DROUGHT ASSESSMENT PROJECT

KAMLOOPS FOREST REGION

1999 - 2000

Kamloops Forest Region Drought Assessment Project

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BACKGROUND

The summer of 1998 was the warmest summer on record in Canada. The average temperature in Canada for June through August was 1.8 degrees Celsius above normal. Most regions in Canada also experienced dryer than normal conditions, ranking 1998 among the driest summers on record.

This report summarizes some of the effects of the 1998 drought on the forests in the Kamloops Forest Region. In addition, the interactions between drought stressed trees and secondary insect pests is discussed with management implications.

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Annual weather patterns have a profound influence on forest environments, affecting tree growth and greatly influencing native insect populations. Moisture stress, caused by low precipitation coupled with high daily temperatures, can cause reduced growth, defoliation, and even tree mortality. Many insects are "opportunists" and take advantage of stressed trees. Many insect pest outbreaks have been cited as having started in drought-affected areas (Haack *et al*. 1989; Markalas 1991; and Dunn and Lorio 1993).

All identified drought affected areas were digitized in an ArcView format. The number of hectares affected in each district was determined and stratified by biogeoclimatic zone and subzone. A detailed flight was made over selected areas to map, photograph and stratify areas for ground survey.

Ground surveys were concentrated in the forest districts with the greatest incidence of drought mortality (Table 1). Eighteen young stands and 28 mature stands were surveyed in the Vernon, Salmon Arm, Kamloops, Clearwater and Merritt Forest Districts.

Drought affected stand of 16 year old lodgepole pine in the Vernon Forest District, Aberdeen Plateau area.

The 1999 Kamloops Regional aerial overview surveys delineated 10,035 hectares of drought affected area (Maclauchlan 2000). The affected area represented mortality only, since other impacts of the drought were not visible from the air. The mapped areas were starting points to focus our investigations in 1999. The objectives of this project were to:

- determine the affected area within the stand;
- assess the stand for incidence and impact of secondary or other pests; and
- determine the relative importance of drought and pests.

Table 1. Forest District and Mortality

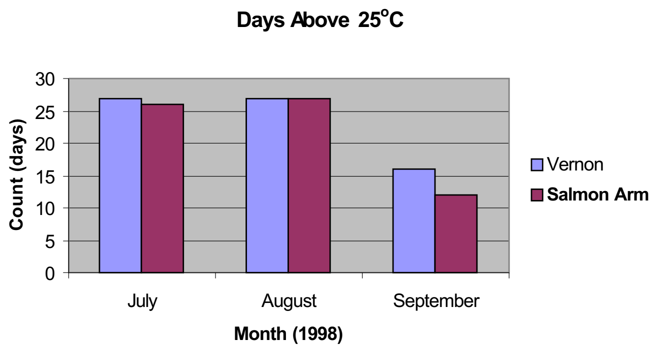
Forest District	Hectares of Drought Mortality	No. of Stands Ground Surveyed
Clearwater	230	2
Kamloops	700	3
Salmon Arm	4030	21
Vernon	4375	19
Penticton	600	0
Merritt	50	1
Lillooet	50	0
Totals	10,035	46

CLIMATE

Climate data were provided by Environment Canada (Lahn 2000).

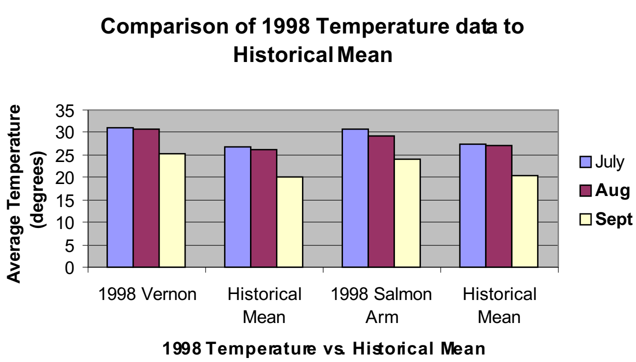
The summer of 1998 was the warmest and one of the driest in Canada on record. The average temperature in the Vernon and Salmon Arm areas was 30.8º C, which was 4.27º C above normal. In July and August there were

Figure 1



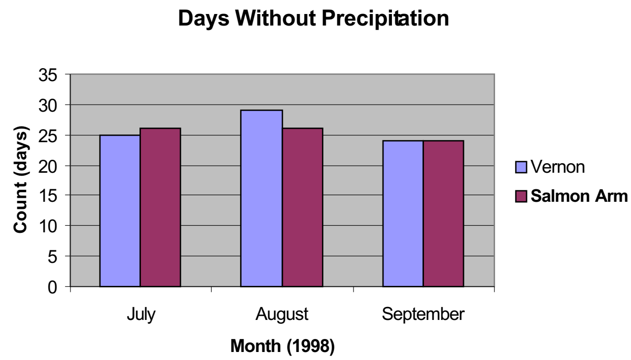
over 26 days above 25º C with the average temperature around 30º C. September was slightly cooler but there were still greater than 12 days above 25 º C (Fig. 1,2).

Figure 2



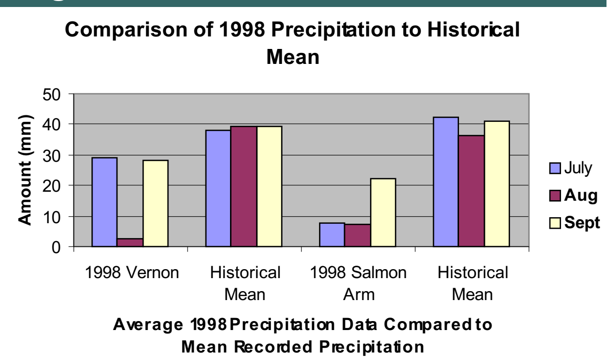
July through September saw over 24 days per month with no precipitation (Fig. 3). Comparison of the total monthly precipitation in the summer of 1998 to the historical mean (Fig. 4) shows a significant difference for all months. In 1998 there was less rain in July and August (22mm and 33.1mm, respectively) than the historic average.

Figure 3



Other effects of this drought were noticeable during the summer of 1998. Numerous, severe forest fires occurred. In the Kamloops Forest Region 24,773.5 hectares were burned. The Kamloops Fire Center imposed a complete Forest closure in the Merritt Forest District from September 9th to September 19th 1998.

Figure 4



Symptoms of drought stress became apparent in some areas by the fall of 1998. During the spring of 1999 many trees began fading and extensive mortality was observed in both young and old trees.

METHODS

The data gathered from the 1999 Kamloops Forest Region aerial overview surveys were used to identify areas with significant drought mortality (Appendix 1,2). Detailed aerial surveys were then performed on the chosen areas to further stratify and photograph affected areas. From aerial surveys and photographs, areas with significant mortality were selected for ground surveys (Appendix 3).

Ground surveys involved a reconnaissance survey of the drought affected area. Data were collected on stand characteristics (tree species composition, understory and ground cover composition), site characteristics (slope, aspect, soil depth, and general site description), representative tree attribute data (tree species, height, dbh, percent live crown, age and drought effects) and forest health information. Representative photographs were taken in each stand. Descriptive photographs of all pests of interest were taken.

Samples of insects pests were collected for identification when field identification was difficult.

In a subset of young stands, surveys of pest incidence (SPI) lines were established. This survey methodology quantifies pest incidence in a stand. Contiguous 100 meter plots are randomly placed in the stand. The plot width ranges from 0.5 to 5 meters wide depending on the density of the stand. All trees and pests encountered are tallied and representative tree attribute data recorded (Maclauchlan and Merler 1990).

The aerial photographs were mapped onto 1:20,000 ORTHO map series. The percent morality attributed to drought was calculated from data recorded during ground surveys and from aerial photo interpretation. Total polygon area and ecosystem information was obtained from Forest Inventory Files (FIP) files.

YOUNG STAND SURVEYS

Eighteen young stands were surveyed in total. Fourteen young stands were surveyed in the Vernon Forest District in the Aberdeen Plateau area and the Harris Creek area. Two young stands were surveyed in the Salmon Arm Forest District both in the Larch Hills area. One young stand was surveyed in the Kamloops Forest District near Spillman Creek on the East side of Adams Lake and one in the Merritt Forest District near Pothole Creek. All stands ranged in age from 5 to 17 years old except for the Spillman Creek stand, that was approximately 22-30 years old. Lodgepole pine was the leading species in most stands. Eight of the stands surveyed were in the MS biogeoclimatic zone, six in the ICH and three in the IDF. In total, six different biogeoclimatic subzones were surveyed (Table 2). The total area ground surveyed was 407.5 hectares. Of this the total affected area was 195.7 hectares. Mortality ranged from 5 to 50 percent per stand, averaging 28.3 percent.

Many of the young stands surveyed were flat to rolling with areas of exposed bedrock and shallow soils. Most of the drought occurred on rock outcroppings, higher, exposed areas and areas with well drained soils. In most cases the heavily drought affected areas had fewer

Table 2. Young Stand Area, Percent Mortality and Ecosystem Data

District	No. Sites	Area (ha) Total	Area (ha) Affected	Average Mortality(%)	Ecosystem	Species Affected
Salmon Arm	2	72.5	41.5	25	ICH mw2	Lw, Fd
Vernon	8	166.2	71.1	36.9	MS dm1	Pl
Vernon	3	50.7	18.7	13.3	ICH mk1	Pl
Vernon	2	62.6	15.3	22.5	IDF mw1	Pl, Fd
Vernon	1	18.5	12.2	20	IDF xh1, MS dm1	Pl
Kamloops	1	37	37	40	ICH mw3	Pl
Merritt	1	Data Unavailable				Pl
Totals	18	407.5	195.7	26.3		

stems per hectare than the unaffected area, indicating that these areas are poor growing sites and are likely difficult to regenerate.

Many secondary insect pests were found colonizing drought affected trees. The most prevalent were twig beetles of the genera *Pityophthorus* and *Pityogenes* found in 66.6 percent of the stands surveyed. *Hylurgops sp.*, were found in 50 percent of the stands surveyed and *Pissodes schwarz*i was found in 56 percent of the stands (Table 3).

Aerial photograph of a young drought affected stand Vernon Forest District.

Drought mortality in a young stand, Vernon Forest District.

Secondary pests found in fewer stands included *Hylastes sp., Scolytus spp., Ips spp., Dendroctonus valens, Magdalis gentilis, Psuedohylesinus sp.,* and *Pityokteines minutus.*

Most secondary insect attack occurred during the summer or fall of 1998. These opportunistic insects were attracted to the drought stressed trees. This secondary insect attack caused greater mortality than would have been experienced from the drought alone.

The literature documents other cases where similar insect pest populations have significantly increased and have attacked not only drought stressed trees but healthy live trees as well (Furniss and Carolin 1977, Markalas 1992, Hack and Schwartz 1997). It is not known what the populations of secondary pests we encountered will do in the summer of 2000, but continued extensive mortality is not expected.

Drought mortality in a young stand.

Table 3. Young Stand Pest Incidence Data

Forest Health Agent: Common Name	Forest Health Agent: Latin Name	No. of Surveyed Sites With Pest	Pests by Occurrence (%) *
Bark Beetles			
Red turpentine beetle	*Dendroctonus valens*	1	5.5
Twig beetles	*Pityophthorus and Pityogenes sp.*	12	66.7
Hylastes species	*Hylastes sp.*	4	22.2
Hylurgops species	*Hylurgops sp.*	9	50.0
Ambrosia beetles	*Gnathotrichus and Trypodendron*	14	77.8
Engraver beetles	*Scolytus sp.*	2	11.1
Engraver beetles	*Ips sp.*	3	16.7
Twig Beetle	*Magdalis gentilis*	1	5.6
Silver fir beetle	*Pseudohylesinus sp*	1	5.6
Pityokteines minutus	*Pityokteines minutus*	1	5.6
Shoot Borers			
Northern pitch mpth	*Petrova albicapitana*	10	55.6
Root and Terminal Weevils			
Root collar weevil	*Hylobius warreni*	3	16.7
Yosemite bark weevil	*Pissodes schwarzi*	10	55.6
Lodgepole pine terminal weevil	*Pissodes terminalis*	5	27.8
Root Disease			
Armillaria root disease	*Armillaria ostoyae*	6	33.3
Black stain root disease	*Leptographium wagneri*	5	27.8
Stem Disease			
White pine blister rust	*Cronartium ribicola*	1	5.6
Western gall rust	*Endocronartium harknessii*	5	27.8
Comandra blister rust	*Cronartium comandrae*	1	5.6
Stalactiform blister rust	*Cronartium coleosporioides*	1	5.6
Foliage Disease			
Lophodermella needle cast	*Lophodermella concolor*	4	22.2
Larch blight	*Hypodermella laricis*	2	11.1
Larch needle cast	*Meria laricis*	1	5.6
Animal Damage			
Bear		1	5.6
Deer		3	16.7
Squirrel		1	5.6
Hare		2	11.1
Cattle		1	5.6

*18 young stands surveyed

Surveys of Pest Incidence

Drought affected lodgepole pine were encountered in all plots. Fewer plots contained sub-alpine fir, spruce, Douglas-fir and western larch affected by drought (Table 4). Yosemite bark weevil was observed in 56 percent of the plots; *Pityophthorus* / *Pityogenes* species in 33 percent and *Hylurgops* / *Hylastes* species in 39 percent of plots. Other non drought associated forest health pests were also recorded (Table 5).

Table 4. SPI Plot Species Composition

Tree Species	Count of Plots containing the given tree species	Percent of Plots with drought effects
lodgepole pine	18	100
sub-alpine fir	11	82
spruce	8	50
Douglas-fir	11	82
western larch	5	40

The average height and dbh of drought killed lodgepole pine was less than the unaffected trees (2.6m and 2.8cm; and 3.2m and 3.7cm, respectively). Results suggest the drought affected trees were growing in poorer sites than the non drought affected trees.

Table 5. SPI Plot Pests

FH Factor	Percent of SPI Plots
Drought	**100**
Bark Beetles	
Pityophthorus / Pityogenes sp.	33
Hylastes / Hylurgops sp.	39
Ambrosia beetles	17
Shoot Borers	
Northern pitch moth (branch)	39
Northern pitch moth (stem)	33
Root and Terminal Weevils	
Root collar weevil	17
Lodgepole pine terminal weevil	44
Yosemite bark weevil	56
Root Disease	
Armillaria root disease	11
Black stain root disease	22
Stem Disease	
Western gall rust (branch)	56
Western gall rust (stem)	61
Comandra blister rust	5.6
Stalactiform blister rust	5.6
Foliage Disease	
Lophodermella needle cast	72
Lophodermium pinastri	5.6

MATURE STAND SURVEYS

Twenty-eight mature stands were surveyed. Nineteen of these stands were in the Salmon Arm Forest District, five in the Vernon Forest District and two each in the Kamloops and Clearwater Forest Districts (Table 6). Twelve stands were surveyed in the IDF; four in the MS; eight in the ICH; one in the ESSF; and one split between the MS and IDF; and one split between the ESSF and the MS. Eight biogeoclimatic subzones were surveyed.

The total area surveyed was 640.2 hectares, and the average percent stand mortality was 25.5% (Table 6).

Mortality in stands ranged from 5 to 60 percent stems affected. Lodgepole pine was the leading species in fifteen stands, Douglas-fir was the leading species in thirteen stands surveyed.

Surveyed stands were located on variable terrain. They occurred on all aspects and with variable slope ranging from zero to 45 percent. There were some commonalities between sites. Most drought affected stands occurred on exposed sites with, shallow or sandy soils, and rock outcroppings or rocky knobs.

Table 6. Mature Stand Location, Area, Percent Mortality, Ecosystem Data

Mature Stand Drought Survey Data

District	Geographic Location	Area (ha)	Mortality (%)	Ecosystem	Leading Species
Salmon Arm	Ashton Creek	24	35	IDF mw1	Fd
Salmon Arm	Enderby Cliffs	data unavailable			Fd
Salmon Arm	NE of Grindrod	21.5	35	IDF mw1	Fd
Salmon Arm	Chase Creek	28	10	IDF mw2	Pl
Salmon Arm	Harper Lake	23.6	5	MS dm2	Pl Fd
Salmon Arm	Butler Road	120	30	MS dm2, IDF mw2	Pl
Salmon Arm	White Lake	20	15	ICH mw3	Fd
Salmon Arm	White Lake	8	46.7	IDF mw2	Fd
Salmon Arm	White Lake	2	40	IDF mw2	Fd
Salmon Arm	Sicamouse	4.75	20	ICH mw2	Fd Pl
Salmon Arm	Sicamouse	46	73	ICH mw2	Fd Pl
Salmon Arm	Lee Creek	5.5	40	IDF mw2	Pl Fd
Salmon Arm	Lee Creek	2.9	40	IDF mw2	Fd
Salmon Arm	Lee Creek	27	10	IDF mw2	Fd
Salmon Arm	Ashby Creek	8.1	55	IDF mw2	Fd
Salmon Arm	Lee Creek	24	35	IDF mw2	Pl Fd
Salmon Arm	Scotch Creek	105	5	IDF mw2	Pl Fd
Salmon Arm	White Lake	3	10	ICH mw3	Fd
Salmon Arm	Scotch Creek	60	60	ICH mw3	Pl Fd
Kamloops	East Barriere River	9	15	ESSF wc2	Pl
Kamloops	Raspberry Creek	9	10	ESSF dc2, MS dm2	Fd Pl
Clearwater	East Adams Lake	4.8	15	ICH mw1	Pl Fd Cw
Clearwater	North Adams Lake	8.3	15	ICH mw3	Pl Fd
Vernon	Aberdeen Plateau	4.5	10	MS dm1	Pl
Vernon	Aberdeen Plateau	6.4	5-10	MS dm1	Pl
Vernon	Aberdeen Plateau	1.4	10-15	MS dm1	Pl
Vernon	Harris Creek	50.95	35	IDF mw1	Pl
Vernon	Beetle Creek	12.5	5	ICH mk1	Pl Fd
Totals		640.2			
Average			25.5		

Many secondary pests were found colonizing drought stressed trees. The pests found in greatest abundance were, Douglas-fir beetle (57%), *Ips spp*. (43%), lodgepole pine beetle (29%), twig beetles (25%), and *Scolytus sp*. (21%). Other secondary pests observed were the red turpentine beetle, ambrosia beetle, *Hylurgops sp*. and *Hylastes sp*.

At endemic levels the Douglas-fir beetle usually survives in freshly downed, fire seared, or otherwise weakened trees. However when climatic conditions are favorable and suitable hosts are abundant, the population grows and the beetle will then attack healthy green trees. Drought events have been documented as having triggered past outbreaks of Douglas-fir beetle (Furniss and Carolin 1977). All Douglas-fir leading stands had some level of Douglas-fir beetle recorded.

Nine of the stands surveyed had Armillaria root disease and ten stands contained laminated root rot (Table 7). Root diseases restrict the translocation of water and nutrients. Without the drought in 1998 the trees affected with root disease in these stands would likely have lived longer. The combination of root diseases and the decreased water availability during the drought likely caused rapid mortality.

Drought affected mature stand, Vernon Forest District.

Table 7. Mature Stand Pest Incidence Data

Forest Health Agent		No. Surveyed Sites With Pest	Pests by occurrence (%)
Common Name	Latin Name		
Bark Beetles			
Lodgepole pine beetle	*Dendroctonus murrayanae*	8	28.6
Mountain pine beetle	*Dendroctonus ponderosae*	11	39.3
Spruce beetle	*Dendroctonus rufipennis*	1	3.6
Red turpentine beetle	*Dendroctonus valens*	1	3.6
Douglas-fir beetle	*Dendroctonus pseudotsugae*	16	57.1
Twig beetles	*Pityophthorus and Pityogenes sp.*	7	25.0
Hylastes species	*Hylastes sp.*	2	7.1
Hylurgops species	*Hylurgops sp.*	8	28.6
Ambrosia beetles	*Gnathotrichus and Trypodendron*	12	42.9
Engraver beetles	*Scolytus sp.*	6	21.4
Pine engraver beetle	*Ips sp.*	12	42.9
Shoot Borers			
Sequoia pitch moth	*Synanthedon sequoiae*	6	21.4
Root and Terminal Weevils			
Root collar weevil	*Hylobius warreni*	2	7.1
	Pissodes faciatus	2	7.1
	Pissodes sp. (on Pl)	2	7.1
Root Disease			
Armillaria root disease	*Armillaria sinapena*	1	3.6
Armillaria root disease	*Armillaria ostoyae*	9	32.1
Laminated root rot	*Phellinus weirii*	10	35.7
Stem Disease			
White pine blister rust	*Cronartium ribicola*	1	3.6
Animal Damage			
cattle damage		1	3.6
Abiotic Damage			
snow/wind damage		13	46.4

* 28 mature stands surveyed

PESTS IN DROUGHT AFFECTED STANDS

The following is a brief description of pests associated with drought stressed trees.

Hylurgops and Hylastes

Species of the *Hylastes* and *Hylurgops* genera can be found under the bark, at the bole or in the root of the host tree. Most conifer species in British Columbia are susceptible including pine, spruce, Douglas-fir, western hemlock, and true firs. These beetle species usually attack stressed, dying or dead trees or stumps. Both these beetles are small, reddish brown to black streamlined beetles. The main distinguishing difference between *Hylurgops* and *Hylastes* adults is that *Hylurgops* are generally a bit larger and more robust than *Hylastes* species and the third tarsal segment is broad and bilobed versus narrow and emarginate.

Pityogenes and Pityophthorus

Twig beetles of the *Pityoghenes* and *Pityophthorus* genera, primarily attack pines. The branches of trees of all ages and the bole on young trees are susceptible. These beetles usually attack stressed, dying and newly felled trees. The adults are slender, brown to dark brown beetles. *Pityogenes* range from 2 to 3.5 mm long and *Pityophthorus* range from approximately 1.5 to 3 mm long. The egg galleries of both genera radiate from a central nuptial chamber, producing star shaped galleries. An external symptom of attack is the presence of orange colored boring dust at the entrance holes. The main distinguishing characteristics between *Pityogenes* and *Pityophthorus* is that *Pityogenes* has 2 to 3 spine like teeth on the sloping rear end of each wing cover.

Yosemite Bark Weevil

Chip cocoon of *Pissodes schwarzi.*

Yosemite bark weevil, *Pissodes schwarzi*, primarily attacks young lodgepole pine, but can attack other pines, spruce and western larch. Eggs are laid under the bark in the bole of the host tree. The larvae mine downwards and create chip cocoons where pupation will occur. These weevils are usually found on stressed trees, often in association with comandra blister rust. Host mortality can occur when populations are large enough or the host tree is stressed. The adults are 5 to 7 mm long and have a rough, mottled, reddish brown to dark brown surface.

Lodgepole Pine Beetle

Lodgepole pine beetle, *Dendroctonus murrayanae,* attacks mature lodgepole pine. This bark beetle usually attacks stressed, old, or weakened trees or stumps and windfall. Mortality can occur if enough attacks occur on a tree. Short fat egg galleries are constructed under the bark of the host trees. Larval galleries formed off the sides of the

Lodgepole pine beetle galleries.

main gallery, usually merge and become indistinct. It takes one year to complete the life cycle. Adults are black with reddish wing covers and average 6 mm long. The presence of two anal shields on the larvae distinguish the lodgepole pine beetle larvae from other beetle larvae that attack pines. Symptoms of attacks can be detected from pitch tubes and boring dust on the lower bole.

Red Turpentine Beetle

The red turpentine beetle*, Dendroctonus valens*, primarily attacks mature ponderosa and lodgepole pine although all species of pine are susceptible. It has been found attacking younger stressed lodgepole pine. This bark beetle is not an aggressive tree killer, and prefers old, weak or injured trees or freshly cut logs and stumps. Repeated attacks are usually required to kill a tree. The adults excavate short irregular galleries at the lower bole. The larvae feed gregariously forming a fan shaped gallery. The life cycle is 1 to 2 years long depending on the temperature.

Red turpentine beetle, pitchtube and frass.

Adult turpentine beetles are the largest of the *Dendroctonus* genus. They are approximately 8 mm long and are reddish brown. Large reddish pitch tubes at the lower bole of attacked trees are characteristic.

The Pine Engraver, *Ips pini*

Ips pini galleries.

The pine engraver, *Ips pini,* attack most species of pine. This beetle usually attacks dead, dying or otherwise stressed trees. They are often found in association with mountain pine beetle or black stain root disease. However when populations are high, healthy green trees can be attacked and killed. Egg gallery patterns are star shaped with larval galleries running off at right angles. Two to three generations can be produced each year thus the population can expand rapidly. The adults are reddish brown to black and are 3.5 to 4.2 mm in length. A distinguishing feature is the concave depression on their rear end. Each side of the depression is lined with six tooth-like spines. Boring dust can be found in the bark crevices but pitch tubes are rarely formed.

Douglas-fir Engraver


Scolytus gallery

Douglas-fir engraver, *Scolytus unispinosus,* attacks weakened, wounded and dying young Douglas-fir. It also attacks recently killed Douglas-fir, slash and trees attacked by Douglas-fir beetle. Drought events can increase the population and attacks may occur on healthy young trees. From a central nuptial chamber egg galleries are constructed up and down the bole parallel to the grain of wood. The larval galleries are formed at right angles and turn either up or down. This beetle has a one year life cycle in British Columbia. The adults fly May through July and the larvae overwinter. On average the adults are less than 3 mm long. The rear end of their abdomen is “sawed off” and sometimes concave.

Pseudohylesinus sp.

Pseudohylesinus sp. usually attack dead, dying or downed trees. However *P. grandis* and *P. granulatus* can be more aggressive. The principle hosts are amabilis fir, grand fir, Douglas-fir and western hemlock. In general the galleries are similar to *Scolytus sp*. but do not etch the wood as much. The elytra of the adults are covered with scales creating a dull mottled appearance. The life cycle is usually 2 years.

Douglas-fir Beetle

Douglas-fir beetle, *Dendroctonus pseudotsugae,* is an aggressive pest of mature Douglas-fir. Outbreaks usually start in areas with downed host trees, slash, damaged or stressed trees but attacks can occur in healthy trees. The galleries are constructed parallel to the grain of the wood. Eggs are laid in groups along the gallery. The larval galleries extend from the egg groups perpendicular to the


Douglas-fir beetle galleries.

main gallery. The normal life cycle is one year but two flights may occur. Adults are 4.4 to 7 mm long. They are dark brown to black with reddish wing covers. Pitch tubes are not present but reddish to yellowish boring dust can be found in the bark crevices and at the base of the tree.

Armillaria Root Disease

Armillaria root disease basal resin flow and mushrooms.

Armillaria root disease, *Armillaria ostoyae,* will attack most conifers of all ages in British Columbia. Symptoms include, thinning foliage, reduced leader growth, and a distress cone crop. Basal resinosus can often be found at the base of the infected tree. Signs of the fungus are white mycelial fans under the bark and rhizomorphs on the surface of dead or infected roots. The honey coloured mushrooms appear beside infected stems or roots in the fall. This disease is spread by root contact and by rhizomorphs. Tree decline and eventual death occurs when the fungus disrupts the translocation of water and nutrients.

Laminated Root Rot

Most conifers in British Columbia are somewhat susceptible to laminated root rot, *Phellinus weirii,* except western red cedar. Symptoms are similar to other root diseases, thinning foliage, reduced leader growth, and a distress cone crop. The wood will first become stained then small pits will form and finally the wood will delaminate at the spring and summer wood. Signs of laminated root rot are a white to mauve ectotrophic mycelia on the surface of the root. When exposed to air a dark brown crust forms over the ectotrophic mycelium. The rare fruiting bodies are buff colored crust like layers on the underside of roots or logs. Tree decline and eventual death occurs when the fungus disrupts the translocation of water and nutrients. Mortality can occur at all ages, but young trees will die faster. This disease spreads via root contact.

Decay caused by laminated root rot.

Drought affected mature stand Salmon Arm Forest District

PHYSIOLOGICAL EFFECTS OF DROUGHT

Water is required for all important physiological processes including photosynthesis, respiration, protein synthesis and cell growth. A primary response of trees to moisture stress is stomatal closure, which decreases the plants ability to photosynthesize. Under moderate drought conditions basic physiological processes will continue, but tree growth will be reduced. Moisture stress may lead to insufficient turgor pressure to allow cell enlargement. In addition water stress increases the viscosity of phloem and decreases mass transfer in the xylem which reduces the trees ability to transport nutrients photosynthates and hormones. Under severe moisture debt enzymes needed for physiological processes can become denatured, and all turgor pressure is lost causing tree death.

SUMMARY

The drought of 1998 caused 10,035 hectares of mortality in the Kamloops Forest Region. 1047.7 hectares of drought affected area were ground surveyed. On average 26.3 percent and 25.5 percent of trees in young and mature stands respectively were killed by drought or drought related events. Drought effects were found on lodgepole pine, Douglas-fir, sub-alpine fir, western red cedar and spruce. Many secondary pests were found including Douglas-fir beetle, twig beetle, *Hylurgops* and *Hylastes sp*., pine and fir engraver beetles, lodgepole pine beetle, red turpentine beetle, and Yosemite bark weevil. The effect of root disease in combination with drought caused early tree mortality in disease-infected stands.

Many meteorologists believe the earth is undergoing human induced global warming. Increased CO_2 emissions into the atmosphere have increased the earth's ability to trap and hold solar radiation. A strong correlation has been made with increasing atmospheric CO_2 and increasing global temperatures (Schwartz 1991). As stated at the beginning of this paper, 1998 was the warmest summer on record in Canada. However temperature data has only been accurately recorded globally for 150 years (Environment Canada 2000). This increased global temperature trend recorded over the past century could be a natural part of a large temperature cycle.

Global climate change models developed in Canada and internationally predict a warming trend. This warming trend is thought to have the greatest effects at northern latitudes (Environment Canada 2000). Mid continental North American temperatures are predicted to increase between 0.3 and 1.0 degrees Celsius every 10 years (Schwartz 1991). Regardless of the cause, the effects of increased temperatures would have significant impacts on forest health specifically and the forest industry in general.

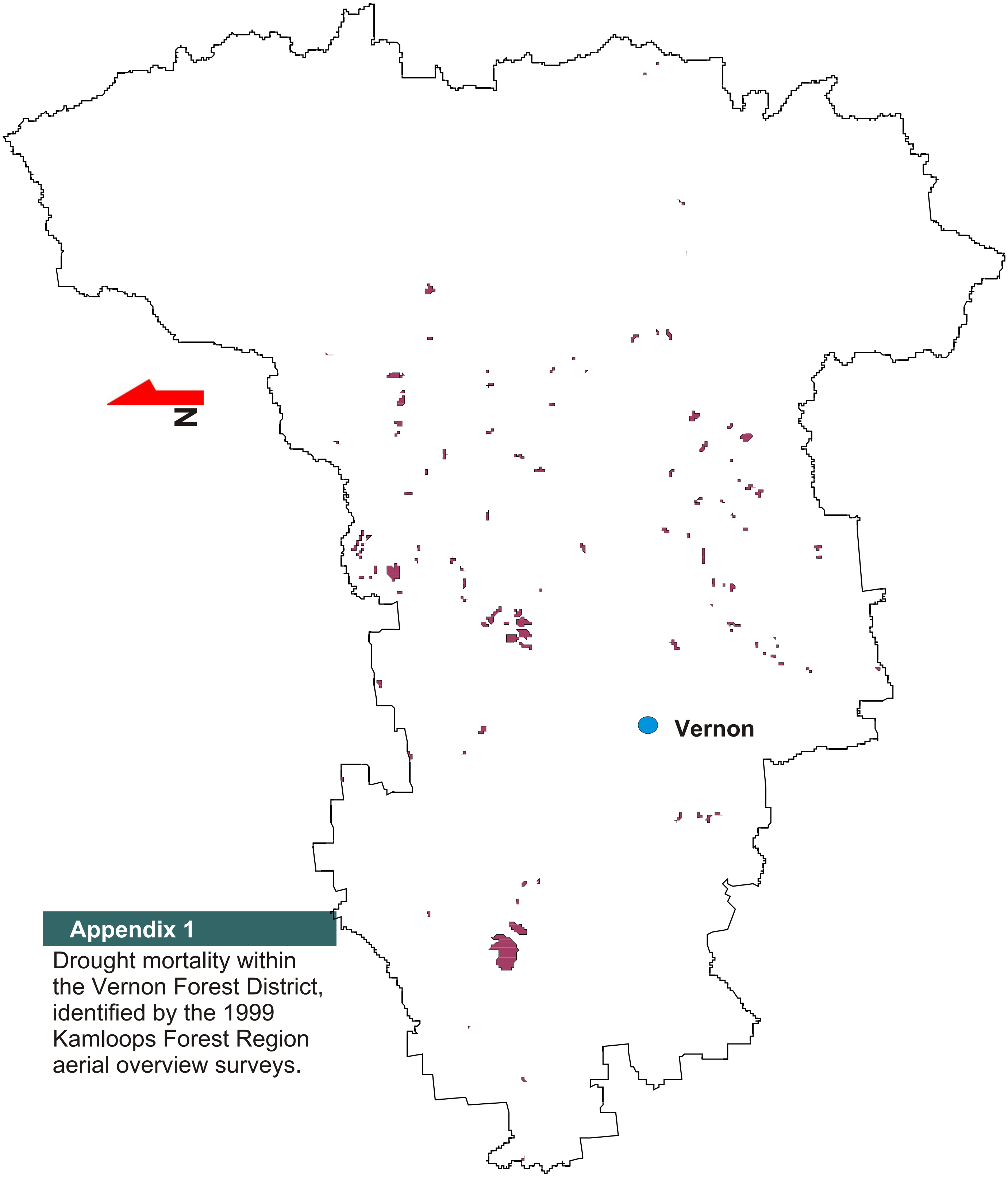
A large portion of the continental climate change is predicted to be increased winter temperatures. Warmer winters could expand the overwintering range and survival of many insect pests (Schwartz 1991). The 1999 aerial overview flights mapped 29,750 hectares of mountain pine beetle mortality. This is the greatest area attacked in at least 12 years. The increase in mountain pine beetle population can be attributed to the mild winters of 1996-1998 and the early spring and warm temperatures in 1998. Two flights occurred in many areas and the host defenses were suppressed due to the drought stress (Maclauchlan 2000).

As discussed, drought stresses attract many secondary insect pests. Stressed trees are less able to withstand insect or disease attack. Longer or more frequent drought events could result in greater volume loss. 10,035 hectares were mapped with drought mortality after one season of drought. Other parts of North America have had 3-5 successive years of drought. Successive years of drought in British Columbia could be devastating.

Neither the aerial overview survey or the results of this survey quantified volume loss due to reduced growth from drought stress. Observable drought effects began appearing in the summer of 1998 and were still occurring during the fall of 1999. Less evident effects of drought stress on the forests will likely continue over the next few years. These effects included reduced growth and productivity.

The data collected during this project suggest a need for forest managers to consider site factors which contribute to drought stress. These considerations become important when harvesting and replanting in areas susceptible to drought events. Susceptible areas include sites with exposed bedrock, shallow, well drained soils, rocky knobs and exposed sites.

Should the warming trend continue and if the global climate models hold true we can expect to see more events like the drought of 1998.

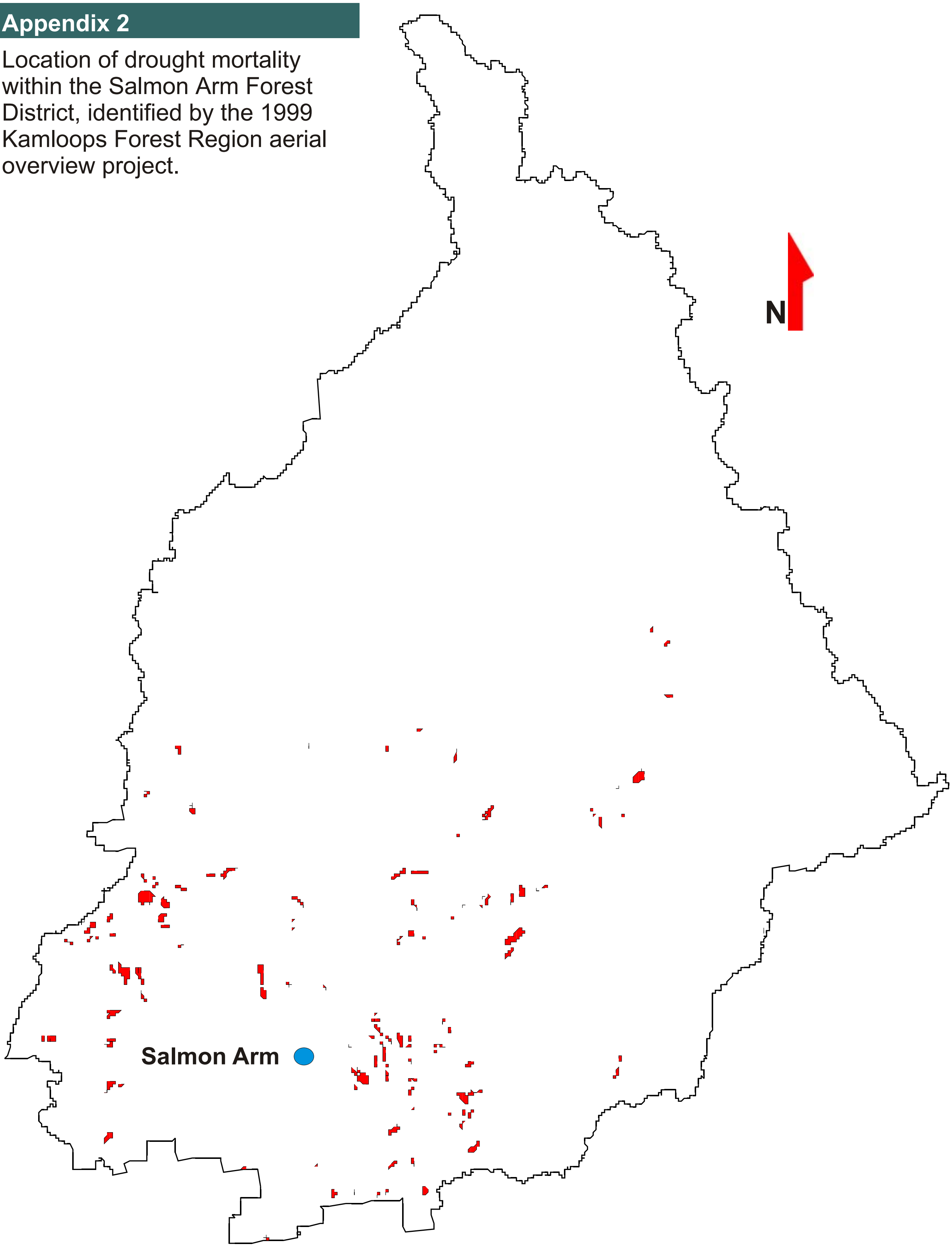


Appendix 1

Drought mortality within the Vernon Forest District, identified by the 1999 Kamloops Forest Region aerial overview surveys.

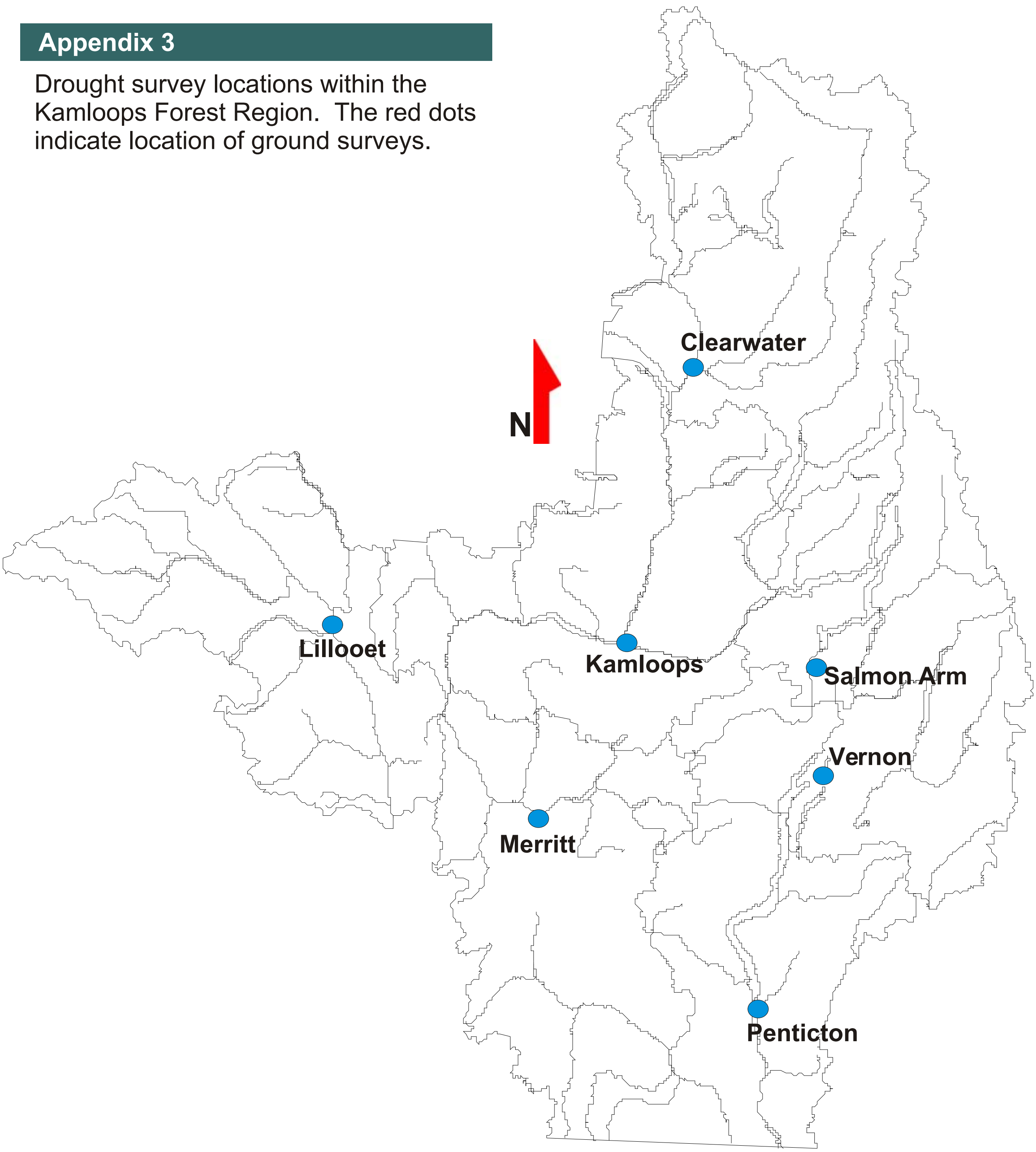
Appendix 2

Location of drought mortality within the Salmon Arm Forest District, identified by the 1999 Kamloops Forest Region aerial overview project.



Appendix 3

Drought survey locations within the Kamloops Forest Region. The red dots indicate location of ground surveys.



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