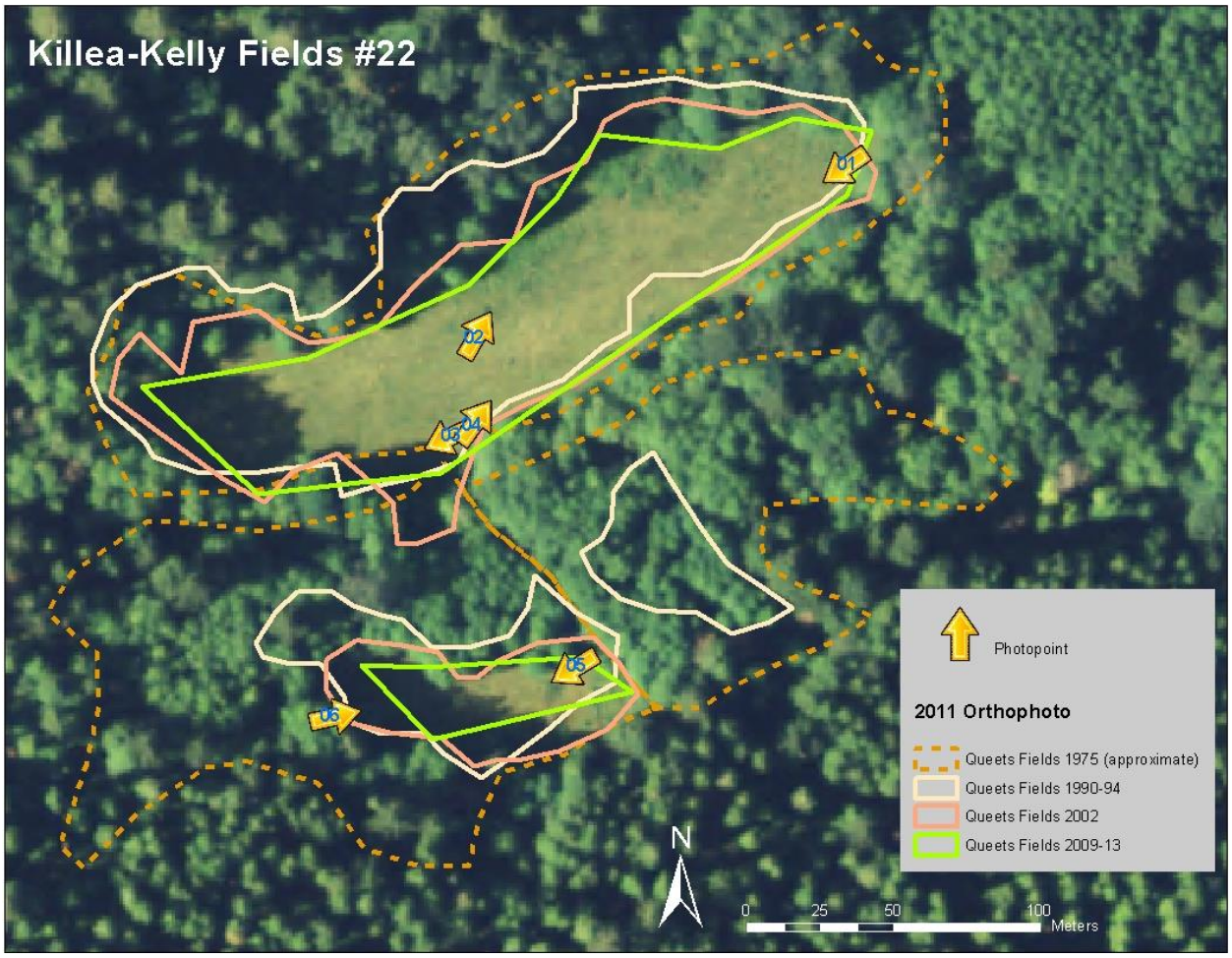
Williams' 1975 oblique aerial (inverted for easier comparison)

Prior land use appears to have had a significant impact on the rate of succession and forest encroachment following cessation of agricultural use of the field. Areas that were never completely cleared of native vegetation and thus were never fully cultivated for pasture planting or other crop production have shown the greatest recovery. Williams's sketch maps (following page) show that large portions of the SE Gwin field were left with logs, stumps and *Picea sitchensis* in 1918 to 1948. By 1975 those same areas had high densities of *Rubus laciniatus*, *Pteridium aquilinum* and *Picea sitchensis*. Those areas are now under forest canopy.


"GWIN FIELD"
1918 - 1948
Location Diagram
Queets River
Queets Road
R11W
N
After 1932
After 1937
Corral
Barn
Flower garden
House
Milk house
Vegetable garden
Root house
• - Picea sitchensis
Pteridium aquilinum
Pasture
Hay
Logs, stumps
Rotated vegetable garden
Orchard tree
Ornamental tree
Low, moist
Buildings
Fence
Photo number
Scale
0
200
400 feet
Mr. Glen Gwin, Queets resident from 1933-1937

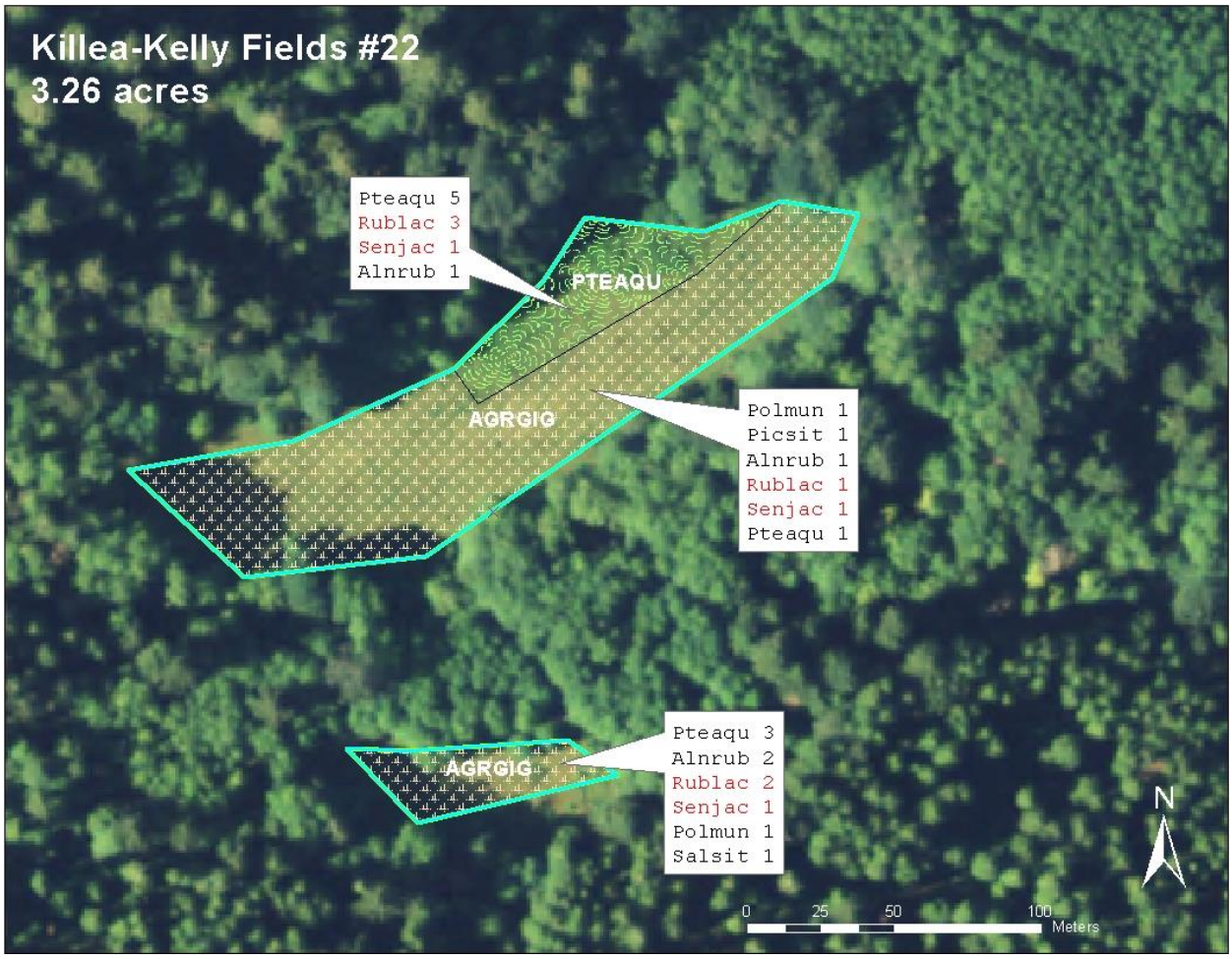

"GWIN FIELD"
FEBRUARY, 1975
T24N
R11W
Location Diagram
Queets River
Queets Road
N
• - Picea sitchensis
Acer macrophyllum
Acer circinatum
Alnus rubra
Pteridium aquilinum
Rubus laciniatus
Pteridium aquilinum
Carex, sp.
Orchard tree
Ornamental tree
Photo number
Scale
0
200
400 feet
Sallie Williams
February, 1975

Killea-Kelly (#22)



Field Name	Williams Number	Williams Acreage (from report)	Tetreau GIS Interpretation of Williams Acreage	Current (2009-13) Acreage	Overall % reduction	Acres lost to river since 1975	% reduction by forest encroachment
Killea-Kelly	22	11	12.5	3.2	74%	0.00	74%

The Killea-Kelly homestead was another prominent Queets location and was occupied for 52 years (1899 to 1941). Like the southeastern Gwin field, the two southern fields at this site are now almost completely covered by forest canopy and it is likely that they were also not completely cleared or heavily cultivated. The northern field, which was the main hay production field, has had only moderate forest encroachment, mostly along the northeastern boundary.



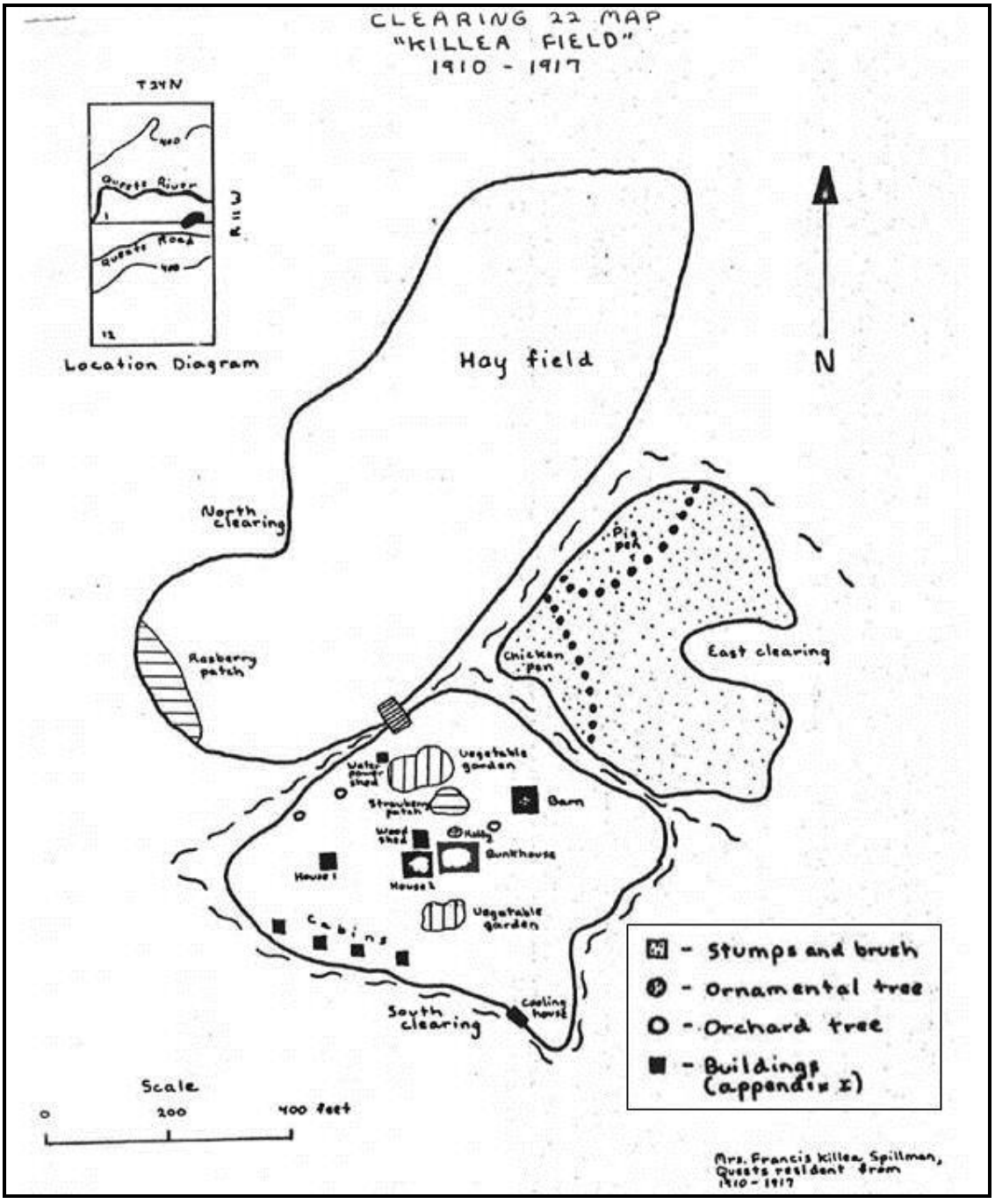
The site is comprised of two separate fields. A narrow band of spruce and alder divide the northern and southern portions. The northern section is described as two polygons: one *Agrostis gigantea* and the other *Pteridium aquilinum*. The *Agrostis* type contains the usual mix of herbaceous associates, some browsed *Polystichum munitum*, and a sporadic distribution of *Senecio jacobaea* and *Rubus laciniatus*. The *Pteridium aquilinum* dominated polygon contains much more *Rubus laciniatus* along with patches of the *Agrostis* mix. The smaller southern field is dominated by *Agrostis gigantea* with *Pteridium aquilinum* contributing roughly 20% cover. The perimeter of the field is defined by older *Acer macrophyllum* and *Populus balsamifera* ssp. *trichocarpa*, some *Acer circinatum*, young *Alnus rubra* and *Picea sitchensis* which are encroaching into the field. Notably absent from this site are *Cirsium arvense* and *Rhamnus purshiana*.

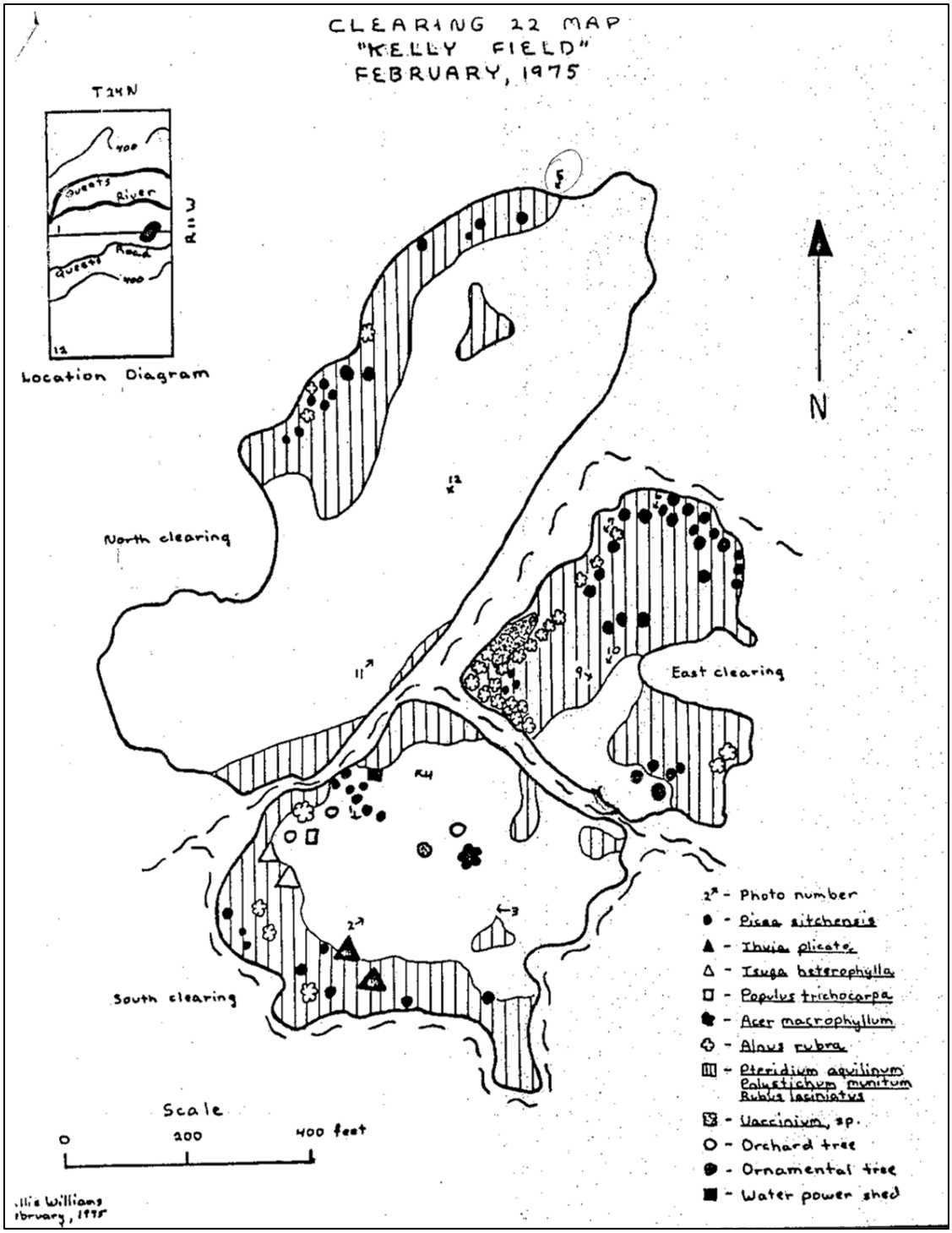
Species List

Agrostis gigantea
Alnus rubra
Anthoxanthum odoratum
Athyrium filix-femina
Cirsium vulgare
Dactylis glomerata
Digitalis purpurea
Elymus glaucus
Holcus lanatus
Hypochaeris radicata
Juncus balticus
J. effusus
Moehringia macrophylla
Ilex aquifolium
Picea sitchensis
Plantago lanceolata
Polystichum munitum
Prunella vulgaris
Pteridium aquilinum
Ranunculus repens
Rubus laciniatus
R. spectabilis
R. ursinus
Rumex acetosella
Senecio jacobaea
Trifolium repens

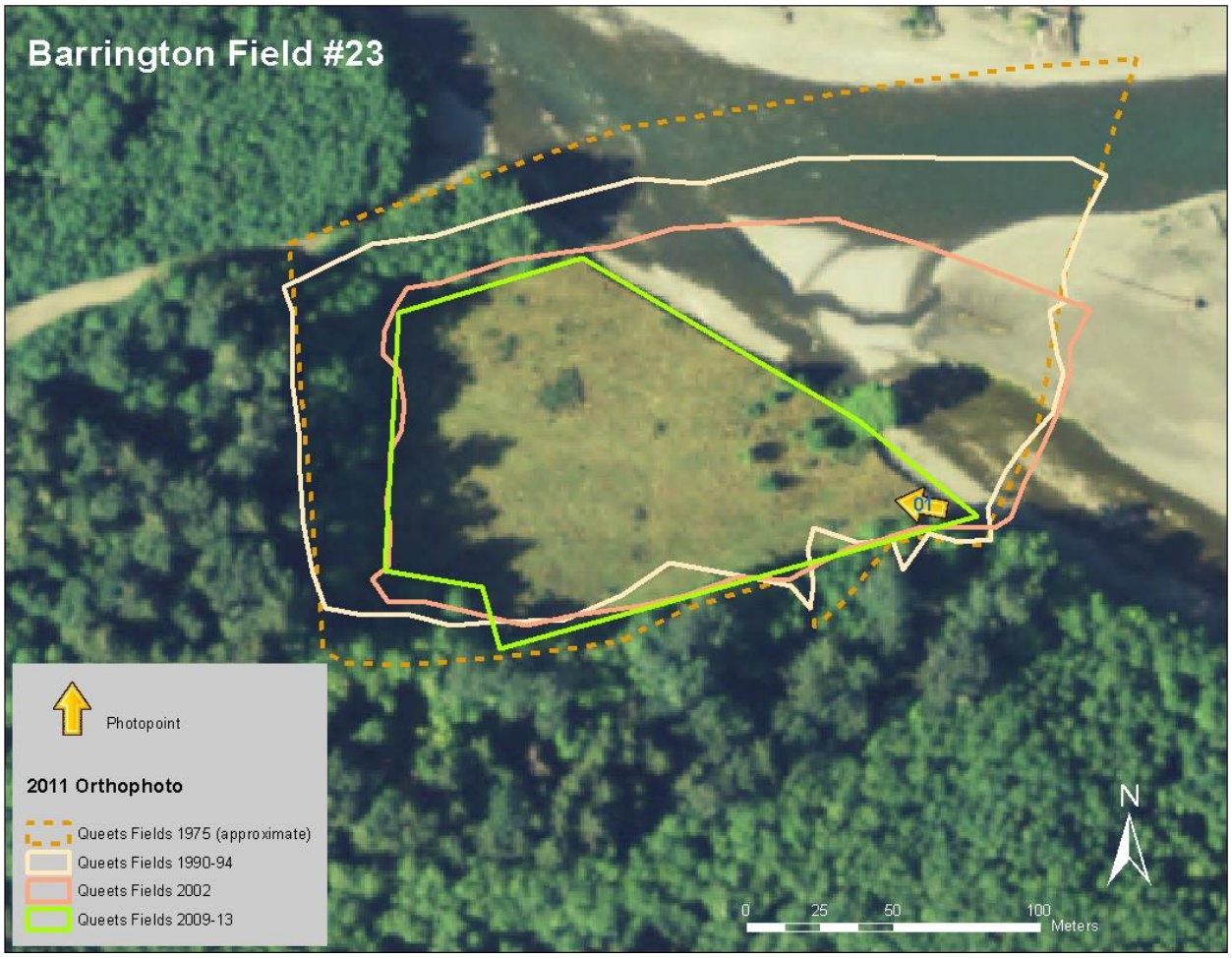
Killea-Kelly, Forest Encroachment

Similar to the southeast field of the Gwin homestead two of the Killea-Kelly fields have seen extensive forest encroachment since 1975. Williams' 1975 sketch maps (below and following page) combined with the current mapping effort show that the poorly-cleared east clearing is completely gone, the cleared-but-not-cultivated south clearing is mostly gone, and the hay field (north clearing) is mostly intact.



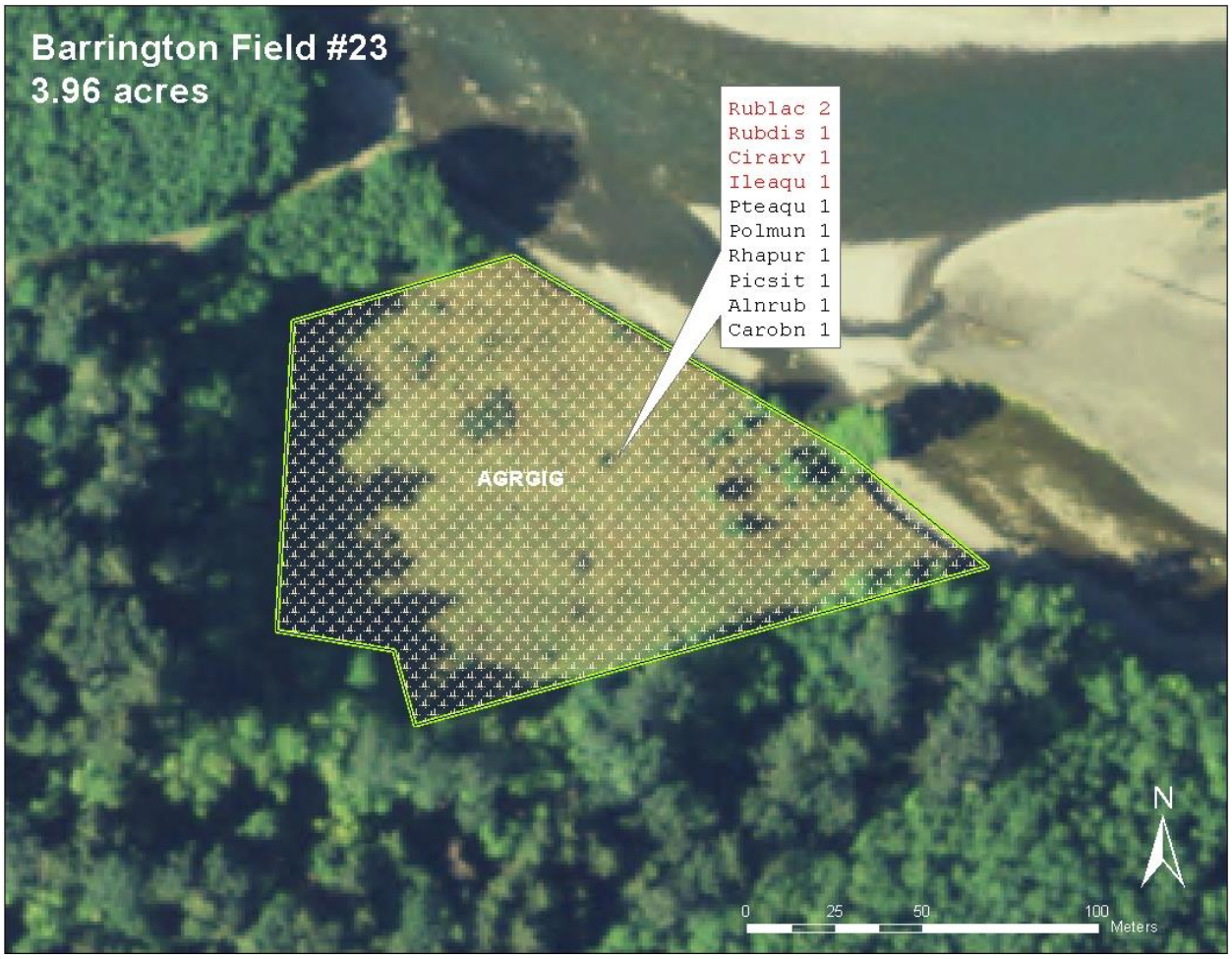

CLEARING 22 MAP
"KELLY FIELD"
FEBRUARY, 1975
T24N
R11W
Location Diagram
N
North clearing
East clearing
South clearing
Scale
0
200
400 feet
2 - Photo number
Picea sitchensis
Thuja plicata
Tsuga heterophylla
Populus trichocarpa
Acer macrophyllum
Alnus rubra
Pteridium aquilinum
Polystichum munitum
Rubus lasiniatus
Vaccinium, sp.
Orchard tree
Ornamental tree
Water power shed

Barrington (#23)



Field Name	Williams Number	Williams Acreage (from report)	Tetreau GIS Interpretation of Williams Acreage	Current (2009-13) Acreage	Overall % reduction	Acres lost to river since 1975	% reduction by forest encroachment
Barrington	23	7	10.46	3.96	62%	4.40	20%

Almost half of this field has been lost to the river, with much of that occurring since 1990 and 60 meters of river bank lost since 2006. The river is now eroding into what appears to be the former house site. There has been only modest forest encroachment into this field, primarily on the western edge where there is open woodland dominated by *Alnus rubra*.

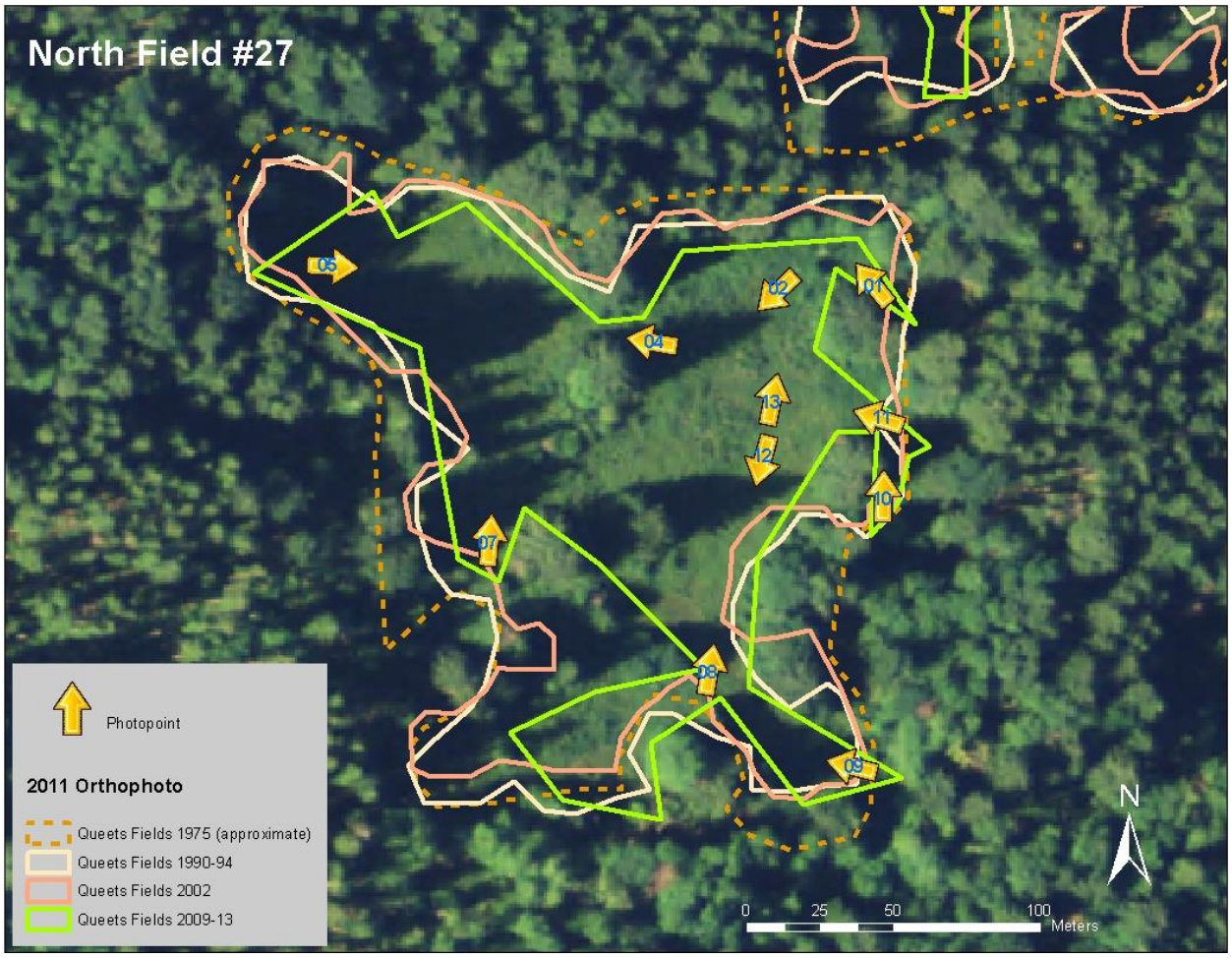


The northeaster edge of the field fronts the river. The site is composed of one polygon, dominated by *Agrostis gigantea* and associates. A band of young *Alnus rubra* rings the field except along the river, which is an actively eroding bank. *Rubus laciniatus* occurs throughout; it is not too dense as yet but is likely to expand rapidly within the next two or three years. Some *Alnus rubra* is within the field and smaller plants show browse damage. *Cirsium arvense* is present but not currently widespread. There is no *Senecio jacobaea*. Weeds are not overly abundant. If action is not delayed, exotic plants could be reasonably controlled.

Species List

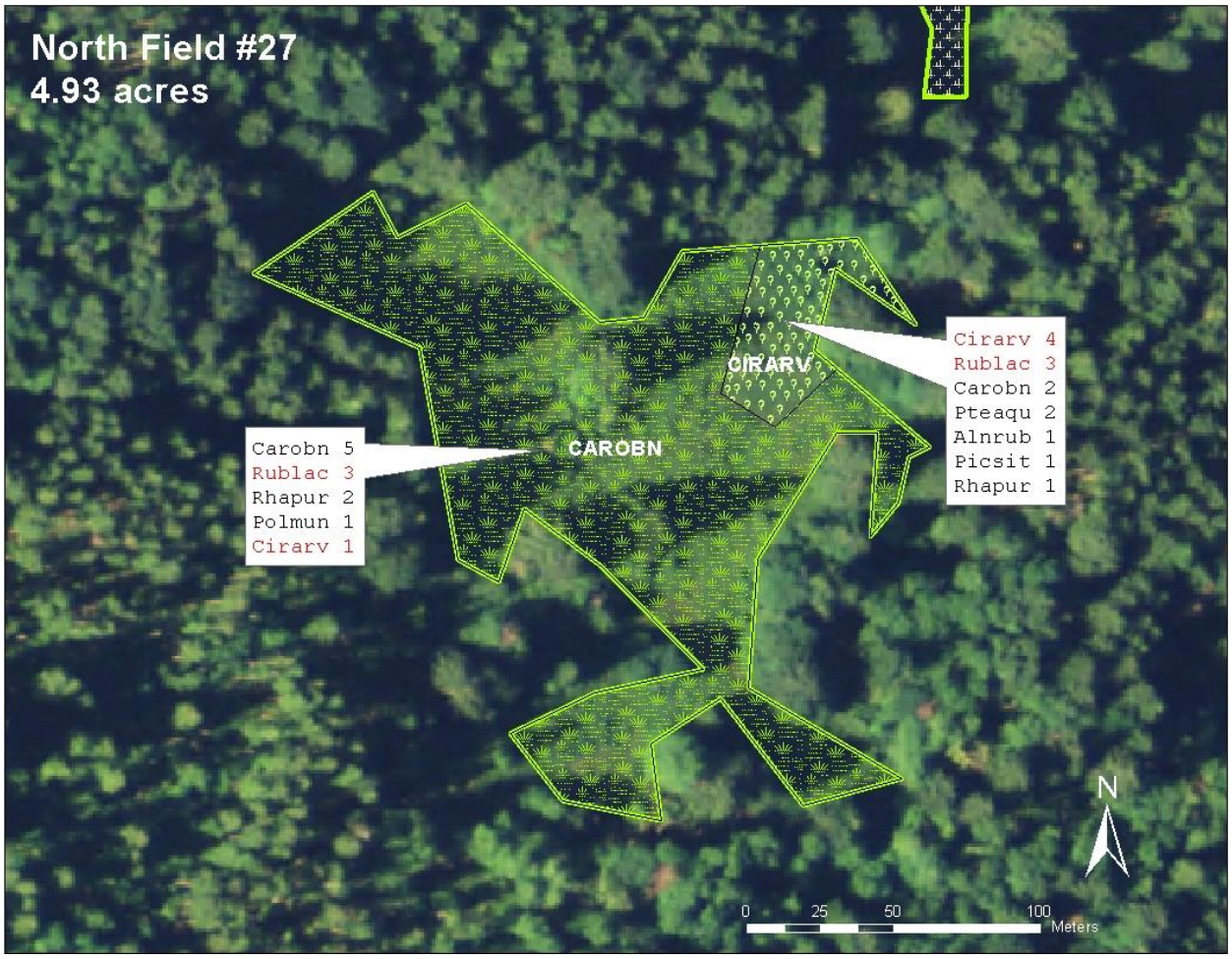
Acer macrophyllum
Alnus rubra
Agrostis gigantea
Anthoxanthum odoratum
Carex obnupta
Cirsium arvense
C. vulgare
Dactylis glomerata
Holcus lanatus
Hypochaeris radicata
Ilex aquifolium
Lonicera ciliosa
Lotus pedunculatus
Malus sylvestris (cultivated)
Plantago lanceolata
Polystichum munitum
Prunella vulgaris
Pteridium aquilinum
Ranunculus repens
Rosa sp. (cultivated)
Rubus laciniatus
R. ursinus
Salix sitchensis
Trifolium repens

North (#27)



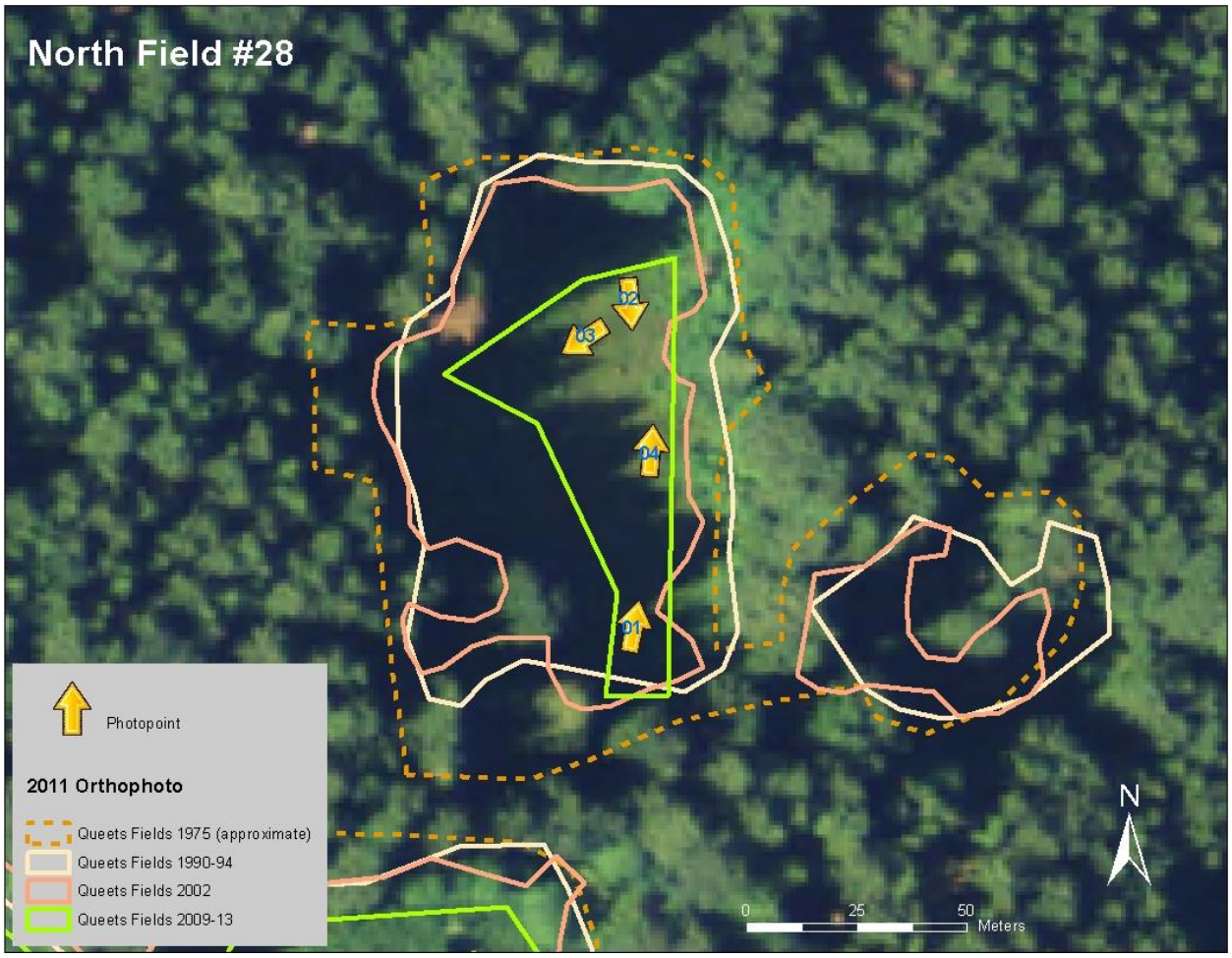
Field Name	Williams Number	Williams Acreage (from report)	Tetreau GIS Interpretation of Williams Acreage	Current (2009-13) Acreage	Overall % reduction	Acres lost to river since 1975	% reduction by forest encroachment
North #27	27	6.5	8.9	4.93	45%	0.00	45%

Not much is known about this convoluted field tucked back in the forest away from the river. Much of the forest encroachment has resulted from the expansion of tree islands or peninsulas pinching off small segments of the field. There are numerous crabapple trees in and around the field, but it is unknown whether or not they were planted. *Carex obnupta* appears to have greatly expanded in this field and now covers approximately 90% of the clearing.



This is a larger, irregularly shaped field (as compared to neighboring North #28). The forest at the perimeter of the field is composed of large *Picea sitchensis*, *Alnus rubra* and *Acer macrophyllum* along with smaller stature *Acer circinatum* and *Rhamnus purshiana*. There is also one, large, old *Populus balsamifera* ssp. *trichocarpa*. The field is wet and appears to be an old flood plain. *Carex obnupta* dominates, accounting for approximately 75% total cover. *Carex obnupta* varies in height from two feet to over five feet. *Rubus laciniatus* is patchy throughout, commonly forming dense thickets where it excludes other plants. Overall, *Rubus laciniatus* contributes approximately 20 to 25% cover. *Rhamnus purshiana* occurs throughout and despite notable herbivory it is encroaching into the field. The field was separated as two polygons, the larger one dominated by *Carex obnupta*, the other being a small polygon dominated by *Cirsium arvense* with *Rubus laciniatus*, *Carex obnupta* and *Pteridium aquilinum* contributing substantially.

North (#28)

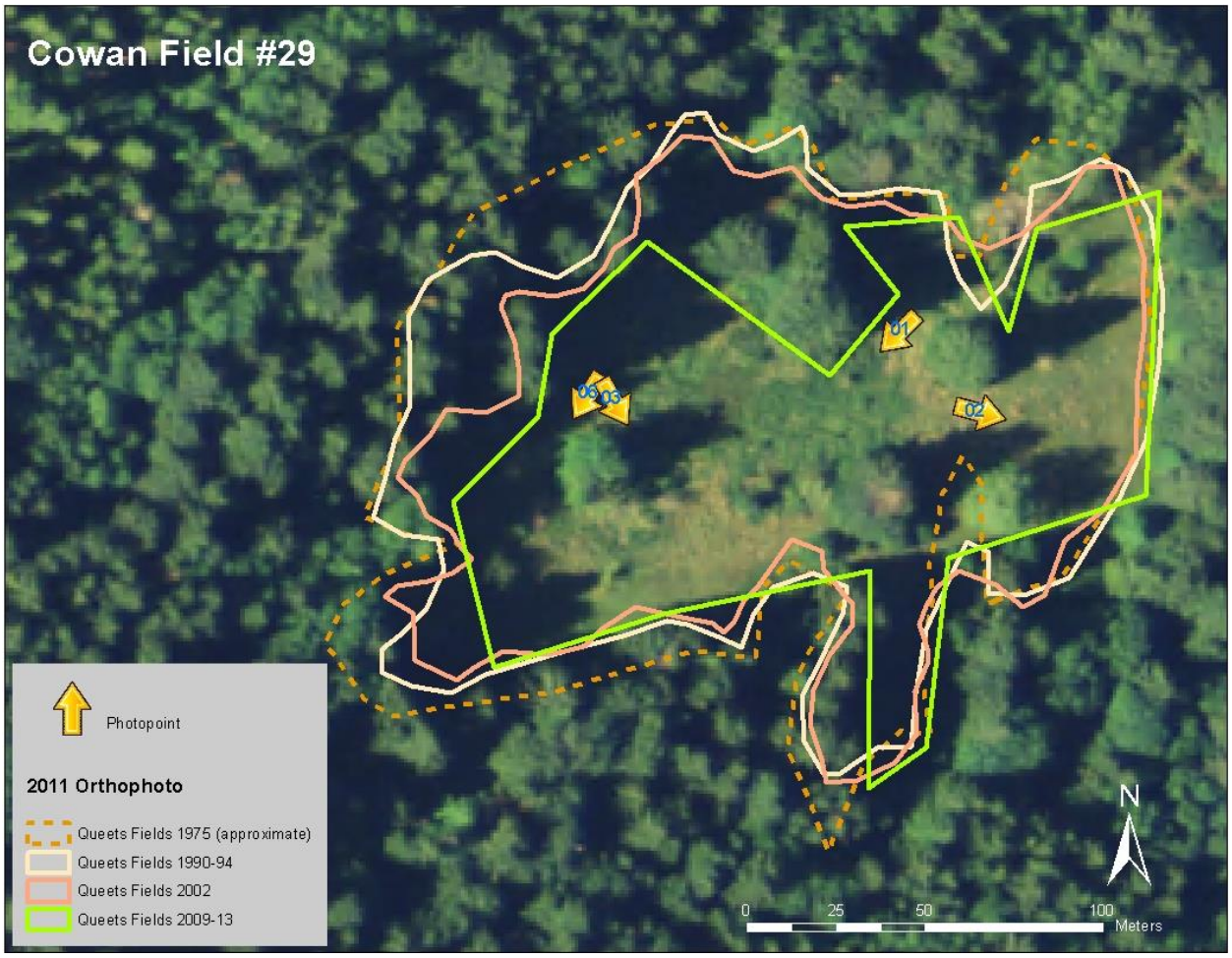


Field Name	Williams Number	Williams Acreage (from report)	Tetreau GIS Interpretation of Williams Acreage	Current (2009-13) Acreage	Overall % reduction	Acres lost to river since 1975	% reduction by forest encroachment
North #28	28	3.5	3.5	0.61	83%	0.00	83%

This started out as a small field tucked in the woods and has decreased in size by 83% since 1975. The small eastern lobe is no longer recognizable as an old field and the western boundary has encroached notably.

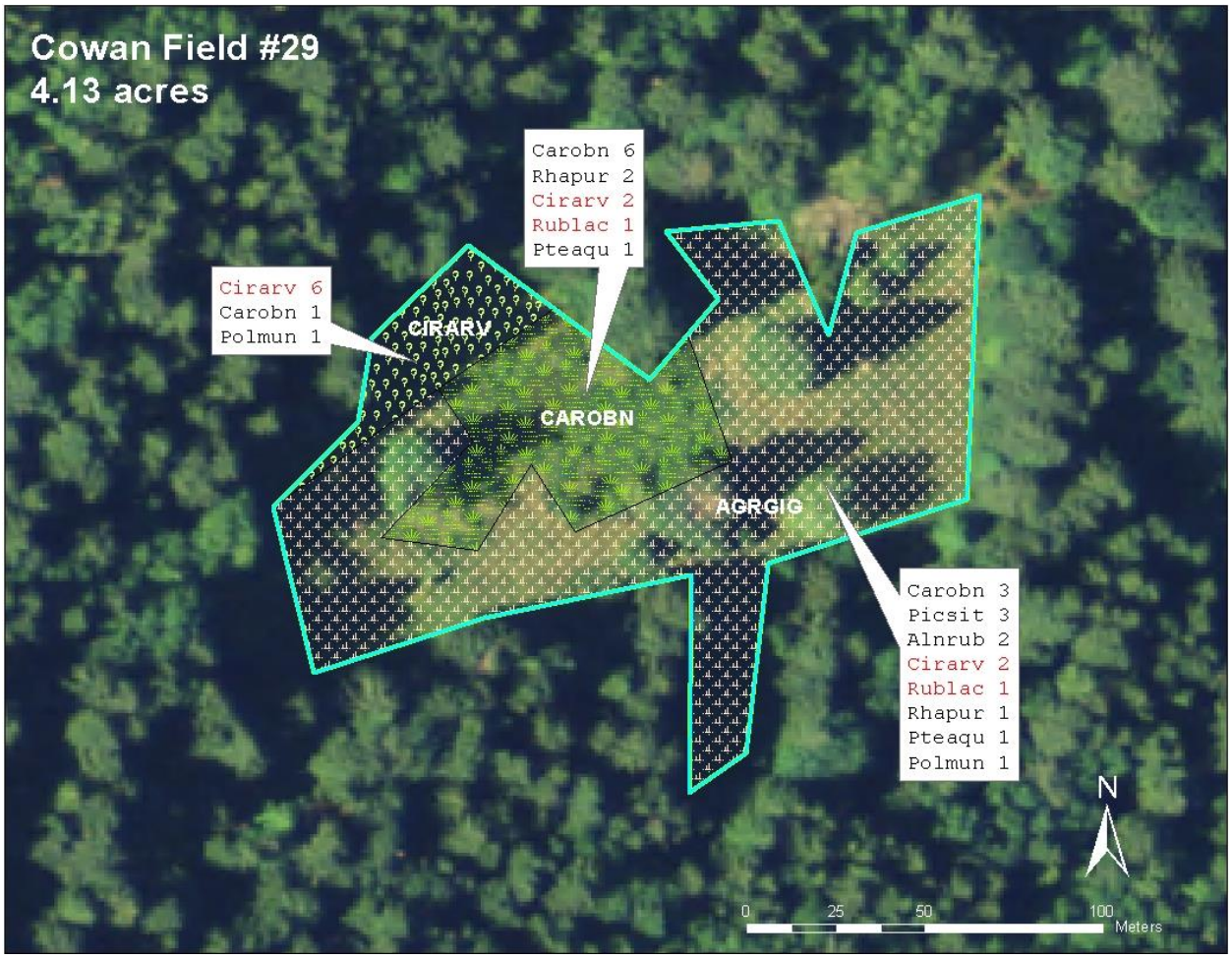
The field is small with a more or less regular shape. The forest at the perimeter of the field is composed of large *Picea sitchensis* and *Acer macrophyllum*, along with young *Rhamnus purshiana*, *Acer circinatum*, crabapple and *Picea sitchensis*. The young trees encircle the field but are especially dense on the north by northeast side. Three standing dead *Picea sitchensis* are also on the field perimeter. The field is dominated by *Agrostis gigantea* and its usual associates. *Pteridium aquilinum*, *Carex obnupta* and *Rubus laciniatus* are common throughout. There were no *Alnus rubra* or *Cirsium arvense* plants and only two *Cirsium vulgare* plants were observed. There were no heritage fruit trees. Along the western side, just outside the field is a row of crabapple along an old fence line.

Cowan (#29)



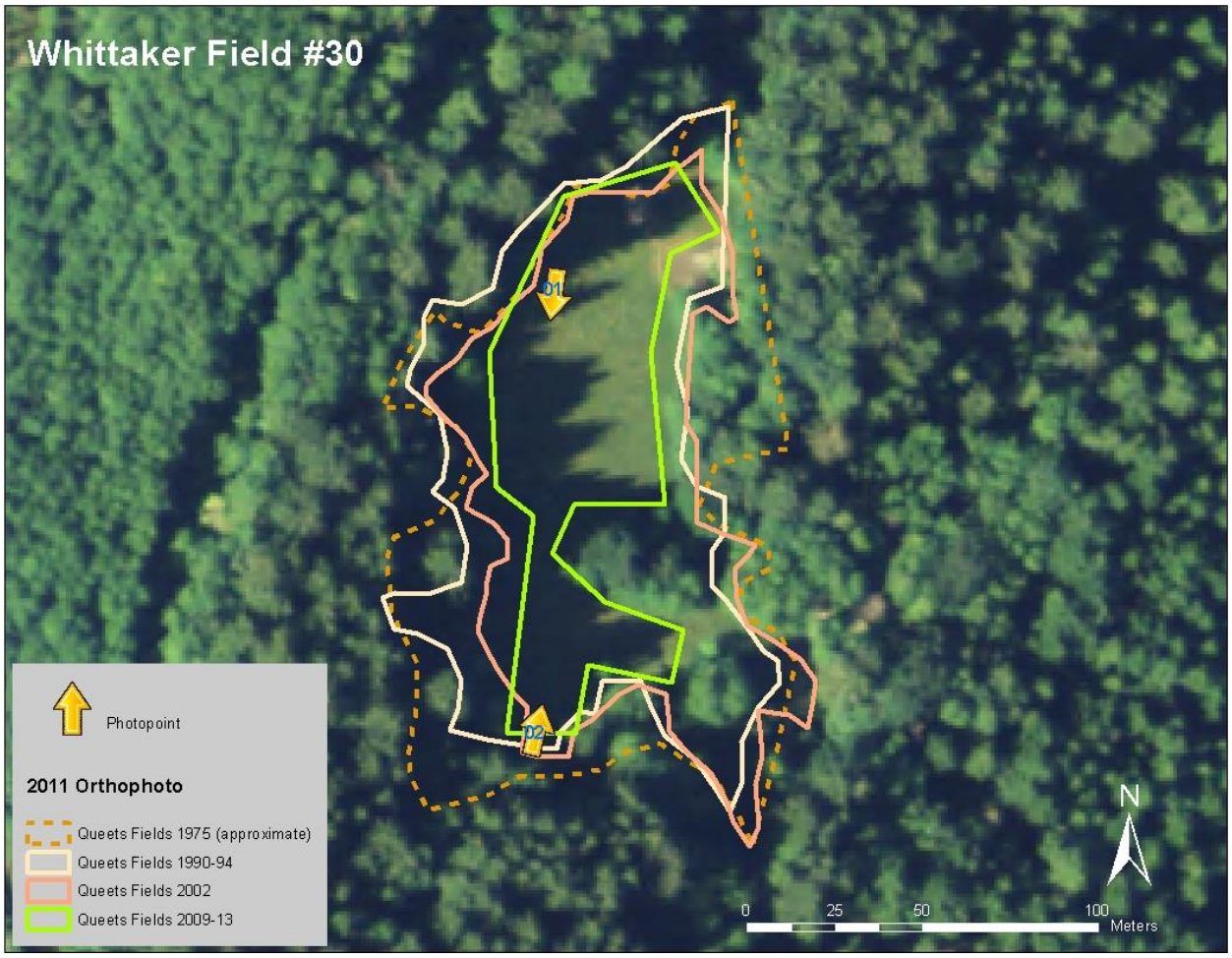
Field Name	Williams Number	Williams Acreage (from report)	Tetreau GIS Interpretation of Williams Acreage	Current (2009-13) Acreage	Overall % reduction	Acres lost to river since 1975	% reduction by forest encroachment
Cowan	29	5.5	6	4.13	31%	0.00	31%

The Sams River Loop Trail passes through this field making it easily accessible for visitors and park staff. The pasture grass portion of the field is being replaced by sedge and *Cirsium arvense*, along with some modest encroachment of the surrounding forest and the expansion of tree islands



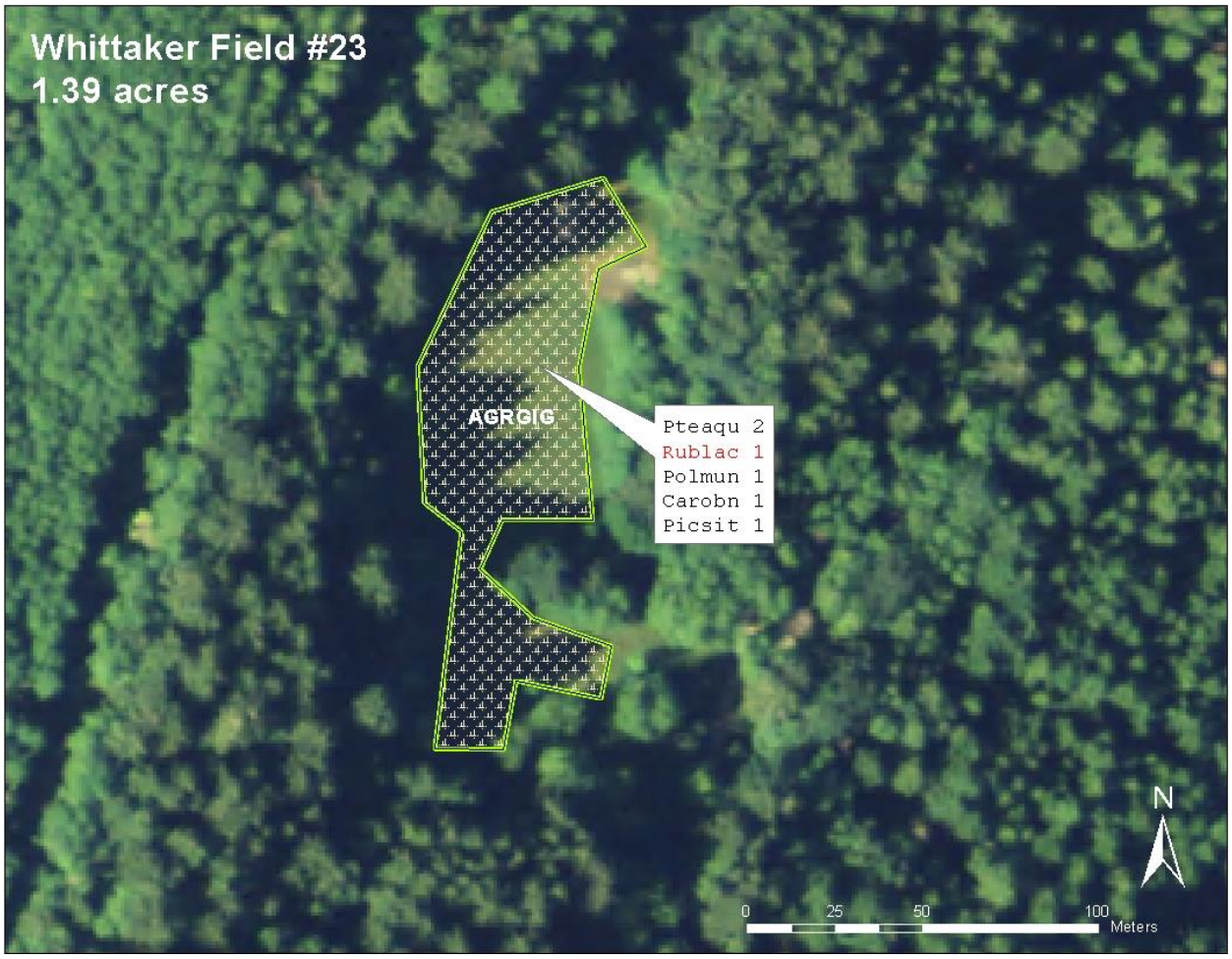
The forest defining the field perimeter is primarily composed of large *Picea sitchensis*. *Rhamnus purshiana* is spotty along the perimeter, dense in places and occasionally encroaching into the field. The field contains some well-established islands of spruce and *Acer macrophyllum* with *Alnus rubra* and *Rhamnus purshiana*. Like most of the other fields, elk use is obvious. While it is not unusual for *Carex obnupta* to form dense patches, this particular patch (at least in part) forms a monoculture. At the southern and southeastern edge of the field in the *Agrostis gigantea* polygon there is an absence of exotic, invasive weeds. Otherwise the *Agrostis* association is typical but does include some *Pteridium aquilinum*, *Polystichum munitum*, *Carex obnupta* and *Rhamnus purshiana*. The *Cirsium arvense* polygon includes some mixture of *Agrostis*, *Carex obnupta*, *Pteridium aquilinum*, *Athyrium filix-femina* and *Rubus laciniatus*. The *Cirsium arvense* is often very dense. Most (if not all) of the *Cirsium arvense* was been treated with herbicides Garlon and Milestone by the Exotic Plant Management Team in early August of 2013.

Whittaker (#30)



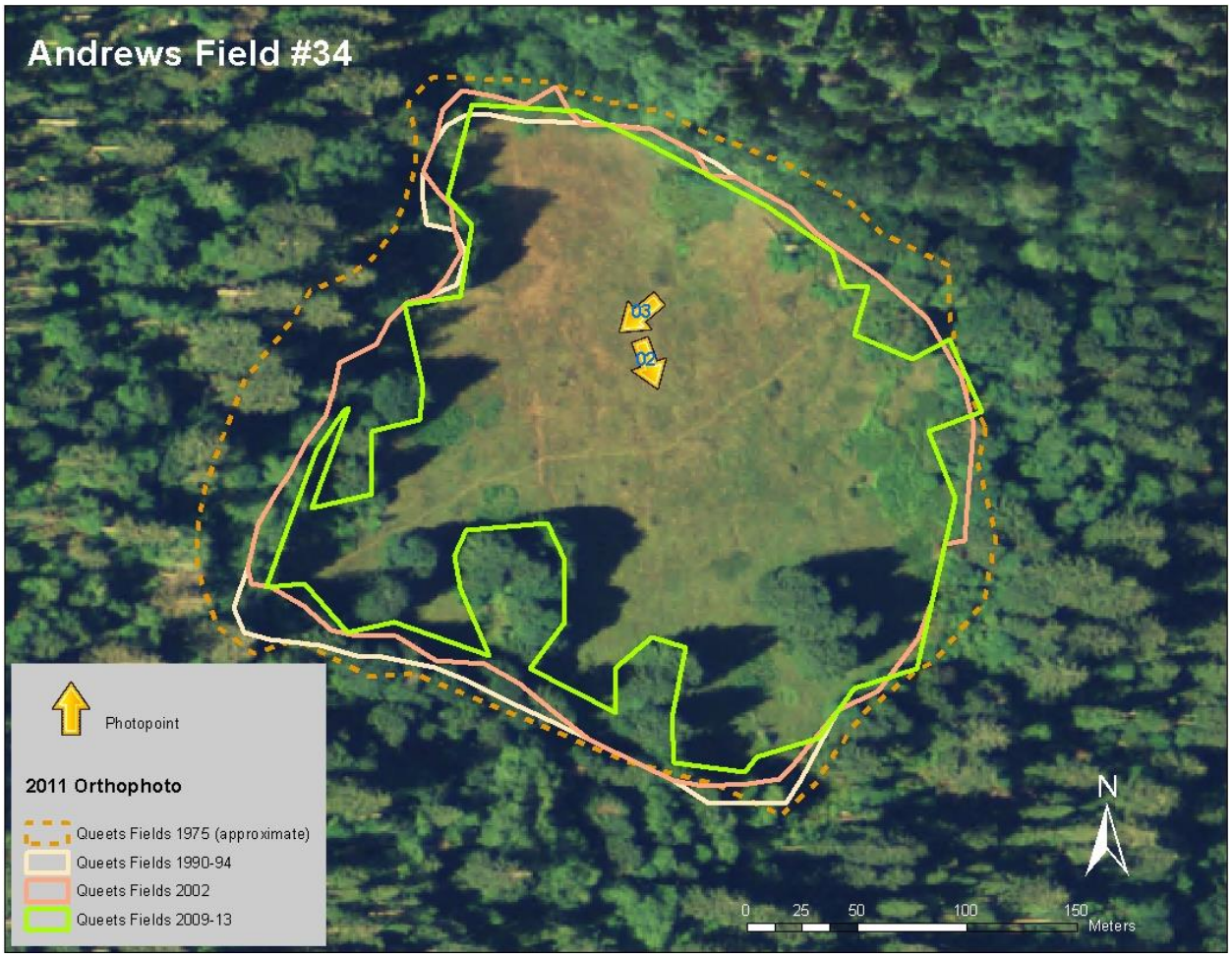
Field Name	Williams Number	Williams Acreage (from report)	Tetreau GIS Interpretation of Williams Acreage	Current (2009-13) Acreage	Overall % reduction	Acres lost to river since 1975	% reduction by forest encroachment
Whitaker	30	4	4	1.39	65%	0.00	65%

The Queets ranger station is located at the north end of this clearing. The field is mowed periodically by park maintenance employees, which appears to be keeping the invasive exotics in check. Forest encroachment has occurred fairly evenly around the perimeter, except near the ranger station. The south end of the clearing is nearly pinched off from the rest of the field.



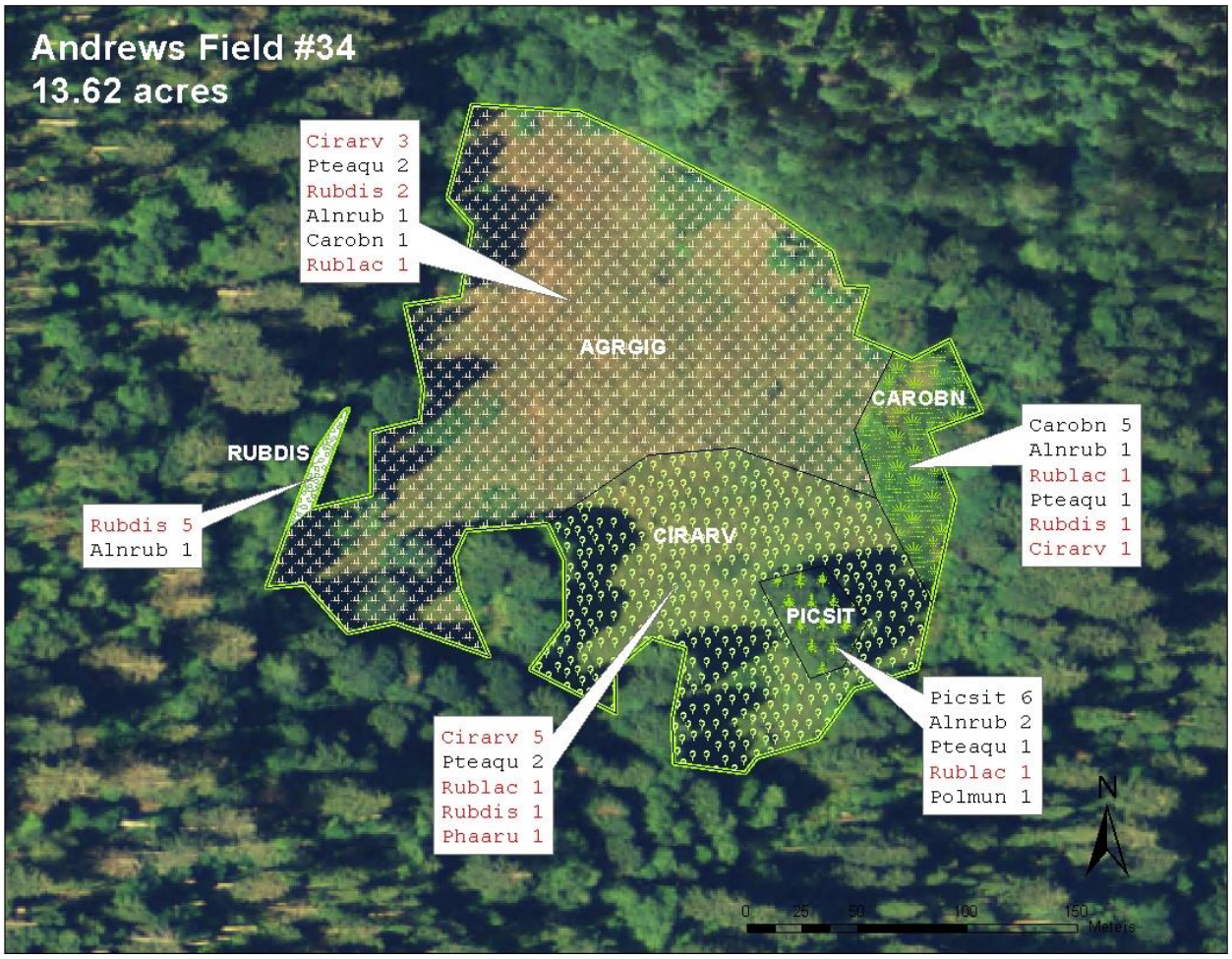
The Queets Ranger Station is located at the north end of this field, which consists of one *Agrostis gigantea* polygon. With the exception of a relatively small occurrence of *Rubus laciniatus*, there are no invasive exotic weeds. The species mix associated with *Agrostis gigantea* is typical of that found in other surveyed fields, except for a very few *Spiranthes romanoffiana* found near perimeter point 4. Unlike other fields this one is subject to occasional mowing. The trees defining the field are tall, younger, thrifty *Picea sitchensis*, *Alnus rubra* and *Acer circinatum*.

Andrews (#34)



Field Name	Williams Number	Williams Acreage (from report)	Tetreau GIS Interpretation of Williams Acreage	Current (2009-13) Acreage	Overall % reduction	Acres lost to river since 1975	% reduction by forest encroachment
Andrews	34	21	21	13.62	35%	0.00	35%

This is currently the second-largest of the old fields and like the Streater field it is well-known to park managers and many members of the public. It was occupied for 44 years (1900 to 1944) and a large barn was still standing in the field as late as 1989. Riege and del Moral both used this field as a study site as the forest encroachment here has been limited to a modest amount the perimeter. The southern third of the field is heavily infested with *Cirsium arvense*, which appears to be expanding into the rest of the field.

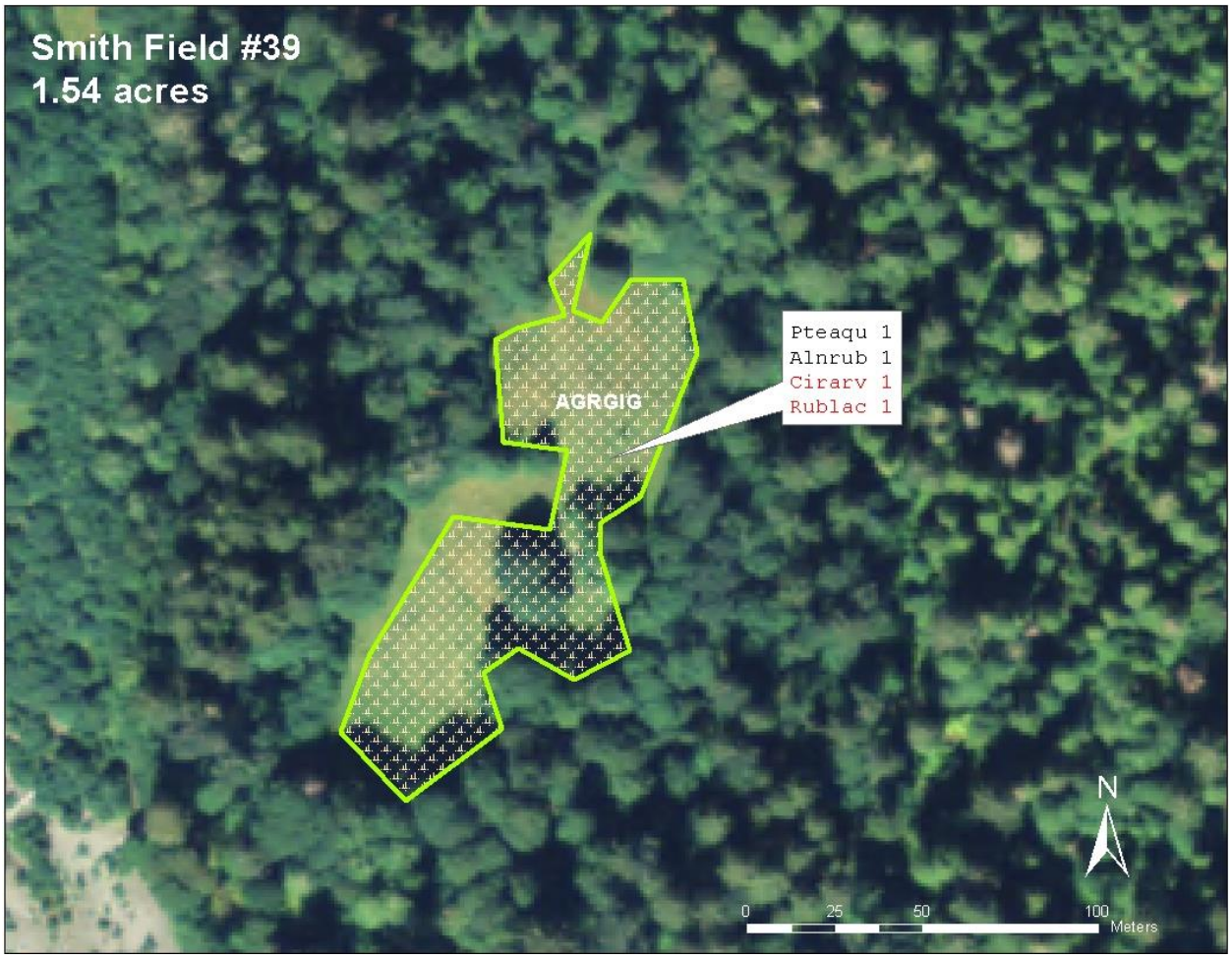


This weedy grass field is dominated by *Agrostis gigantea* with *Holcus lanatus* and *Anthoxanthum odoratum*, with occasional islands of *Rubus laciniatus*. The southern half of the field has greater than. 50% cover of *Cirsium arvense*. Most of the entire perimeter is defined by a band of *Rubus discolor* and *Rubus laciniatus* , along with *Rubus ursinus*, for an average with of about 30 feet. There are a few *Cirsium arvense* along the northern perimeter, but noticeably less in the north half of the field compared to the south half. *Pteridium aquilinum* is limited to northwest edge, a few in the shadow of the southern edge and at edge of the *Carex obnupta* patch. In general, the perimeter is large *Picea sitchensis* (to 80') and *Alnus rubra* with very few saplings of *Picea* invading the field.

Smith (#39)

Field Name	Williams Number	Williams Acreage (from report)	Tetreau GIS Interpretation of Williams Acreage	Current (2009-13) Acreage	Overall % reduction	Acres lost to river since 1975	% reduction by forest encroachment
Smith	39	3.5	4	1.54	62%	0.00	62%

Located approximately 6 miles from the trailhead, this homestead field is the furthest up-valley. Forest encroachment has occurred primarily along the northwestern edge. Peninsulas of trees are gradually pinching the field in half.



This is an open, weedy, grass field with *Cirsium vulgare* and an occasional *Alnus rubra*. There are no young *Picea sitchensis* invading field. Invasive exotics are very limited at this point, providing a good opportunity to control them. There are one or two large, dead *Picea* on the perimeter.

Species List

Agrostis gigantea
Anthoxanthum odoratum
Holcus lanatus
Hypochaeris radicata
Lotus corniculatus
Plantago lanceolata
Prunella vulgaris
Ranunculus repens
Rumex acetosella
R. crispus
Trifolium repens

Photo points

The following table contains data for the photo points indicated in the field boundary maps. The file name indicates the field number (F##) followed by the photo point number for that field.

File Name	Date	Latitude	Longitude	Bearing (TN)
QUEETS2013_F01_02.JPG	8/13/2013	47.559567	-124.231417	116
QUEETS2013_F01_04.JPG	8/13/2013	47.559317	-124.229383	328
QUEETS2013_F01_05.JPG	8/13/2013	47.558600	-124.228467	280
QUEETS2013_F01_06.JPG	8/13/2013	47.558967	-124.228233	289
QUEETS2013_F01_07.JPG	8/13/2013	47.559200	-124.228750	282
QUEETS2013_F01_08.JPG	8/13/2013	47.559283	-124.228667	256
QUEETS2013_F04_01.JPG	8/12/2013	47.551917	-124.221333	130
QUEETS2013_F04_02.JPG	8/12/2013	47.550817	-124.220033	327
QUEETS2013_F05_01.JPG	8/12/2013	47.555617	-124.218550	171
QUEETS2013_F05_02.JPG	8/12/2013	47.555250	-124.218217	195
QUEETS2013_F05_03.JPG	8/12/2013	47.555317	-124.217983	224
QUEETS2013_F05_04.JPG	8/12/2013	47.555217	-124.217933	285
QUEETS2013_F05_05.JPG	8/12/2013	47.555200	-124.217933	330
QUEETS2013_F05_06.JPG	8/12/2013	47.554850	-124.218100	347
QUEETS2013_F05_07.JPG	8/12/2013	47.554867	-124.218467	337
QUEETS2013_F05_08.JPG	8/12/2013	47.555050	-124.218767	172
QUEETS2013_F05_11.JPG	8/12/2013	47.555533	-124.218550	33
QUEETS2013_F06_01.JPG	8/28/2013	47.549533	-124.216333	137
QUEETS2013_F06_02.JPG	8/28/2013	47.549550	-124.215200	214
QUEETS2013_F06_03.JPG	8/15/2013	47.550233	-124.214800	145
QUEETS2013_F06_04.JPG	8/28/2013	47.549983	-124.215133	338
QUEETS2013_F10_01.JPG	8/12/2013	47.556217	-124.187533	42
QUEETS2013_F10_02.JPG	8/12/2013	47.555917	-124.187283	213
QUEETS2013_F10_03.JPG	8/12/2013	47.555917	-124.187267	259
QUEETS2013_F10_04.JPG	8/12/2013	47.555933	-124.187267	309
QUEETS2013_F10_05.JPG	8/12/2013	47.555933	-124.187300	37
QUEETS2013_F10_06.JPG	8/12/2013	47.555933	-124.187300	359
QUEETS2013_F10_07.JPG	8/12/2013	47.555767	-124.187533	320
QUEETS2013_F10_08.JPG	8/12/2013	47.555433	-124.189100	126
QUEETS2013_F10_09.JPG	8/12/2013	47.555433	-124.189217	84
QUEETS2013_F10_10.JPG	8/12/2013	47.555367	-124.189167	56
QUEETS2013_F10_11.JPG	8/12/2013	47.556750	-124.186633	41
QUEETS2010_F19_01.JPG	5/11/2010	47.582630	-124.117263	265
QUEETS2010_F19_02.JPG	5/11/2010	47.582949	-124.117705	95
QUEETS2009_F21_01.JPG	8/23/2009	47.616167	-124.032383	200
QUEETS2013_F22_01.JPG	8/14/2013	47.607400	-124.048550	235

File Name	Date	Latitude	Longitude	Bearing (TN)
QUEETS2013_F22_02.JPG	8/14/2013	47.606850	-124.050233	30
QUEETS2013_F22_03.JPG	8/14/2013	47.606567	-124.050350	245
QUEETS2013_F22_04.JPG	8/14/2013	47.606567	-124.050350	36
QUEETS2013_F22_05.JPG	8/14/2013	47.605850	-124.049750	239
QUEETS2013_F22_06.JPG	8/14/2013	47.605683	-124.050867	77
QUEETS2013_F23_01.JPG	8/14/2013	47.610517	-124.043817	280
QUEETS2013_F27_01.JPG	8/28/2013	47.609683	-124.021800	321
QUEETS2013_F27_02.JPG	8/28/2013	47.609683	-124.022450	226
QUEETS2013_F27_04.JPG	8/28/2013	47.609700	-124.023350	280
QUEETS2013_F27_05.JPG	8/28/2013	47.609733	-124.024867	93
QUEETS2013_F27_07.JPG	8/28/2013	47.608733	-124.023783	5
QUEETS2013_F27_08.JPG	8/28/2013	47.608500	-124.022800	10
QUEETS2013_F27_09.JPG	8/28/2013	47.608150	-124.022000	284
QUEETS2013_F27_10.JPG	8/28/2013	47.608833	-124.021900	1
QUEETS2013_F27_11.JPG	8/28/2013	47.609117	-124.022017	288
QUEETS2013_F27_12.JPG	8/28/2013	47.609167	-124.022517	195
QUEETS2013_F27_13.JPG	8/28/2013	47.609333	-124.022483	11
QUEETS2013_F28_01.JPG	8/28/2013	47.610600	-124.021700	11
QUEETS2013_F28_02.JPG	8/28/2013	47.611217	-124.021733	176
QUEETS2013_F28_03.JPG	8/28/2013	47.611033	-124.021883	237
QUEETS2013_F28_04.JPG	8/28/2013	47.610917	-124.021667	4
QUEETS2013_F29_01.JPG	8/14/2013	47.614017	-124.020617	225
QUEETS2013_F29_02.JPG	8/14/2013	47.614467	-124.020933	105
QUEETS2013_F29_03.JPG	8/14/2013	47.614617	-124.022217	150
QUEETS2013_F29_06.JPG	8/14/2013	47.614633	-124.022217	212
QUEETS2013_F30_01.JPG	8/28/2013	47.616167	-124.032383	188
QUEETS2013_F30_02.JPG	8/28/2013	47.615033	-124.032433	13
QUEETS2009_F34_02.JPG	8/22/2009	47.616167	-124.032383	160
QUEETS2009_F34_03.JPG	8/22/2009	47.616167	-124.032383	230

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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