UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
DISTRICT 6

ADDRESS REPLY TO
DISTRICT FORESTER
AND REFER TO:
SI
Pw-1, D-6,
2-24-'15

BECK BUILDING
PORTLAND, OREGON

SI
Protection – Weather
Windfall Study

February 12, 1915.

DIGEST

Forest Supervisor,

Dear Sir:

A study of windfall in yellow pine following selection cuttings in Forest Service timber sales has been made recently by Forest Examiner Smith, assisted by Field Assistant Weitknecht, and the results incorporated in an exhaustive report.

Windfall is such an important consideration in the silvicultural management of yellow pine that I desire all Forest officers to get a résume of this study, so that they may share its interesting results and more intelligently handle the windfall problem in their yellow pine timber sales.

On the Whitman National Forest several large yellow pine timber sales are in progress, and have been since 1911, so that there are now in the aggregate some 6,000 acres which have been cut over by the selection system. The marking on these sales has been done by the usual standard method, leaving evenly distributed about 20 percent of the thriftiest, soundest, and youngest trees of the original stand, except for a small area where the marking was groupwise. The usual precautions against leaving trees liable to windthrow have been taken and at first no particular apprehension was felt that there would be an undue amount of loss from this source.

Then came a storm on May 26, 1913, which blew down 792 yellow pines on 880 acres of cut-over land on the W.H. Eccles Lumber Co. sale. A few more trees fell during the following summer, and on September 18, 1914, there occurred another severe storm in which 808 yellow pines blew down on the 1,624 acres cut over up to that time. This meant that 969,876 feet, or 17.5 per cent by volume of the reserve yellow pines over 12 inches in diameter had been windthrown on this one sale area – a loss in two years which, if continued, would mean in a few years more the total loss of the reserved trees. Curiously enough, on an adjacent and older cut-over area of somewhat similar topography and forest conditions – that of the Baker White Pine Lumber Co. – the loss was but a sixth as great. Here only 441 yellow pines were thrown in the two severe storms on about 2,280 acres – a loss which, though heavy, is not alarming.

The above figures, and those used later in this letter, do not include the loss by wind of larch, Douglas fir, lodgepole, and white fir; the study indicates that these species are even more subject to windfall than yellow pine.

To find out the principals which control windfall so that this loss can be guarded against in future cuttings, a study was started immediately after the September blow-down. It was exceedingly detailed in character. A 100 per cent cruise of the 1,624 acres of the Eccles sale was made, each windfall was described specifically as to its size, trunk, roots, crown, relation to neighbors, soil hold, relation to topography, etc.; a 16-inch to the mile topographic map was made of the whole area, and a 1-inch to 50 feet map made of a part of it upon which the position and index number of every windfall are shown graphically. Almost as intensive a study was made of the Baker White Pine Lumber Co. area.

This detailed record of 3,631 windfalls, 2,160 of which were yellow pine, on nearly 4,000 acres of cut-over land, resulted in an enormous mass of data, which, reduced to simplest terms, is about as follows:

1. No diameter class over 12 inches is immune from windthrow, although the trees under 18 inches in diameter are considerably less subject to windthrow than those larger. On the Eccles Lumber Co. area 7 per cent of the 12-inch trees fell, and 40 per cent of the over 30-inch diameter trees – the per cent of fall increasing with size. Much of the falling and breaking in the smaller diameters is due to the falling of big adjacent trees, rather than directly to the wind itself.

2. The danger of windfall increases with height; of the trees over 110 feet tall on one 40-acre tract, 50 per cent were windthrown. Any tree more than 100 feet tall is a poor risk.

3. Trees with dense or mediumly dense crowns are particularly subject to windthrow. Trees with open foliaged crowns, regardless of size, are much less liable to be blown over.

4. The character of the trunk of the trees has very little effect upon their windfirmness; most of the trees reserved in Forest Service timber sales are sound, and one class of trunk withstands the wind about as well as another.

5. Contrary to expectation, the windfall is apparently as great on medium and deep soils as on shallow soils, other things being equal.

6. In groups of five or more trees there is considerably more windfall than where the trees are evenly distributed. Where there are sixteen or more trees in a group the loss is 13.4 per cent greater than where the groups are smaller. A good deal of the loss in groups comes from firm trees being knocked over or broken off by windthrown neighbors, or by their root anchorage being weakened by the uprooting of adjacent trees. This is on the principal that groups of trees do not give mutual support, but do give mutual resistance to the wind.

7. On 566 acres of virgin timber adjoining the Eccles Lumber Co. cut-over area, there was but one yellow pine windthrown on each five acres, while on the cut-over land itself there was an average of one tree per acre thrown, showing that the windfall in the green timber was not excessive. It is interesting that on the windward edge of the virgin timber on a strip five chains wide there was an average of 1.3 windfalls per acre.

8. Local topography apparently does not have a very marked influence on liability to windthrow. Windfall occurs indiscriminately without regard to slope or exposure, but is slightly more severe on ridge tops and on lee slopes than elsewhere.

At the time of these two especially disastrous high winds the weather records for Baker, Oregon, showed a maximum velocity of 36 and of 42 miles per hour respectively. Winds of this intensity are of more than annual occurrence in Baker, so that it cannot be said that these two

gales were unusual. In the last twenty years the wind has attained a velocity of over 30 miles an hour on 61 occasions. Under like conditions, therefore, a loss by high wind such as occurred in 1913 or in 1914 on the Eccles Lumber Co. area is liable to occur any year.

It must be remembered that this information was collected in a single locality, and that in other timber sales in yellow pine throughout the District the loss by windfall has not been excessive. Whether the Eccles area is topographically such that it is subject to very high winds or whether its timber is especially susceptible, we do not know. Neither do we know why the loss was four or five times greater on the Eccles Lumber Co. sale area than on the adjacent Baker White Pine Lumber Co. area. But we do know that in localities like the Eccles Lumber Co. area, evidently subject to windfall, we must adjust the method of marking so that this great loss will not be suffered. This probably means that the marking must be very much heavier on risky areas than it is at present, so that no tree of a size liable to windthrow will be reserved. This will of course revolutionize our theoretical scheme of management for yellow pine stands, and our method of marking, and have some economic influence in the appraisal of yellow pine stumpage. The problem, however, seems to be local, and until we have more widespread evidence of loss from windfall, I do not propose to make any District-wide changes in our methods of marking. Nothing in this letter, therefore, authorizes you to make any changes in the method of handling yellow pine sales which you are now using, but its conclusions may be of value to you in selecting reserved trees under the standard system of marking now in effect. For the present, our method of marking will be changed in the light of results of this study only by specific instructions in each individual sale.

Very truly yours,
{*signed*} F.A. Ames
Assistant District Forester.

S July 31, 1917.
Sales, D-6.

Memorandum for Files:

While on the Whitman in June 1917 the relation of the windthrow problem to the marking in sales was discussed with Assistant District Forester Ames and the local force. The question of the problem and the factors which underlie it was discussed in a report (SI, Pw-1, D-6, 2-24-15) entitled "Windfall Damage on Cut-Over Areas, Whitman National Forest" by Smith and Weitknecht. This report was written just after the full effects of the disastrous winds of 1913 and 1914 had become apparent. Since that time the marking on the Whitman has been heavier and probably justifiably so from a silvicultural standpoint wholly aside from the probability of windfall. It seemed to Mr. Ames and myself, however, that the question of windfall had been over-emphasized and in our discussions with the local force it was suggested that the probability of windfall be not given so much weight in marking.

The basis for this decision was the almost complete absence of windfall on the cutover areas on the Whitman since the fall of 1914. In spite of the tabular statement in regard to the frequency of severe winds on page 56 of the Smith and Weitknecht report, it appears that there has been severe windfall in only 3 out of the past 9 windfall seasons, considering the spring and fall of each calendar year as a separate windfall season. In making this computation the 3 seasons in which windfall has been severe are considered the spring and fall of 1913 and the fall of 1914 and no consideration is given to the relative absence of windfall prior to 1913. The seasons when no abnormal windfall has occurred have been the spring of 1914, both spring and fall in 1915 and 1916, and the spring of 1917. In short, the Smith and Weitknecht report was written immediately after what appear to have been wholly abnormal losses from windfall during 3 windfall seasons out of 4 but since the time this report was prepared there has been no serious windfall in the region. This fact should be carefully considered in connection with the report.

Practically the same statement of fact applies to MacDaniels' report on the windfall on the Pelican Bay Lumber Company sale dated May 25, 1915, and designated "RS, Pw, D-6, Crater, 7-12-15."

E. E. C.
Forest Inspector.

SI
Pw-1, D-6,
2-24-'15

WINDFALL DAMAGE

on

CUTOVER AREAS

WHITMAN NATIONAL FOREST

FEBRUARY 1, 1915.

By

{*signed}* Kan Smith
Forest Examiner.

{*signed}* Robert H. Weitknecht
Field Assistant.

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WINDFALL DAMAGE ON CUT-OVER AREAS WHITMAN NATIONAL FOREST

by
Kan Smith, Forest Examiner
R.H. Weitknecht, Field Assistant

February 1915

INTRODUCTION

The severe damage by windfall sustained on large cut-over areas on the Whitman National Forest calls attention to the necessity of thoroughly investigating the windfall problem as it affects the selection method of cutting now being used in cutting yellow pine.

The extensive cutting of timber under selection systems in the yellow pine region in Eastern Oregon began on this Forest in the fall of 1910, and has grown steadily in number and size of sales and area cut over. Prior to that time much yellow pine timber had been cut on private lands but under logging methods which were in effect clear cutting systems, while the only sales of National Forest timber under selection system were small, isolated and covered only small areas so that the effects and ultimate results of windstorms on reserved tree stands could not be seen or foretold.

At the present time, with two large sales completed and four more in full operation with cut-over areas ranging from 400 to 2500 acres and from 1 to 4 years old, some definite results and probable conclusions regarding windthrow hazards may be drawn.

Beginning with the oldest large sale, the marking was done with the object in view of leaving approximately 20% of the mature stand evenly distributed over the area, but after a time this policy was changed to a group system in which the reserved trees were left in large, almost intact, groups, with nearly a clear cutting of all merchantable timber in between them. Still later the policy reverted to the even distribution of reserved trees again leaving an average of about 4 M ft. per acre, or approximately 15% to 25% of the stand, depending on the density of the original stand, the number of trees suitable for reservation, etc. Necessarily, because of the widely varying density and conditions of virgin stands, all gradations of reserved stand from clear cutting and scattered seed trees through even distribution to scattered groups of various sizes and density may be found on these cut-over areas and give opportunities for observation and research on the effects of windstorms.

OBJECTS OF THIS INVESTIGATION

The main objects of this study are to determine the principles which govern windfall and windbreak damage in yellow pine, specifically:

1. The size of trees most liable to windthrow.
2. The crown character of the trees most liable to windthrow.
3. The trunk character of the trees most liable to windthrow.

4. The effect of soil conditions upon liability to windthrow.
5. The effect of the distribution of the trees – singly, in groups, or near virgin timber – upon their liability to windthrow.
6. The influence of topography upon liability to windthrow.

Incidentally, this study will give information about the size, volume and distribution of the windfalls on the area covered, which will be needed in making a timber sale of these windthrown trees.

DESCRIPTION OF AREAS EMBRACED IN THIS STUDY

1. *W.H. Eccles timber sale 12/22/10 area, hereafter referred to as the Eccles area*. (See map of this area including virgin and cut-over areas.)

This area comprises 2190 acres of which 1624 acres are now cut-over and 566 acres are still virgin timber.

Roughly, this area is 1½ miles wide east and west by 2½ miles long north and south. It has a general northern aspect. The topography of the area is quite uniform. The south end is bounded by a rather sharp divide some 5250 ft. high. From this divide a series of parallel lower, rather uniform, ridges extend northward into the area. These ridges are characteristically broad and round with gentle to moderate sloping sides, their relative heights from top to bottom of the intervening draws ranging from 50 to 200 ft. From distinct and pronounced ridges in the south half these gradually merge, in a rather prominent line, into a lower, rolling, much more flat topography of approximately 4500 ft. elevation with broad gentle slopes and shallow draws.

Soil and Surface.

The soil in general is a sandy loam, moderate to very deep on gentle slopes and in bottoms, and of moderate depth on the ridges; only in restricted areas is the soil shallow as on narrower ridges or near rock outcrops. The soil, except where it is shallow, is usually fresh and quite fertile. The ridges in the eastern part have a deep subsoil of mixed loamy clay, wash gravel and boulders indicating glacial origin. The rock formation is a basalt. In the notes this rock is often spoken of as solid – by this is meant that practically it is solid. In reality it is divided into small angular pieces by a close vertical cleavage and subsequent weathering. In some instances the roots have penetrated this "solid" rock by means of vertical cleavage.

Under virgin conditions, before cutting the forest cover was for the most part a typical yellow pine type of the region. The northern portion is more nearly pure yellow pine with scattered Douglas fir and western larch associated species with here and there in draws and moister situations understories of small lodgepole pine, often in quite dense stands. In the southern portion the inferior species, Douglas fir, western larch, lodgepole pine and white fir, become more abundant and the type approaches, on the northeast slopes, the north slope subtype.

The density of the stand varies considerably from open to very dense, though with one exception there were no openings of more than two or three acres and this one was about six acres in extent. (See Forty #110.)

The stand is mostly over-mature, but excepting white fir, and less so Douglas fir, is not badly diseased or defective. White fir above 16-18" d.b.h. is almost without exception totally defective from frost crack and heart rot, conky.

The virgin timber considered in this study comprises a belt from one-quarter to three-quarters of a mile wide on the northeast, east and southeast (the leeside of the cut-over land) and a triangular tract on the southwest side (the windward side) – in all 566 acres – and embraces as near as may be the same actual conditions of topography, aspect and exposure to windstorms. Enough depth of virgin timber was secured to show results under absolutely virgin conditions in the vicinity.

From data secured in this study it is evident that a small amount of windfall occurs as a normal condition and the past two years is fairly comparable to the windfall of other years, and in either case it is confined largely to defective timber, showing that this is one of nature's ways of harvesting the mature and defective stock.

The forest cover as it was left after cutting varied considerably in density and distribution, due largely to irregularity of virgin stand and systems of marking. Over most of the area the stand was more or less evenly distributed, often in small groups of 2 to 10 trees, but usually as single trees in degrees of density ranging from very light to almost the density of a virgin stand. In other places, however, the cutting was decidedly group-wise, with the intervening spaces in effect clear cutting. Some idea of the distribution may be gained from photographs Nos. 4, 6, 8 and 11 [11 was crossed out in pen on original copy].

The reserved cover necessarily includes large numbers of tall and large-diameter trees because of a scarcity of young trees in the virgin stand. Although the general average height of the reserved cover is naturally less than that of the original, yet the maximum height is not greatly reduced. Thus those tall trees which were reserved are considerably more exposed to windstorms.

2. *Pw-1 Plot*. (See map of Pw-1 Plot.)

This is a permanent sample plot of 40 acres laid out within the cut-over land of the Eccles area. By reference to the larger Eccles map it is located in Forties 93 and 86 – 15 acres in the northern part of the former and 25 acres adjoining the latter. It lies in a square 20 chains each way and is marked on the ground by permanent corner posts marked Pw-1 and temporary stakes every 5 chains between.

Its primary object was to make a careful comparison of windthrown trees with standing trees and a very intensive study of the effects of the more recent windstorms for future reference and observation.

It lies in the northern part of the cut-over area and has sustained severe losses, indicating it to be an area of the greatest windfall hazard. The three storms, May and August 1913 and September 1914, all inflicted serious damage to it and the trees that have survived have sustained the severest of the windstorms. For these reasons this plot was selected as most likely to yield satisfactory conclusions in this study.

The plot has very gentle rolling slopes – a flat, in fact, breaking off on the east edge by steep slopes to a bottom 50-100 feet lower. The exposure is westerly. The soil is fairly representative of the soil on the Eccles area. About one-fourth of the plot has a deep, fertile, fresh, friable, sandy loam of light brown color, often approaching the grayish white powdery "volcanic ash" soil of the region. Over half of the area the soil is of medium depth, much similar in other respects to the deep soil. In a few places this soil has a light admixture of small angular broken rock and angular gravel. The remainder, less than a quarter, is a shallow soil running out in a few places

to bare rock outcrops. This soil is usually dry, friable, sandy loam, in a few places strewn with small broken rock.

The underlying rock formation is a metamorphosed basic rock, probably basalt, finely divided by parallel vertical cleavage and near the surface, especially under and around the tree roots, profusely broken into small cubical fragments by weathering.

The forest cover of this plot will be described and discussed later.

3. *Baker White Pine Area*.

This tract comprises about 3½ sections of cut-over land embraced in four sales – Baker White Pine Lumber Company's Timber Sales of 6/13/10, 3/20/13, 5/25/11 and 5/5/14. This cut-over land is in one contiguous body and lies roughly 2½ miles north and south by 1½ miles wide east and west, and is located in the northwest corner of unsurveyed T. 11 S., R. 35½ E., W.M., and is approximately 2½ miles due north of the Eccles area. It lies on the upper slope and crest of the slopes on the north side of the Middle John Day valley at a mean elevation of 5200 feet and has a decided southern aspect. The tops of the ridges are broad and gently rolling or flat with high slopes to the creeks and draws. The general trend of the water courses is southwest but locally they are diverse.

The surface is in many places much more rough and broken than that of the Eccles area, there being numerous outcrops and cliffs of broken basalt and numerous rocky depressions, often called "blow-outs".

The soil is in general similar to that of the Eccles area and hardly need be described again. The rock formation varies in that there is much less weathering and the outcrops generally are masses of broken basalt.

Forest Cover.

Although this area has a southern exposure, because of the greater elevation and rougher irregular topography, much of the virgin stand was and is a typical north slope forest with inferior species dominating; what yellow pine there is, however, being individual trees of large size, fine form and quality where sound. Otherwise the forest cover description is applicable to this also.

Two natural openings occur on this tract, one being Crawford meadows, some 200 acres in extent, lying in a triangle, which is a treeless meadow fringed on the edges with young lodgepole pine pole thickets. The other is hardly more than a lane on Jap Gulch in the central part, being some 20-25 chains long by 2-3 chains wide and lying at right angles to prevailing southwest winds.

OTHER AREAS CONSIDERED IN THIS REPORT

The notes on these are more general and were mostly incidental to other work on them and will be submitted as matters of interest bearing on this subject. These will be treated in more detail further on in this report.

METHODS OF GATHERING DATA

1. *Eccles Area*.

In the inception of this study it was planned to base this work on a percentage (20%-50%) cruise of the areas to be considered with supplementary intensive studies of temporary sample plots for details. However, upon starting field work it became evident that a percentage cruise would be very unsatisfactory, if not absolutely misleading, as a basis for determining actual losses, drawing of definite conclusions, and making recommendations. The reason for this becomes self-evident when it is known that the reserved stand is the result of man's interference with the natural, more or less uniform distribution of trees and of necessity, in this case, materially upsets that established distribution or rough uniformity of stand. This, of course, is considered more with respect to effects of windstorms on the stand. A more important factor though is the fact that windfalls, unlike growing timber, do not occur regularly over the area, but in indeterminable patches and groups and in varying density, depending upon a combination of circumstances not common to the prior virgin stand, as may be seen by referring to the map.

The 100% cruise has added materially to the cost of both field work and somewhat to that of the office, yet since the effect of windfalls on cut-over lands of selection forests in the region is of vital importance, it is believed that the extra expense is justified.

In addition to securing the windfall data it was deemed necessary that a new topographic map of the Eccles area be made.

After trying various methods in the field, it was found best to work in two-man parties, consisting of a compass man and an "estimator" or recorder. From two base lines, 60 chains apart, previously established, strips 5 chains wide were run consecutively east and west across the area.

As the party advanced along the strip, the compass man, using a standard compass and Jacob staff, located the center of the strip, kept his distance by pacing and mapped topography in 50 contours by use of Aneroid barometer readings and hand level. By appropriate symbols he also located on his sketch map all windfalls in their respective positions, nature and direction of windthrow, their serial number and year of fall.

The recorder inspected each windfall separately and recorded on blanks provided for the purpose the serial number, species, D.B.H., merchantable height in logs, crown character (length, width and density), trunk character, root conditions, soil and rock depth and character, relation of tree to topography and standing timber, date of fall, nature of fall – i.e., uprooted, broken off, etc. – indirect cause of fall, if evident, and such other information as was noted. He also stamped in a blaze each windfall with marking hatchet as a check and as a guide to future cruisers.

By this equal division of labor it was found that the work could be done most expeditiously and economically, although of necessity one man worked alone a portion of the time carrying on both operations simultaneously in a satisfactory manner, though of course slow and tedious.

Later, after inking in of these field sketches, they were taken into the field and 25 ft. contours interpolated with reference to the actual topographic features.

2. *Pw-1 Plot*.

On this plot a large scale map, 50' = 1", was made with plane table and stadia. Every yellow pine above 4" d.b.h and lodgepole pine above 12" *{10"}*, including standing and windthrown trees, stumps, etc., was located upon this map in its relative position. All trees of the sizes

mentioned above were given a serial number marked with crayon in a bark blaze at about breast high and indicated on the map. Topography is indicated in a contour interval of 5 ft. owing to the flat nature of the area.

The same tree data was secured for each tree in more detail and in addition the total height of all trees was secured, of windfalls by pacing, of standing trees by standard hypsometer.

3. *Baker White Pine Area*.

The existing maps of this area were considered sufficiently accurate for this work, therefore no new map was made. However, it was necessary that a cruise of the cut-over area be made and as it would be of use in the study it was thought best to be made at this time. Therefore a two-man party, composed of compass man and estimator, made a 10% cruise of this area by running a two-chain strip once through a forty. These strips were run north and south across the area from a base line established east and west through the approximate middle of the area.

The windfall data secured on this area is a 100% cruise of windfalls by two recorders working independently on separate areas. Each carried a topographic map upon which was located, by topography, each windfall, its direction of fall and number. The same data of each windfall was secured as on the other areas and the tree marked. This method was less intensive and accurate than that of the Eccles area, yet sufficiently so for all practical purposes in this case.

TABULATIONS

Size.

1. *Eccles Area*. Cut-over lands, 1624 acres.

This table is based on 8909 yellow pine trees, of which 1654 were thrown. The total number of trees is based upon a 100% cruise of 880 acres made in the fall of 1913, while the trees thrown are by actual tally on 1624 acres, fall of 1914. This table shows the relation, by diameter classes, between windthrown trees and those left standing, the reserved stand and the total windthrow.

Table I

D.B.H. of Yellow Pine Reserved, Thrown and Standing
Eccles Area (Cut-over lands)

	Windthrown trees					Reserved Stand		
DBH	1913*	1914 Spring	1914 Fall	Total	% of Total	Total No.	% of Re-served	% of Diameter thrown
12	57	3	56	116	7.0	1,579	17.71	7.35
14	49	3	73	125	7.5	1,330	14.92	9.40
16	75	11	69	155	9.4	1,030	11.55	15.05
18	85	8	89	182	11.1	925	10.37	19.67
20	92	7	96	195	11.8	1,008	11.30	19.34
22	104	4	91	199	11.9	489	5.48	40.69
24	123	3	103	229	13.8	902	10.11	25.38
26	92	3	91	186	11.2	692	7.76	26.88
28	54	8	67	129	7.9	472	5.29	29.44
30	24	2	28	54	3.3	210	2.35	25.71
32	14	1	17	32	1.9	153	1.75	20.91
34	11	1	11	23	1.4	82	.91	28.05
36	9		14	23	1.4	25	.27	92.00
38	2		3	5	0.3	6	.06	83.33
40	1			1	0.1	6	.17	16.66
Totals	792	54	808	1,654	100.0	8,909	100.00	18.56
%	8.89		9.67	18.55			100.00	18.56

* Includes spring and fall.

Of the 8,909 trees reserved nearly two-thirds, 65.9%, are found in the fine *{five}* diameter classes 12" to 12" *{20"}*, inclusive. These five classes sustained 46.7% of the total windfall, although the heaviest windfall, 69.1%, occurred in the six classes, 16" to 26", inclusive, representing 46.6% of the stand. While the seeming high loss sustained by the smaller diameters is accounted for by the relatively larger numbers of reserved trees in them, yet the last column shows that all excepting 12" and 14" have lost more than 15% in two years. Above 20" the loss averages better than 25%. The average tree windthrown is 22" d.b.h.

Table II gives the same data for 3,413 reserved inferior species of which 1,083 were windthrown and shows differing results but even more detrimental to the smaller diameters.

Table II

D.B.H. Inferior Species Reserved, Thrown and Standing
Eccles Area (cut-over)

						Reserved Trees		
DBH	1913	1914 Spring	1914 Fall	Total Windfall	% of entire Throw of Inferior Sp.	Total No.	% of Diameter thrown	% Reserved
12	170	10	134	314	28.9	1,136	27.6	33.27
14	118	7	106	231	21.3	750	28.1	21.97
16	86	3	85	174	16.1	555	31.4	16.25
18	69	1	59	129	11.9	269	47.5	7.87
20	38	3	39	80	7.4	239	33.4	7.00
22	29	0	33	62	5.7	117	53.0	3.45
24	12	0	18	30	2.8	160	18.9	4.69
26	11	0	14	25	2.3	99	25.0	2.90
28	9	0	10	19	1.8	44	43.2	1.29
30	3	1	4	8	.7	23	34.8	.67
32	2	0	1	3	.3	7	42.9	.20
34	0	1	1	2	.2	6	33.3	.18
36	1		2	3	.3	4	75.0	.16
38	0		1	1	.1	2	50.0	.06
40	1			1	.1	1	100.0	.02
46	1			1	.1	1	100.0	.02
Total	550	26	507	1,083	100.0	3,413	31.7	100.00

The percentage of all species windthrown is 22.21%.

Tables IV and V show similar data for the Baker White Pine area and give much the same results.

2. *Pw-1 Plot*. 40 acres Eccles cut-over area.

The basis of this table is 100% tabulation of 288 reserved yellow pine 12" d.b.h. and over by 1" classes. Of these, 115 trees were thrown.

Aside from a few groups of small lodgepole pine and two western larch, no inferior species occur on the plot at present. The original stand was an almost pure yellow pine with an understory of young lodgepole pine in the depressions. It averaged 17.9 M ft. per acre or 718.5 M ft. total. For the most part it is on site quality I and had maximum heights of 135 ft. It was mostly over-mature but not especially defective. It was healthy and of fairly even distribution, although more open areas occurred on the west, south and central parts. The eastern border, or one-fourth, was logged during the winter of 1913-14 and thus was a windward edge of virgin timber during the storms of May and August 1913. No unusual windfall occurred on it during these storms. The remainder of the tract was cut-over during the fall of 1912, and thus was

exposed to all of these storms. Approximately 1¼ acres in the extreme northeast corner is as yet uncut and suffered windfall in common with cut-over areas.

The relative stands of virgin and cut-over stands of this plot are tabulated below.

	Original Stand.	Reserved Stand.	Per Acre Original Stand.	Per Acre Reserved Stand.
No. of trees	665	288	16.6	7.2
Percent	100	43.3	—	—
Est. Vol. M ft.	718.5	147.07	17.9	3.68
Percent	100	20.46	—	—

The lesser percent by volume is accounted for by the larger volume taken out in fewer large-sized trees.

The average volumes per acre indicate (a) that the virgin stand was heavier than the average volume per acre for the whole tract; (b) the average volume per acre reserved is less than the average volume per acre for the whole tract; (c) thus the percent reserved is less than that for the whole area – all of which may be of interest in comparing with other areas.

Table III

Pw-1 Plot - D.B.H. of Yellow Pine Thrown (Cut-over)

	Fall by Years				Reserved Trees		
DBH	1913	1914	Total Windfall	% of Total Thrown	Total No.	% of Dia. thrown	% of reserved
12	1	4	5	4.35	14	35.71	4.86
13	2	1	3	2.61	23	13.04	7.98
14	1	3	4	3.48	15	26.67	5.20
15	1	1	2	1.74	17	11.76	5.90
16	4	3	7	6.09	23	30.43	7.99
17	1	4	5	4.35	14	35.71	4.86
18	2	2	4	3.48	14	28.57	4.86
19	2	2	4	3.48	16	25.00	5.56
20	3	3	6	5.22	22	27.27	7.64
21	1	6	7	6.09	16	43.75	5.56
22	1	9	10	8.69	17	58.82	5.90
23	5	3	8	6.95	16	50.00	5.56
24	3	8	11	9.56	20	55.00	6.94
25	3	2	5	4.35	8	62.50	2.77
26	5	5	10	8.69	16	62.50	5.56
27	2	1	3	2.61	8	37.50	2.77
28	2	8	10	8.69	12	83.33	4.17
29	1	3	4	3.48	7	57.14	2.43
30	1	4	5	4.35	5	100.00	1.74
31	0	0	0	0	0	0	0

	Fall by Years				Reserved Trees		
DBH	1913	1914	Total Windfall	% of Total Thrown	Total No.	% of Dia. thrown	% of reserved
32	0	2	2	1.74	3	66.67	1.40
33	0	0	0	0	0	0	0
34	0	0	0	0	1	0	.35
Total	41	74	115	100.00	288	39.93	
%	14.23	25.7	39.93				100.00

Six points of interested may be noted from the above table –

1. No diameter is exempt from loss.

2. All diameters except 13" and 15" lost 25% or more and roughly percent of loss increases with diameter.

3. The largest diameters suffered most heavily.

4. The nine diameter classes, 12"-20", have 54.9% of total stand, lost 25.33% of the diameters, or 34.8% of total loss.

5. The eleven diameter classes, 16"-26", have 63.2% of total stand, lost 42.3% of the diameters, or 66.96% of total loss.

6. Percentage of loss in 1914 almost double that of 1913, but this is modified in that only three-fourths of the area was cut over in 1913.

On this plot also was collected data on all yellow pine 4" to 12" D.B.H. Of these there were 165 trees after logging, of which only 4 were windthrown, or a loss of 2.4% by number. Of the four that blew over, one 8" tree's roots were intertwined with a larger tree that was windthrown. One 8" tree stood on an exposed rocky ridge in soil only 6" deep and two 9" trees were broken off by larger trees falling on them.

From this it may be seen that if all larger trees were removed the loss of trees 12" d.b.h. and less would be negligible.

3. *Baker White Pine Area*. Cut-over area, 2280 acres.

Basis of tables 10% cruise of reserved stand, 100% cruise of windfalls; 12510 yellow pine, 507 thrown; 11720 inferior species, 671 thrown.

Table IV

D.B.H. of Yellow Pine Thrown (In cut-over)

	Fall by Years					Reserved Trees		
DBH	1912	1913	1914	Total Windfall	% of Total Thrown	Total	% of Dia. Thrown	% of Total
12	5	12	24	41	.08	1,640	2.50	13.11
14	2	11	31	44	.09	1,490	2.21	11.91
16	4	16	19	39	.08	1,450	2.69	11.59
18	6	34	33	73	.15	1,190	5.13	9.51
20	6	20	41	67	.13	1,220	5.49	9.75
22	7	16	42	65	.13	1,430	4.54	11.43
24	14	22	50	86	.17	1,770	4.86	14.15
26	9	17	25	51	.10	1,130	4.51	9.02
28	6	7	13	26	.05	890	2.92	7.14
30	7	4	0	11	.02	200	5.50	1.59
32		1	2	3		60	5.00	.48
34						10		.08
36		1		1		30	3.33	.24
Total	66	161	280	507	100%	12,510	4.05	100.00
%	0.54	1.28	2.23	4.05				

For comparison this table shows 12"-20" diameter classes to have 55.87% total stand, 53% of total windfall, and these diameters to have lost 3.78%; 16"-26" diameter classes have 65.45% of total stand, 76% of total windfall, and lost 4.65% of these diameters.

Table V

Baker White Pine Areas
D.B.H. of Inferior Species Thrown (In Cut-over)

	Fall by Years					Reserved Trees		
DBH	1912	1913	1914	Total Windfall	% of Total Thrown	Total	% of Dia. Thrown	% of Total
12	9	19	82	110	17	3490	3.15	29.77
14	7	25	91	123	18	1990	6.18	16.98
16	5	10	55	70	11	1830	3.82	15.62
18	7	12	50	69	10	970	7.11	8.29
20	2	10	54	66	10	920	7.17	7.85
22	0	3	26	29	4	650	4.46	5.55
24	1	6	35	42	6	810	5.19	6.91
26	0	4	33	37	6	400	9.25	3.41
28	2	3	21	26	4	260	10.00	2.22
30	0	2	26	28	4	240	11.66	2.04
32	0	3	14	17	3	50	34.00	.42
34	0	0	14	14	2	20	70.00	.17
36		1	13	14	2	30	46.66	.26
38			10	10	1	40	25.00	.34
40			16*	16	2+	20	80.00	.17

	Fall by Years					Reserved Trees		
DBH	1912	1913	1914	Total Windfall	% of Total Thrown	Total	% of Dia. Thrown	% of Total
Total	33	98	540	671	100	11720	5.73	100.00

* Including diameters to 48"; percent of all species windthrown, 4.86.

In this table 12"-20" classes have 78.51% of total stand, 66% of the loss and 4.76% of the diameters.

Classes 16"-26" have 47.6% of total stand, 47% of total loss and 5.55% loss of those diameters.

{*CHART - **AVERAGE HEIGHT CURVES***}

AVERAGE HEIGHT CURVES.
Showing relation of windthrown trees to trees left standing.

Pw-1 Plot.

Based on 109 windthrown and 112 standing trees, 12" and over D.B.H., Yellow Pine only.

Height – Pw-1 Plot, 40 Acres.

Average Height Curves.

These curves include all trees 12" d.b.h. and above on the sample plot, including 27 trees in virgin timber in the northwest corner. Careful inspection shows curves unaffected by heights of these in diameters below 30". Above 30" d.b.h. curve for standing trees is too high as these trees would not ordinarily be left after cutting. One 32" tree 135' and one 28" - 135' left in cut-over, went down.

By diameters the curve average height of windfalls above standing tree is as follows:

D.b.h	12"	14"	16"	18"	20"	22"	24"	26"	28"	30"
Diff. ft.	12	10	9	9	9.5	10	10.5	11	11.5	11.5

In three diameters only (19", 22" and 29") do the average heights of windfalls fall below average height of standing trees, also of all trees. Investigation shows the windfalls of these diameters especially subject to windfall for the following reasons: large, dense crowns, poor roots, shallow soil or medium soil on solid rock, butt rot and group unusually exposed; while the trees standing are favored by medium crowns, deep soil, young or protected.

Of the whole number, 8.3% were windfalls with total height less than the average height curve for standing trees, while 9.3% were standing trees above the average height curve for windfalls.

Windfalls – 34.9% of total number of trees tallied. (Does not include 9 trees logged and for which no data was available.)

In the following diameters the average height of windfalls is as high or higher than the maximum height of trees left standing.

D.b.h.	12	17	18	27	28	32
Number	3	2	1	3	9	1

In the next two tables are tabulated for comparison the maximum height relations of standing and windthrown trees.

Diameters in which Maximum Height of Standing Trees Exceeds Maximum Height of Windfalls

D.b.h.	15	17	19	20	21	24	27
Number	3	3	3	1	2	2 (equal)	1

Diameters in which Maximum Height of Windfall Trees Exceeds Maximum Height of Standing Trees

D.b.h.	12	14	16	17	18	22	23	25	26	27	28	30
Number	5	1	1	3	3	1	1	3	6	3	4	1

Based on a consideration of relative heights of reserved trees left after cutting, it is the trees with heights extending above the average height of reserved tree crown cover that are maximum windfall risks and this holds also for average heights of individual diameter classes.

The difference of average heights of windfalls over the total average is 8.5 ft. for 12" trees, and increases with diameter, while the difference of maximum heights ranges as high as 29 ft. in any one diameter class.

By 10' height classes the percent of trees for each class windthrown is as follows:

Class	50-59	60-69	70-79	80-89	90-99	100-109	110-119	120-129	130-139
% Thrown	0	25%	14.6	30	37.2	46.7	50	69.2	100

The danger of windfall increases with the height until at 110 ft., 50% of the trees are subject to windfall. These average a little less than 26" d.b.h.

Conclusions.

Reserved trees most subject to windthrow are those taller than the average height of reserved tree crown cover and risk increases rapidly with height above crown cover. Trees above 100 ft. in height are unsafe risks.

INFLUENCE OF CROWN CLASS ON WINDFALL

Pw-1 Plot. Table VI a & b.

Based on total reserved stand of 288 yellow pine trees; tabulations of "a" table compiled from computations of both windfalls and trees left standing and shows their relations in each crown

class. Table "b" gives number of windfalls and percent of total windfalls for comparison of Eccles and White Pine areas. (Tables VII and VIII)

The classification is based upon the length, width and density of crown. The diagramitic {*diagrammatic*} sketches show nine typical crowns of relative lengths and widths. Each of these forms is further classified into three degrees of intensity {*density*} as indicated in the tables.

In the tables are also the percentages of throw together with the average diameters of trees thrown in each crown class through all sizes, etc.

The combined tables and diagram show that on this 40-acre area all the big sized crowns which have dense and mediumly dense foliage are subject to severe windthrows {*windthrow*}. The open foliaged crowns, regardless of size, are comparatively immune from throw. The small sized crowns, i.e., the short ones and narrow ones, are only slightly subject to throw, although the table actually shows them to have suffered heavily. The reason for this lies in the fact that these small crowns and the open crowns were knocked down and pulled down by their bigger neighbors and not as a direct effect of crown resistance. These small ones would not be thrown if big ones were not in stand.

Out of 23 types of crown existant {*existent}* on the plot 17 types suffered more than 25% windthrow, while many of these suffered in the neighborhood of 50% windthrow, and these types are the best crown types for purposes of reserved growth.

Eccles Area. Table VII.

Based on 978 windfalls of 1914; does not include the 1913 windfalls because they had been logged and tops burned. There were approximately 800 trees and it is reasonable to suppose that they were largely large sized crowns.

Baker White Pine Area. Table VIII.

Based on 420 trees, all for which necessary data could be secured.

{*diagram of crown types*}

TABLE VI-a. Pw-1 PLOT. Percent of Reserved trees thrown in each class.

	No. Reserved	% Thrown	No. Reserved	% Thrown	No. Reserved	% Thrown	No. Reserved	% Thrown	No. Reserved	% Thrown	No. Reserved	% Thrown	No. Reserved	% Thrown	No. Reserved	% Thrown	No. Reserved	% Thrown
DENSE	27	74	36	33	7	43	11	1	47	51	3	33	3	33	10	0	4	25
MEDIUM	13	46	33	42	15	33	14	43	33	21	11	18	0	—	2	50	1	100
OPEN	0	—	7	0	3	33	1	0	5	0	0	—	0	—	1	100	1	100
	Ave. Diam.		Ave. Diam.		Ave. Diam.		Ave. Diam.		Ave. Diam.		Ave. Diam.		Ave. Diam.		Ave. Diam.		Ave. Diam.	
Thrown	26"		21"		18"		25"		22"		14"		23"		19"		14"	
Standing	21"		19"		17"		21"		18"		16"		23"		18"		15"	

TABLE VI-b. Pw-1 PLOT. Percent of thrown trees in each class.

	No. Thrown	% Thrown	No. Thrown	% Thrown	No. Thrown	% Thrown	No. Thrown	% Thrown	No. Thrown	% Thrown	No. Thrown	% Thrown	No. Thrown	% Thrown	No. Thrown	% Thrown	No. Thrown	% Thrown
DENSE	20	17.4	19	16.5	3	2.6	1	9	24	20.9	1	.9	1	.9	0	0	1	.8
MEDIUM	6	5.2	14	12.2	5	4.4	6	5.2	7	6.1	2	1.7	0	0	1	.9	1	.9
OPEN	0	—	0	0	1	.8	0	.0	0	0	0	0	0	0	1	.9	1	.8
Ave. Diam.	26"		21"		18"		25"		22"		14"		23"		19"		14"	

TABLE VII. ECCLES AREA. Percent of thrown trees in each class.

	No. Thrown	% Thrown	No. Thrown	% Thrown	No. Thrown	% Thrown	No. Thrown	% Thrown	No. Thrown	% Thrown	No. Thrown	% Thrown	No. Thrown	% Thrown	No. Thrown	% Thrown	No. Thrown	% Thrown
DENSE	130	13.4	166	17.0	62	6.3	42	4.3	118	12.1	49	5.0	5	.5	11	1.1	2	.2
MEDIUM	47	4.8	104	10.7	33	3.3	30	3.0	95	9.7	17	1.7	1	.1	34	3.4	7	.7
OPEN	3	.3	4	.4	6	.6	2	.2	5	.5	1	.1	1	.1	3	.3	2	.2
Ave. Diam.	25"		21"		20"		26"		20"		16"		18"		17"		14"	

TABLE VIII. BAKER WHITE PINE AREA. Percent of thrown trees in each class.

	No. Thrown	% Thrown	No. Thrown	% Thrown	No. Thrown	% Thrown	No. Thrown	% Thrown	No. Thrown	% Thrown	No. Thrown	% Thrown	No. Thrown	% Thrown	No. Thrown	% Thrown	No. Thrown	% Thrown
DENSE	90	21.5	60	14.3	5	1.2	46	11	62	14.8	6	1.4	14	3.3	25	6	3	.8
MEDIUM	14	3.3	14	3.3	2	.5	9	2.1	9	42.1	4	.9	2	.5	8	1.3	5	1.2
OPEN	8	1.9	9	2.1	8	1.9	1	.02	4	.9	0	0	2	.5	2	.5	8	1.9
Ave. Diam.	22"		18"		18"		20"		18"		18"		18"		18"		16"	

INFLUENCE OF TRUNK CHARACTER

1. Eccles Area.

Following tables include only yellow pine over 12" d.b.h.

Table IX

Number thrown in storm of May 1913.

	Uprooted	Broken off	Total thrown
All types of trunks	749	33	782

Number thrown in storm of September 1914.

Character of trunk	Uprooted	Broken off	Total thrown
Sound Normal	596	193	789
Sound Forked	17	15	32
Sound Basal fire-scar	0	20	20
Heart rot	0	28	28
Totals	613	256	869

In the case of the windfalls of 1913 it was not possible to classify the trunk types because these trees had been logged previous to the initiation of this study. The terms used in the 1914 table are defined under the discussion of trunk characters in connection with the intensive sample plot.

The data in this table do not afford a sound basis for a determination of the comparative liability to windthrow of the several types of trunks, because it was not possible to determine the total number of trees reserved in each trunk type on such a vast cut-over area as 1600 acres. The trunk data obtained on the intensively studied sample area of 40 acres, which did afford a basis of determination, showed conclusively that the best type of straight normal trunk was blown over as easily as the crooked and forked trunks.

In connection with the classification into uprooted and broken off windfalls in the above tables, it is interesting to note that in the storm of May 1913 only 4% of all the thrown trees were broken off, while in the storm of September 1914, 29% were broken off. This difference is explained largely by the difference in soil conditions in the fall and spring; in the spring storm the soil was moist and loose; in the fall storm it was dry and solid and furnished a more stable anchorage. The 1914 table shows also that in the case of the windfalls which had basal fire scar, and of those which visibly contained heart rot, all had been broken off, and of those which had forked trunks, practically 50% were broken off.

Of special interest is the case of forked-trunk trees – commonly called schoolmarms – which had only one prong broken off. Altogether there were 24 such trees – 5 in 1913 and 19 in 1914. Of the five trees which lost one prong in 1913, three lost their remaining prongs in 1914, thus rendering them a total loss as reserve trees.

This discussion of the uprooting and breaking off of the different types of trunks indicates what types are unfavorable for reserved trees under normal meteorological conditions.

2. Pw-1 Plot.

Table X

Trunk Characteristics For all Yellow Pines over 12" d.b.h

Character of Trunk	Number of Trees Reserved	Number of Trees Bent over but not Thrown	Thrown Trees	
			No.	%
Normal	236	3	94	40
Leaning	22	0	4	18
Crooked	4	0	2	50
Forked	28	0	12	43
Total	290	3	112	39

None of the reserved trees on the plot, including both windfalls and standing trees, gave evidence of unsound trunks or of serious fire scar; thus all the trunks in the table are sound. The term "normal" trunk as here used means a straight, single, vertical bole. "Leaning" means a straight, single, inclined bole. The term "crooked" means a crooked single bole. A tree with forked trunk is one which has two or more trunks – commonly called a schoolmarm in Oregon and Washington.

In the case of the leaning trunks in the table, too much dependence must not be placed on the figures given. It was not possible always to determine whether a windfall had had a leaning or a vertical trunk; therefore the number of thrown leaning trees would be greater than in the table. It is interesting to note that of the total number of leaning trees standing after the windstorms, 55% lean badly, as follows – 33% lean toward the wind direction; 11 lean away from the wind direction; 11% lean at right angles to the wind direction, and the remaining 45% lean only slightly and in all directions.

In the case of the crooked trunks the two standing are short windfirm trees of big diameters, 20" and 34" respectively; the two thrown area 12" and 13" in diameter and their fall was not due to any factor of trunk or crown but to being pulled over by bigger neighboring trees.

Of the fork-trunked trees, 43% were completely thrown and 7% had their crowns deformed by the breaking off of one of the prongs. It is significant to note in this connection that in the extensive examination of that part of the Eccles cutting which suffered both the storms of 1913 and 1914, many instances were noted where forked trees had one prong broken off in 1913 and the other in 1914, leaving the tree a total loss.

3. Baker White Pine Area.

Table XI

Trunk Characteristics, Yellow Pine 12" d.b.h. and over

	Normal		Crooked		Rotted		Scarred			Schoolmarms			Bending	Totals	
	UR	BO	UR	BO	UR	BO	UR	1/4	1/2	UR	1 pr.	BO		No.	%
1912	61	0				1	2					1		65	12.6
1913	107	34	3	2	0	3	1		3			1		154	29.8
1914	165	60	11	6	0	12	2		10	1	6	3	22	298	57.6
Totals	333	94	14	8	0	16	5		13	1	6	5	22	517	
%	64.4	18.2	2.7	1.5		3.1	1		2.5	0.2	1.2	1-	4.2	100	100
% by trunk class		82.6		4.2		3.1	0		3.5	0		2.4	4.2	100	

Based on 517 yellow pine trees on Baker White Pine area.
1912 comprises all trees windthrown on cutting area from beginning of cutting, fall of 1910, to end of 1912.
Normal trunk – one that is straight, sound and normal with regard to windthrow.
Crooked trunk – one that has natural crooks with a tendency to weaken it and make it more than normally subject to windfall.
Rotted trunk – one in which heart rot or butt rot was a weakening cause and resulted in windfall.
Scarred trunk – one that bore scars from any cause such as fire barking, etc., which weakened it and resulted in wind damage.
Schoolmarm (forked) trees with one or more forks of the main stem segregated to show – number uprooted (UR); number in which one prong only was split off (1 pr.); broken off (BO), in which breakage resulted in death or uselessness of tree for further growth.
Bending trees (shown in 1914 only, though many originated before) – those in which the boles have been permanently bent by wind action to such an extent that they are extremely susceptible to destruction in the near future, either by snow or wind or, if escaping, their commercial value is very materially diminished because of the bend. These trees were all numbered in a bark blaze at about breast height for future reference and observation.

From the tallies it appears that all diameters are subject to heavy losses from windthrow but as might be expected, the greater losses are found in the diameters from 16 inches on up to the heaviest running from 18 to 24 inches naturally, as it is trees of these diameters that make up a large part of the stand numerically. It is not believed, however, that trunk characteristics have any material influence upon susceptibility to windfall except those such as had scar, rot, etc., which have undoubtedly weakened the bole. This is clearly evidenced by the large number (82.6%) of total windfall that had normal trunks and of those, 28.2% were windbroken. This breakage is not confined to any diameter but is well distributed throughout the range of diameters, showing that even if the root anchorage were sufficient to resist windthrow, the natural strength of the trunk is still not sufficient to sustain the strains encountered.

RELATION OF WINDFALLS TO SOIL, ROCK, AND ROOT SYSTEMS

1. *Eccles Area*. Yellow pine only.

Basis 1,363 yellow pine uprooted; 90 broken off out of 415 windthrown trees. Soil conditions of broken off trees not tabulated except on the area of these 415 windfalls.

Tabulations showed only four trees with unusual roots, therefore defective roots are not a factor of windfalls.

Table XII
1363 Yellow Pines Uprooted

1913						1914 (spring)						1914 (fall)					
Deep		Medium		Shallow		Deep		Medium		Shallow		Deep		Medium		Shallow	
L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S
285	0	290	56	83	47	9	0	15	8	4	5	97	3	195	64	112	9

90 Yellow Pines Broken Off (1913 & 1914 S & F)

Deep		Medium		Shallow	
Loose	Solid	Loose	Solid	Loose	Solid
32	1	27	22	0	8

These 90 broken off trees represent 21.6% of the 415 windfalls, which is slightly higher than for the whole area which was 289 out of 1,654 yellow pines, or 17.4%.

This tabulation shows that rock character is not a factor of windfalls since windfalls are common to both. Neither is soil a real factor since windfall is common to all depths of soil in about equal proportion to the respective areas of each.

2. *Pw-1 Sample Plot*. Soil and Rock Characteristics, Yellow Pine 12" d.b.h and over.

Table XIII
Basis 288 Trees.

1913												1914												Standing			
Deep				Medium				Shal.				Deep				Medium				Shal.				Deep	Medium	Shal.	
L		S		L		S		L		S		L		S		L		S		L		S					
U	B	U	B	U	B	U	B	U	B	U	B	U	B	U	B	U	B	U	B	U	B	U	B				
14	0	5	0	4	0	16	0	1	0	0	1	3	2	9	0	14	2	28	1	0	0	10	3	41	100	34	
19				20				2				14				45				13				41	100	34	288

Deep		Medium		Shallow	
1913	19	1913	20	1913	2
1914	14	1914	45	1914	13
Stand	41	Stand	100	Stand	34
	74		165		49

Of the trees growing in deep soil, 44.5% were thrown as against 39.3% in medium soil, and 30.6% in shallow soil, due to the following factors – 2 broken off; 18 were tall and had large dense crowns; 5 were schoolmarms and 3 leaned badly to leeward, and 2 were united at base; the other 3 had no special factors to account for their fall. Of those in shallow soil, approximately 31% only fell. Of those left standing the greater number were due to short boles,

a few to open crowns, and others to protection afforded by other trees. Of those broken off in shallow soil, 2 were broken down by others falling on them and one had a bad butt rot.

Based on the number of trees in each soil class, the following percentages of soil classifications were obtained. Based on the number of windfalls, the percentage of soil in each class is approximately that of the whole Eccles area. (See Table XV)

	Deep		Medium		Shallow			
	Number	Percent	Number	Percent	Number	Percent	Total	%
Windfalls	33	29.2	65	57.5	15	13.3	113	100
Total	74	25.7	165	57.3	49	17.0	288	100
% of Soil class windthrown		44.6		39.3	30.6			

Less breakage occurred on this plot and the low lying flat of which it is a part and yet the wind damage has been as great or greater than elsewhere. That so few trees were broken off here as compared with other places is probably due to the natural virgin conditions under which these trees grew. Being on a low rolling flat and dense even stand they found mutual protection and consequently developed less root anchorage than those trees which grew on more rolling slopes and higher, more exposed ridges where the stronger root development was necessary for existence and greater breakage resulted in these localities.

3. Baker White Pine Area.

Table XIV
Relation to Soil, Rock and Root Systems.

Basis 343 uprooted or total of 517 yellow pine trees.

	Deep				Medium				Shallow				Roots			
	Loose		Solid		Loose		Solid		Loose		Solid					
Year	UR	BO	UR	BO	UR	BO	UR	BO	UR	BO	UR	BO	Sound	Defect	Not placeable	Totals
1912	20	0	2	0	35	3	2	0	4	0	1	0	66	1		67
1913	27	6	0	2	59	23	14	1	10	6	5	0	151	2		153
1914	37	7	0	0	55	40	24	5	33	5	15	1	208	14	75	297
	84	13	2	2	149	66	40	6	47	21	1				75	517
No.			86				189			68						*343
%			25				55.1			19.9						100%

*75 trees bending and broken off could not be placed in soil classes as no notes were made on them; therefore, to obtain percentages in this table all broke off trees were eliminated and percentages based on uprooted only, or eliminating the 75 trees only, the percentage stand - deep, 22.9%; medium, 59.0%; shallow, 18.1% on a total of 442 trees as 100%. In either case the relative fall on each soil class is approximately the same.

It is seen by this table that defective roots are almost a negligible quantity as a contributing cause of windthrows as it is seldom found in the yellow pine that is ordinarily reserved.

For comparison the relative percentages of windfall on the different soil classes on the three areas considered (Permanent Pw Plot, Eccles Sale Area and Baker White Pine Sale Area) are set forth below and also the relative percentages of total reserved stand on the different soil classes of the Pw Plot. It is believed that this area is fairly representative of the soil conditions of the larger areas and being so nearly coincident with the percentages of windfall on itself, sets forth an interesting fact.

Table XV

Relative Percent of Windfall on Different Soils.

Area	Deep	Medium	Shallow	Total	No. of trees
B.W.P	25.0	55.1	19.9	100	343
Eccles	28.9	46.1	25.0	100	1363
Pw Plot	29.2	57.5	13.3	100	113

Relative Percent of Total Reserved Stand of Different Soils.

Area	Deep	Medium	Shallow	Total	No. of trees
Pw Plot	25.7	57.3	17.0	100	288

Evidently this reveals a condition that is the opposite of what might be expected and one not to be desired, i.e., by far the heaviest windfall occurred in medium and deep soils and as shown by lower row of percentages in Table XV, the ratio percent of windfall of total reserved stand on different soils is proportional to the soil class, being heaviest in deep and medium soils, the very sites where windfall is least to be desired.

Based on field observations as well as tabulated data, the explanation of this condition is that on medium and deep soils where the growing conditions are the most favorable, growth has been more rapid, greater height is attained, and being in denser stands, interdependence and protection from storm stresses has resulted in less development of secure root anchorage and consequently less resistance to windthrow when exposed by opening up of the forest by selection cutting. On the other hand, trees growing on the shallow, poor soils, growth has been retarded, height growth is much less and stands much more open, often approaching cut-over conditions of distribution as to exposure to wind stresses so that in the course of the trees' development, root anchorage and resistence {*resistance}* to windthrow has been developed sufficiently to reduce the relative percentage of windfall. Yet even on these sites the rate of windfall (31% in two years) points to total loss of reserved stand long before the end of the cutting cycle.

That the root anchorage on medium and shallow soils is well developed may be shown in the fact that of the 30 pines broken off in 1913, 23 were of normal conditions, 3 as a result of scars, 2 of rot, one forked, and one broken by another falling on it.

A comparison of root development and soil depth is shown in photos 9 and 10.

Effects of Distribution on Windfalls.

1. Eccles Area.

Basis 1569 trees yellow pine only; over 12" d.b.h. Density of even distribution of reserved stand is based on a percentage, by volume, of the density of the virgin stand which is considered as 100%. Dense, 35%; Medium, 25%; Open, 15%, more or less evenly distributed over the area.

By intact group is ment {*meant}* typical large groups of trees covering ¼ acre or more left intact as they stood in virgin timber i.e. left regardless of the condition, age and distribution of the trees composing them. Open groups, usually means smaller groups of trees, somewhat opened up by cutting and often the result of accidental grouping in even distribution rather than intentional grouping by the marker.

Table XVI
Number of Trees Windthrown.

	Even Distribution				Isolated	Groups		
Year	Dense	Medium	Open	Totals	Trees	Intact	Open	Totals
1913	8	166	265	439	12	143	116	259
1914	21	173	276	470	19	224	146	370
Totals	29	339	541	909	31	367	262	629

This table is of interest only in indicating that extensive windfall damage occurs in both even distribution and in groups. No conclusions other than that can be deduced for the reason that the relative number of trees in each class in unknown. The same is true also of the different degrees of density of even distribution.

Of considerable value, though, is the following table showing the relation of windthrown trees to those left standing in groups of 5 or more trees. By this it is seen that trees standing in groups suffer considerably more than trees in even distribution, and also greatly more than the average for the whole area. This is partially accounted for at least by considerable portions being knocked down by other windthrown trees of the group and by the weakening of root anchorages of trees in the group left standing by their windthrown neighbors. In numerous instances groups were noted where a part of the group fell in 1913 and the remainder in 1914.

The groups of 16 or more trees are typical intact groups of the group system of marking. These suffered 13.4% more loss than the smaller groups which averaged 52.7% windthrown and were more often the result of unavoidable grouping in selection system rather than intentional grouping.

Table XVII
Relation of Standing to Windthrown Trees in Groups Containing 5 or more Trees

No. in Orig. Group	5	6	7	8	9	10	11	12	13	14	15	16
No. of Grps.	23	26	21	14	6	5	3	10	2	1	1	1
No. windthr'n	68	86	80	49	32	20	19	63	18	2	7	10

% windthr'n	59.1	55.1	54.4	43.8	59.2	40	57.5	52.5	69.2	14.3	46.6	62.5

No. in Orig. Group	17	18	25	26	48	53	54	Total
No. of Grps.	2	2	1	1	1	1	1	1134 trees
No. windthr'n	24	20	14	13	38	47	27	637
% windthr'n	70.6	55.5	56	50	79.2	88.8	50	56.1

As an indication of what loss might be expected during a spring without severe storms, an unusual condition, the following table is of interest. On 1080 acres, the fall {*throw*} of the spring of 1914 and that of the fall of 1914 were tallied separately, with the following results for spring windfall. This shows a loss of 32 B ft. per acre for 1914 as against 568 B ft. for the spring of 1913 and 367 B ft. for the fall of 1914.

Table XVIII
Windthrow, Spring of 1914.

D.B.H	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	Total No.	Volume
Yellow Pine	3	3	11	8	7	4	3	3	8	2	1	1				54	28.775 M
Inf. Species	10	7	3	1	3	0	0	0	0	1	0	1				26	6.031 M
Total	13	10	14	9	10	4	3	3	8	3	1	2				80	34.806 M

2. Pw-1 Plot.

Distribution of Reserved Trees.

On this sample area of 40 acres the following number of trees over 12" d.b.h. were reserved: 287 yellow pines, 36 lodgepole pines, and 2 larches, a total of 325 trees. The arrangement of these reserved trees was as follows: even distribution, 165 trees; groupwise distribution, 160 trees. By even distribution is meant more or less evenly scattered trees whose density, in this instance, is between 10% and 15% of the original stand by volume. There were 25 groups which, with but two exceptions, were the small groups characteristic of local marking practice, containing from 3 to 9 trees each. The following table shows the windthrow.

Arrangement	No. Reserved	No. Thrown	% Thrown
Even distribution	165	78	47.3
Groups	160	60	37.5

The lower percentage of thrown in the group arrangement given here is misleading because of the two exceptional groups mentioned above. These were both big groups of small, young bull pines. One group contained a total of 71 trees of which 28 were over 12" d.b.h; in this group

only 2 trees were thrown. The other group contained a total of 22 trees, 17 of which were over 12" d.b.h.; 4 were thrown in this group. If these two exceptional groups are eliminated, the percent of thrown in groups becomes 47% – or practically equal to the throw in evenly distributed reserved trees.

The following tables show the amount of throw by years for yellow pines only.

	Number Thrown		
Arrangement	1913	1914	Total both years
Even distribution	23	42	65
Groups	18	31	49

To show where windthrow occurs in groups.

	Number Thrown		
Side of group	1913	1914	Total both years
Windward side	17	28	45
Leeward side	1	2	3

Trees United at Base.

A frequent occurrence in yellow pine is that of two and sometimes more trees growing with bases together. Under the present system of marking many of those are left as reserved trees. On the Pw-1 Plot there were reserved 11 such cases. Of these, 8 or 73% were windthrown. The average diameter of these was 21" d.b.h. In the case of the three pairs left standing, the average diameter was 18".

On the Eccles area of 179 yellow pines growing thus, 140 fell in pairs, 5 in pairs with other species, and 30 with three in the clump, 4 with four in the clump. Often the trees of the smaller diameters were pulled over by larger trees of the clump which otherwise would have stood.

Because of the unusually large crown surface exposed and ordinarily restricted root development of trees growing together, they are especially subject to windfall.

3. Baker White Pine Area.

Table XX
Influence of Distribution of Windfall.

	Even Distribution Yellow Pine				Isolated	Group Sides	
Character	1912	1913	1914	Totals		Windward	Leeward
Open	41	96	90	227	4	66	37
Medium	14	29	78	121	6		
Dense	2	19	17	38	7		

Totals	37	114	185	386	17	66	37
Grouped	4	15	84	103			

	Even Distribution Other Species				Isolated	Group Sides	
Character	1912	1913	1914	Totals		Windward	Leeward
Open	25	47	140	212	5	80	60
Medium	4	20	92	116	8		
Dense	0	6	214	220	12		
Totals	29	73	446	548	25	80	60
Grouped	1	13	126	140			

Nothing of importance is brought out by this table for the same reasons as stated under Table XVI of Eccles Area.

Eccles Area.

Windfall in Virgin Timber. (See Eccles map)

The 566 acres of virgin timber on this area were covered by a 100% cruise. This timber is located on the borders of the cut-over area and the conditions affecting windfalls are as similar to those of the cut-over as may be obtained. The object is to obtain a true comparison between the cut-over and virgin timber.

The windthrow is very much greater on the edge to the windward, adjacent to cut-over lands, than in the interior. Similarly the edge facing the wind suffers more than the opposite edge - these are termed the windward and leeward edges respectively.

Since the influence of the edge is felt for some distance into the virgin stand, and the windfall map indicates that this seldom exceeds 5 chains, this distance is taken as the width of the belts considered when speaking of these respective edges. Below is assembled in convenient form the data on these virgin timber areas.

	Windward Edge	Interior	Leeward Edge
Length	5-1/2 miles	–	2 miles
Area	220 acres	266 acres	80 acres
No. tree per acre - YP	1.3	.2	.3
No. tree per acre - OS	.3	.15	.2

Thus it is seen that 1.3 trees per acre, yellow pine, fell on the windward edge, .2 trees in the interior, and .3 on the leeward edge. These average figures need some explanation. The windfall on the windward edge did not occur uniformly over the belt either in its length or depth. For instance, many portions of the belt, 5 to 15 chains in length, had no windfalls at all. In another portion 15 chains long, 60 trees were windthrown or 8 trees per acre; another portion of the same length had 37 windthrown trees or 5 trees per acre. As to depth, the windfall was much heavier on the extreme outer edge and usually rapidly lessened toward the interior.

While the heaviest windfall occurred mostly in the denser timber, it is not conclusive that it was because of the density, as other important factors entered in, as for instance, in one of the cases cited above (see Forty 86 and photo #2) topography and distribution in the adjacent cut-over combined to form a wind channel, concentrating the wind at that point. In the other, the edge of cutting coincided with a high, sharp ridge, as the edge of cutting usually does.

Even granting that density influenced windfall and that windfall could be averted by a "grading off" marking, such a method of marking would be impracticable because the topography and practical logging methods prohibit logging by this method of marking.

Where the present windward edges are within the limits of a current timber sale and will be cut over in the course of a year or two, this windfall is of much less importance as the only loss will be that caused by bluing, etc., and special precautions need seldom be considered.

In the interior the windfall is scattered more or less uniformly over the are as is also that of the leeward edges and may reasonably be assumed to be normal as compared with that on cut-over areas. It does not appear that the leeward edge has any considerable influence on windfalls. Practically 32% of these were defective trees which made them especially susceptible to windfall.

Considering the virgin timber area as a whole, it is noted that the heaviest windfall occurs on the extreme windward edge and rapidly lessens as it proceeds inward until it becomes almost normal for virgin timber at about 5 chains from the edge.

Where windfall has been especially heavy it has been in the nature of windrows taking more or less all of the trees on a narrow strip several chains in length, directly into the virgin timber.

The prominent factor here brought out is that trees grown under virgin timber (close or dense stands) conditions, are mutually protected, having only their tops exposed to heavy windstorms and thus have not developed root anchorage to withstand greater stresses. When these have the full sides of their crowns exposed by the cutting away of their neighbors, they are not prepared to withstand severe storms and are windthrown.

The theory sometimes advanced that old and mature trees, as these reserved trees must often be, will upon exposure by selection cuttings develop root systems and strength to meet these new conditions, hardly seems reasonable, certainly it is not in the case of the bole, and it does not seem probable that such vigorous accelerated response will be found in the root systems. Certainly it will not within the first few years in which the required change in foliage is taking place, and a tree having survived windstorms for this length of time probably is already qualified to withstand all but the severest storms. With young and vigorous growing trees such increased root development may reasonably be expected and probably will if the tree escapes during the first few years.

Influence of Topography of Liability to Windthrow.

1. Eccles Area.

Basis - The yellow pine only that fell under cut-over conditions and not that on the edge of virgin timber. In 1913 this area was 880 acres in extent; in 1914, 1624 acres. The windfall of 1914, of course, fell on the entire 1624 acres.

In the field notes under the heading "Relation of Windfall of Topography", brief notes were made of the location of each windfall with reference to topography. The following table shows the results of these notes, the number and percent of windthrown trees by topographic location.

Table XXI

Influence of Topography on Windfalls - Eccles Area.

Topographic Location	Number Thrown		Total both years	
	1913	1914	Number	Percent
Bottoms of draws	62	26	88	5
Windward slopes	91	85	176	11
Leeward slopes	140	199	339	21
Tops of Ridges	331	399	730	45
Broad flats	149	146	295	18
Totals	773	855	1628	100

The results show that of the total number of yellow pine windfalls the greatest percentage occurred on the tops of the ridges and the smallest in the bottoms of draws, while the broad flats suffered very considerably. The results for the sides of ridges are rather striking and unexpected, the sides exposed to the prevailing storm direction apparently suffering considerably less than the opposite sides which ordinarily are considered as sheltered. This apparently inconsistent difference would be greatly accentuated if the inferior species were included, for these species are practically confined to the north and east slopes and many Douglas and white firs were thrown. We were unable to discover a definite reason for this. There are several explanations. The west (windward) sides or slopes, originally had a less dense, and in many places a more uniformly old, stand, thus it happened that the actual number of reserved trees were far fewer than on the east (leeward) slopes. Consequently there were proportionally less trees to be blown down. Second, the wind sweeping across the tops of ridges on a level with the crowns of the trees on the opposite slope; these trees in a denser stand which under virgin conditions was {*are*} sheltered by the trees on the top of the ridge and on the exposed side of ridge. They were not windfirm and when opened up and shelter removed were easily thrown by a force which they had never felt and were not prepared to resist. The trees of the open stand on the west side and on top under virgin conditions were comparatively windfirm - had always been subject to wind and had developed resistance, while the trees on the other side had no need for resistance.

The ridges were mostly not very high. The windfall on the tops of ridges was greater on the leeward side of the ridge than on the west or wind-exposed side. Explanation above holds here also.

2. Pw-1 Plot.

Because of the lack of variation in topography on this area it was not possible to secure data for this plot.

3. Baker White Pine Area.

Table XXII includes all species, yellow pine and other species, separately.

The results very some from those of the Eccles Area, due largely to the lay of the land, i.e., different exposure and general aspect, a preponderance of windward slopes, etc. Besides, it was not possible to distinguish between "top ridges" and "flats" in working up the notes. In fact, on this area the "flats" occur mostly as tops of ridges, yet the results do not differ so much but that they would be comparable to those of the Eccles under similar conditions.

Conditions.

Windfall occurs indiscriminately with regard to topography, but is slightly more severe on tops and leeward slopes than elsewhere.

Table XXII

Relation of Windfall to Topography

	Yellow Pine					Other Species					Total all Species				
	Lee	Top	Wdd.	Bottom	Total	Lee	Top	Wdd.	Bottom	Total	Lee	Top	Wdd.	Bottom	Total
No	52	340	112	25	529	145	314	121	96	676	197	654	233	121	1205
%	9.8	64.3	21.2	4.7	100	21.4	46.5	17.9	14.2	100	16.4	54.2	16.3	10.1	100

Meteorology

The all-dominating meteorological factor affecting this problem is windstorms, although in an indirect and minor way precipitation, drouth {*drought}* and temperature are influencing factors in that they greatly vary the effective root anchorage of trees. Thus in a general way the seasons of the year become a rough index of trees' susceptibility to windfall for, of course, they are much more liable to windthrow in the spring when the ground is soft and soggy than in summer or winter when the ground is hard and dry or frozen. Not only is this indicated by the greater proportion of wind breakage which occurred in the storm of September 18 as compared with those of spring months. This is further confirmed by field observations of the writer, Forest Ranger Donaldson and others that occasional scattering big trees on moist soils often go down as windfalls during light wind in the spring; this happens to some extent every year.

Records of precipitation on the Eccles area are available from March 1912 to July 1914 inclusive, but are of very little value in this connection as the soil moisture of the spring is so largely dependent on snow conditions preceding and of which there are no records. However, it is a fact that the ground was soft and soggy at the time of the May 26, 1913 storm and was dry and hard or solid at the time of the August 11, 1913 and September 18, 1914 storms. There had been a light rain a few days previous to the latter but not sufficient to soften the ground and affect the root anchorage.

Generally speaking, in this region the ground is frozen from December to March inclusive, dry from July to September, and wet from April to June and October to November.

The Meteorology of Eastern Oregon as it affects the Windfall Problem in the Blue Mountains

In analyzing the windfall problem on the Whitman National Forest, it is important to know something regarding the time of occurrence and frequency of winds such as those which have done damage on the Eccles timber sale area. Unfortunately the Weather Bureau wind velocity records in Oregon are very meagre. At but three stations in Oregon is the wind movement recorded at all – Portland, Roseburg and Baker. At the last of these only is the data of any value for the present study.

The Baker anemometer records at the time of the famous hurricane and tornado on the Malheur Forest, and of the three recent disastrous high winds on the Whitman Forest are as follows:

June 3, 1894 – At Baker, 36 miles per hour, SW, (highest in 1893 and 1894)

May 26, 1913 – At Baker, 36 miles per hour, SW, (highest in 1911, 1912 and 1913)

August 11, 1913 – At Baker, 31 miles per hour, SW.

September 18, 1914 – At Baker, 42 miles per hour, S.

These records seem to indicate that the Baker high winds are coincident and fairly comparable with those on the adjacent National Forests, i.e., the winds known to be exceptionally high in the timber of the Whitman National Forest are shown by the records to be exceptional.

Their direction, moreover, on the Forest is the same as it is in Baker. The statements of volunteers weather observers and local reports indicate that the high winds, such as those of May 26, 1913, and September 18, 1914, are widespread geographically, and occur as exceptional storms over an extensive territory. The storm of September 18, for example, was general throughout the State. At North Head, Washington, a velocity of 72 miles an hour was recorded, and from all over Eastern Oregon came reports of the unroofing of houses and the breaking off and uprooting of trees. On the Wallowa Forest, in Sections 11 and 15, T. 3 N., R. 44 E., the storm developed tornado characteristics and blew down most of the trees in a strip 50 to 200 feet wide and at least a mile long. Let us take, therefore, the Baker wind records as a fair analogy of the wind conditions on the Whitman Forest. It is evident that a general storm having a 30-mile velocity in Baker, will throw a good deal of timber in an exposed situation, such as the Eccles timber sale area. The important consideration is to find out how frequent are these 30-mile winds, what is their direction, and at what season do they occur.

The following table shows the number of times that there has been a monthly maximum five-minute wind velocity of over 30 miles an hour at Baker in the 20 years from 1890 to 1909:

Month	No. of times in which max. monthly wind has been over 30 miles	Maximum in each month
Jan.	11	36 (3 times)
Feb.	4	44
Mch.	8	40
Apr.	7	40
May	4	36
June	4	46

July	2	32
Aug.	2	36
Sept.	2	36
Oct.	4	40
Nov.	7	36
Dec.	6	50

This table is of great significance for it shows that winds of 30 miles an hour may occur in any month of the year, that there are at least three such winds annually, and that scarcely a summer season (April to November) passes that there are not from 1 to 5 of such winds (average 1-3/5).

The direction of these maximum velocity winds is as follows, for four-month periods.

	Percentage of high winds from each direction							
Seasons	N	NE	E	SE	S	SW	W	NW
Dec. Jan. Feb. March	2	2	-	32	17	18	4	25
Apr. May, June, July	16	2	1	11	11	21	1	40
Aug. Sept. Oct. Nov.	7	2	1	17	11	26	6	30

This table brings out no particular important fact except that a high wind is possible at any season from almost any quarter except east.

The season of the year is, of course, a matter of importance, for when the ground is soggy with moisture windfall is most severe. In the winter when the ground is frozen high winds are the most frequent and severe, but the months during which the ground is wet are more windy than the summer and have a record rivaling in windiness the winter.

The conclusions to be reached in this study of the meagre local meteorological records are:

1. Winds which are severe enough to blow over a considerable amount of timber in exposed situations, are of frequent occurrence, i.e., at least semi-annual.

2. They may come at any season of the year.

3. They are liable to come from any direction except possibly the east.

Volumes of Windthrown Timber.

1. Eccles Area.

This includes all species except white fir, a total of 2737 windthrown trees on the cut-over area, and gives the volumes by species, years and percents.

The main object of these tabulations is as a basis for timber sales to dispose of the windthrown timber. It is also of interest for comparison of windfall by years and with other areas and for other purposes.

Table XXIII

Volume - Windthrown - Eccles Area

		Blown down - Years						Total	Vol. Thrown	% Thrown	% of Total Thrown
Species	(M ft) Vol. left	1913		1914-S		1914-F					
Y.P.	5521.60	792	468,595	54	28,775	808	472,506	1654	969,876	17.5	80.3
W.L.	324.80	60	15,078	4	2,025	72	17,020	136	22,478	6.9	1.8
D.F.	698.32	308	87,850	20	3,765	326	95,650	654	187,265	26.8	15.5
L.P.	81.2	182	19,739	2	241	109	8,988	293	28,968	35.4	2.4
Total	6,625.92	1342	591,262	80	34,886	1315	594,164	2737	1,208,587	18.2	100.

Small numbers in left-hand corner are number of trees. Present stand after windfall, 5,417.22 M ft.

Of the timber blown down in 1913, 458 M ft. have been logged under special sale. A large part of the remainder was logged with virgin timber under the regular contract. All of the timber that fell in 1914 is now on the ground and should be sold at once. Perhaps a small part of it will be a total loss by reason of being too scattered or inaccessible to log. In considering this table it should be remembered that the greater part of the 1913 windfall occurred on approximately on half of the total area.

2. Pw-1 Plot.

The volumes were computed for both standing and windthrown timber on this plot for purposes of comparison and since they are included in the totals of the preceding table should not be again included to obtain a total for sale, etc.

Table XXIV

Volume - Windthrown - Pw-1 Plot

Species	Vol. reserved M ft.		Windthrown -- Years 1913		1914		Total		% Thrown	% of total windfall
Y.P.	288	147.07	41	26.69	74	51.55	115	78.24	53.2	96.67
L.P.	36	3.48	17	1.97	5	0.36	22	2.33	67.0	2.88
W.L.	2	.37			2	.37	2	.37	100.	.45
Totals	150.92		28.66		52.28		80.94		60.26	100.

Figures in left hand corner are number of trees.

The windfall of 1913 occurred in cut-over on approximately three-fourths of the area, while that of 1914 occurred over the whole area. Under these conditions, 18.1% fell in 1913 and 35% in 1914.

The figures in this table, probably more than any other, convey an idea of the extent to which some of the more restricted areas have suffered from windfall.

3. Baker White Pine Area.

This table includes all species except white fir, of which no merchantable trees were supposed to be left.

Table XXIV

Baker White Pine - Volume Windthrown - By Species

Species	* Volume Reserved	Windthrown -- Years 1912		1913		1914		Total		% Thrown	% of total windfall
Y.P.	7,330.72	66	41.09	161	71.76	280	120.96	507	233.81	3.	74.6
W.L.	623.37	9	2.38	12	2.57	31	6.98	52	11.93	2.	3.81
D.F.	1,189.11	18	4.13	51	10.38	203	48.77	272	63.28	5.	20.20
L.P.	154.88	5	.34	15	1.31	43	2.60	63	4.24	3.	1.35
Totals	9,298.08	98	47.94	239	86.02	557	179.31	894	313.26	3.4	100.
W.F. No. only		1		20		263		284	Total vol., 119.76		

* Volume less volume windthrown.
Numbers in left-hand corner are number of trees.
1912 includes all windfalls since cutting began (1910)
1913 volume at least 75% logged.
1914 volume (and 25% of 1913 volume) now on ground.

The windfall is much more scattering than on the Eccles area and all logging operations on this area have been completed and railroads removed. It is, therefore, probable that a large part of this may be considered a total loss as the special arrangements and cost of logging will prohibit its being taken out.

Volumes of Windthrown Virgin Timber.

On the 566 acres of virgin timber, 235 yellow pine trees fell, having a volume of 197 M ft. As practically all of this is in timber that will be logged in the near future, the principal loss will result from bluing and {*of*} 1913 windfalls and possibly doty sapwood. However, this is more of a coincidence, as it would have been all loss if this were not to be logged soon.

General Topography.

With respect to the general topography of the region, the areas embraced in this study lie on the opposite north and south slopes at the band of the narrow, irregular valley of the Middle Fork of the John Day River. This valley is bounded on the right and left by two rather sharp and well defined ridges with general elevations of 5500 feet and extreme points of 7000 to 8000 feet. The right-hand ridge is the higher. These ridges connect at their upper ends with the main divide of the Blue Mountains, which also form the head of the valley. This divide, rather encircling the hand of the valley, has an elevation of some 5600 feet, sloping off gradually to a broad saddle midway between where it is some 700 feet lower.

The general trend of the country is northwest. The left-hand ridge separates this valley from the broader, more open one of the Main Fork of the John Day River. This latter, so far as prevailing wind direction is concerned, comes to a broad, rather square, abrupt head with its northeast angle or corner lying directly southwest across the ridges from the head of the Middle Fork valley and more particularly the Eccles area.

Here again the apex of this angle is another prominent saddle in the ridge, flanked on either side by higher points, on the northwest especially by Dixie Butte, some 1800 feet higher than the saddle (5200 ft.) and the culminating point of the left-hand ridge described above. Moreover, the valley of the main John Day has a much more westerly trend, is much broader and more open, and probably less effectively protected on its south from prevailing winds by an irregular broken ridge, composed of high peaks and very low saddles. What effect this topography may have upon prevailing air currents is of course an open question and would require long and painstaking study to determine, yet this topography is in the direct path of prevailing winds before they reach the areas studied. The fact that the logs by windfall has varied considerably on the two large tracts requires a search for causes, of which topography may well be one to be kept in mind.

That the two years' successive storms have been at once so destructive on the Eccles area and much less so on the White Pine area and have been from the southwest, where this factor holds, lends color to this thought.

Financial Costs.

Perhaps just at this point we should consider the effects of these windstorms from a financial standpoint, one which is very pertinent in the present marking policy.

Considering the yellow pine on the Eccles area, the present stumpage price is $2.50 per M. The reserved stand was 4.08 M per acre, or $10.20. The loss in 1913 on 850 acres averaged

.545 M ft. or $1.36 per acre, being 13.3%. In 1914 the loss was 309 M ft. on 1624 acres, or $.77 per acre, or 7.6%; the total loss for the two years being .854 M ft., $2.13 or 20.9%. However, since the windfall of 1913 was actually sold at 50 cents per M stumpage and it is probable that the 1914 windfall can be sold at the same figure, the actual loss would be only 16.7%. This percent will, of course, be raised by the unavoidable total loss of such portions as are totally inaccessible, extra cost of making sale and administration, etc., so that the actual percent of loss will in all probability approximate 20%. Incidentally the cost to the purchaser of logging the 1913 windfall was approximately 10% more than under the regular sale, with railroads already more or less conveniently located. The costs for logging the 1914 windfall will be rather more than less, as many railroads have been taken up.

4. Other Areas.

a. Mc-1 Plot.

This permanent sample plot of 45 acres laid out for the study of methods of cutting lies on the extreme east edge of the cut-over lands of the Eccles area (see map) and it was thought that some valuable data relating to effect of windfall in the several degrees of density might be obtained. However, upon investigation the factors influencing windfall on the different parts were so diverse, the conditions at present existent on each so variant, and the parts in themselves so small and without neutral bordering belts, that no data not misleading could be obtained.

b. Pw-2 Temporary Plot. (See Photo #3 and map of Forty #92).

This is a plot of 10 acres, lying in SE1/4 of Forty #92, Eccles Area. It is marked on the ground by stakes at the corners. It lies on a low, gently sloping flat with northerly exposure; its elevation is less than that of the country adjoining on south and west, and seemingly is well protected by it and by good even stand of thrifty young timber of a reserved stand. It was chosen as giving the impression to casual observation of being a protected tract and for the uniform character of its stand. However, on close inspection later it developed that it was not especially protected as it had within its limits 3 broken off, 10 thrown, and 11 badly bent by the wind, showing it to be not especially protected. Its special interest lies in the number of wind bent trees. These were all marked alphabetically with crayon in a bark blaze for future reference and observation. Without a doubt, several of these will be broken off by snow this winter if indeed they stand that long.

That they may not stand is proven by an incident which occurred in the course of this field work. One morning a "strip party" passed a leaning tree which was especially noted. Passing on, an hour later a cracking and thud were heard to the rear and upon the return trip this same tree was seen to be broken off where the bend had been. There was only a slight steady breeze blowing at the time. Even should these trees persist, their value for lumber will be greatly reduced because of the bends.

c. Windfall in 20-year old Yellow Pine Cuttings in Sumpter Valley.

This data was secured in "Methods of Cutting" study by R.H. Weitknecht in the summer of 1914. It is based on study of five one-acre sample plots, two of which are on the north side of the river in Section 34, T. 9 S., R. 37 E., and three on the south side in Section 9, T. 10 S., R. 37 E. The reserved trees on these five plots average 15 trees per acre, with a range of diameters from 10" to 24" and an average of 18". The arrangement of the trees on these plots is mostly even distribution. The cutting was done from 15 to 20 years ago.

	Number Thrown	
Plot No.	Before Cutting	After Cutting
I	1	3
II	2	3
III	1	6
IV	2	0
V	1	5
Total	1	5

The date of windthrow, of course, is estimated, but is a close approximation which was determined by careful examination of the state of decay of the windfalls as compared with that of the tops resulting from logging. The table shows that 7 trees fell on 5 acres under virgin conditions, and 17 fell on the same 5 acres under cutting conditions. A total of 93 trees was reserved and 17 were windthrown, or 18% by number. Of the trees thrown after cutting, 14 were sound, 2 had basal fire scars, and 1 had heart rot, while 3 of the 17 were schoolmarms. Of the 17, ten were broken off.

The stand of the plots is practically pure yellow pine with a small percentage of larch, probably less than 5%. All the windfalls were yellow pines except one, which was a larch. The windfall after cutting fell over the whole period of years since cutting, namely, 15 to 20 years. Judging by the state of decay of the trunks and tops, most of them fell in the first several years after cutting. By the condition of the needles still hanging to the branches, and by increment borings, some were found to have fallen about 5 years ago, while one or two fell in 1913. While windthrown did not occur on any of the five plots in the storm of September 1914, a noticeable number of trees were thrown in the cutting surrounding the plots.

Conclusions.

(1) Windfall does occur in evenly distributed reserved trees in the Sumpter Valley and on five separated sample acres this throw amounted to 18% by number during a period of 15 to 20 years.

(2) Severe windstorms are of normal periodical occurrence in the Sumpter Valley, occurring at least as frequently as every 5 years, the five sample acres giving conclusive evidence of windthrow at intervals of about 5 years.

Other Forests.

Chelan National Forest, Washington.

Forest Assistant Oliver F. Erickson in recent report states, –

"The windfall on a cutting of 500 M ft. on the Chelan National Forest, logged during the summer of 1913, showed about .32% of the remaining timber after cutting to be blown over by the wind... Another tract on which 400 M ft. was cut, leaving 25% of the stand for seed, showed 3 months after cutting about .6% of the remaining stand to be blown over by the wind."

These are evidently only small tracts and may be protected however. Another tract on the same watershed logged in 1908, six years later showed only a few trees blown over. This may be due to "protected situation", "heavy stand and deep soil".

Forest Service Bulletin 101 reports -

On Tusayan National Forest, Arizona, 480 acres having 33-1/3% of stand reserved showed only .0067% windthrown.

Coconino National Forest, seven sections showed less than 1% windthrown in one to two years after cutting.

When these figures are compared with those of the Whitman ranging from 3.4% to 60% by volume, it becomes evident that the windfall problem on the Whitman is much more serious than elsewhere.

Reproduction.

One of the principal objects of selection cutting in yellow pine is to insure natural reproduction on cut-over lands; but where, as in the yellow pine regions of the Blue Mountains reproduction is not only prolific but absolutely assured, in the absence of fires this justification of the selection system falls by the wayside. That this reproduction is assured either by advance or new reproduction after cutting is amply self-evident by observance of any of the old cut-over areas of the region. This is all the more confirmed when it is remembered that these areas were handled absolutely without regard to reproduction, being ruthlessly exposed to drying-out, frosting, erosion, etc., by clear cutting, burned over or not, as chance decreed, and brush piling unknown. That fires now, with the efficient system of fire patrol and control in effect, are reduced to the point of merest accident only, also mitigates against the need for selection system. That cut-over areas are not inevitably doomed, as was once thought, to be burned over even under absolute neglect, is evidenced by these same old cuttings and certainly under the best and most efficient management fire hazard may be dismissed as an influencing factor.

With reference to advance reproduction, these windfall areas are no exceptions to the general rule of cut-over areas and on this point alone good reproduction is already established. Even if it were not observations and several counted plots go to show that reproduction since cutting is generally satisfactory. That fire is no objection and may be even a benefit is indicated by any number of noted instances of which the following are samples.

On an area cut-over in the spring of 1912, brush piled and burned in the fall of 1912, two plots on the area of burned brush piles gave the following counts of reproduction 1-2 years old.

Plot	Size ft.	No. Yellow Pine	Douglas Fir	W. larch
1	6x7-1/2	10	3	1
2	9x12	7	7	12

The plots were rough, elliptic in shape and about one-quarter covered with moss and chunks of wood. No seedlings occurred in the moss. These seedlings generally were stronger and more vigorous than those in non-burned areas. Some of the most vigorous growth ever noted in

yellow pine seedlings was found on these spots of burned brush piles. This reproduction is more marked on the Eccles than on the Baker White Pine area and on the better sites.

The Maps (only the Pw-1 map was included with this copy of the report)

Pw-1 Plot Map.

In considering this map, one should constantly bear in mind that many of the standing trees shown are mere poles, that most all windfalls are 12" or more d.b.h., and that lodgepole groups and sapling areas are of minor importance as affecting windfalls.

The map graphically illustrates the distinction and density of the original and of the reserved stands, and also distribution and direction of windfalls.

The serial numbers are for correlation of the field data and for future reference.

Eccles Area Map.

This map covers all the area covered by this study and shows topography, the location and direction of windfalls by years of windthrow, the various areas logged and dates when logged, and the virgin timber.

Serial numbers of the windfalls are recorded on the original maps only since they are of little or no value without the field notes for reference.

On the map is seen the disposition of windfalls with relation to topography, the distribution in the cut-over areas along the edge of cutting and in virgin timber.

No map of the Baker White Pine area is submitted as no features not common to these other maps were developed.

Conclusions.

1. Windfall in the Blue Mountain region is much more severe than generally reported elsewhere, and is very menacing to the selection system of cutting.

2. Storm winds severe enough to throw considerable numbers of reserved trees are at least of semi-annual occurrence, and may occur at any season and from any direction except possibly east.

3. No quality of windfirmness, whether inherent in the single tree or secured through various arrangements of trees, or afforded by character of site, is sufficient to resist the severe winds of this region.

a. All types of crowns are subject to throw but thrifty, full crowns, the most desirable for reserved trees, suffer heavily while culls and poor crowns are comparatively safe.

b. Practically all heights are subject to throw, but it usually is the taller trees of a stand that are thrown; trees over 100 ft. suffer much more heavily than those under 100 ft., while in trees under 60 ft. the throw is negligible.

c. Diameters show that no diameter above 12" d.b.h. is exempt and roughly that the throw increases with diameter, ranging from 7% of 12" trees to 40% of the 36" trees on the Eccles area.

d. Practically all reserved trees have sound, perfect trunks, therefore trees of this character are subject to windthrow.

e. Each of the several arrangements of reserved trees is subject to heavy throw. On the intensively studied Pw-1 Plot the throw in groups and in even distribution was about equal, amounting in each case to 47% of all trees over 12" d.b.h.

f. No feature of topography is free from windthrow.Ridges and flats suffered much more heavily than draws. Average results for the two big areas studied show that windthrow was just as great on the leeward slopes of the ridges as on the windward slopes.

g. Trees on all depths of soil are subject to heavy windfall. The Pw-1 Plot actually shows a slight heavier throw on deep and medium soils than on shallow soils. This plot is believed to be representative of the whole Eccles area.

4. Windfall does occur in virgin timber. Eccles area shown this to have been 0.2-0.3 trees per acre in the interior of virgin timber.

5. The severity of windfall is not uniform in the Blue Mountain region. The windfall by volume on the Eccles area was 18%, on the Pw-1 Plot 60%, and on the Baker White Pine area, three miles away, it was 3%.

a. This may be due to influence of general topography on heavy wind currents.

b. The lack of definite knowledge or in fact any knowledge of consequence regarding the behavior and distribution of surface storm winds in this region, is the real barrier to predicting area of heavy windfall liability in advance of cutting. That it does vary greatly within local bounds is evidenced by this study. This suggests that in order to predict areas of windfall hazard with some degree of certainty it might be necessary to conduct a series of observations continuing over a period of several years on each potential near future timber sale area. These observations should be of wind direction and velocity read daily, or, better yet, recorded by automatic registering anemometers located in typical locations on each area.

c. Aside from the immediate neighborhood of these areas it does not seem possible from anything herein contained to be able to predict windfall liabilities of other areas. It has been suggested that a "windfall reconnaissance" be made of future sales areas and if the number if windthrown trees per acre approximates that found to exist in virgin timber (0.2-0.3 trees per acre) in the present case, to assume that a heavy windfall hazard will exist when cut over. This would require at least a 50% cruise and a 100% would be better.

6. A consideration of the relative merits of factors investigated as guide for any future work that may be done in this line.

First and most important of all is a study of storm winds to ascertain, if possible, wind hazard areas and their causes.

Next, and probably no less important factors, are crown and height classes.

Topography, soil and arrangement of trees still offer some good problems, though not in themselves holding a complete or good remedy for the windfall hazard.

In all these except the first, it is essential that the trees left standing, as well as the windfalls on any given area, must be studied. It is better to study a quarter of the area in strips thus, than the whole area for windfalls only, as was done in this study.

In reserved stands trunk and root characteristics are of no consequence and should be disregarded.

Recommendations.

1. Because of the heavy losses sustained by the Forest, the public, and to the manufacturers in reduced revenues, lost efficiency and increased costs, it is not advisable to continue the selection system on the Eccles and similar areas such as Summit Creek, etc. The method here should be to clear cut, i.e., all mature timber down to 12" d.b.h and less than 100 ft. in height. This will upset the practice of a selection forest, but will be offset by greater revenues, less administrative expense, better public sentiment, while not altogether defeating the object of a selection forest, but rather postponing it to a later date when economic conditions should make it far more practical than at present. It will also have the advantage of better opportunity for producing a windfirm selection forest than is possible by conversion directly from a virgin forest, in that the forest will be developed from relatively young trees growing up under the conditions they will be required to sustain.

2. The present selection system, either in groups or even distribution, may be continued on Baker White Pine and similar areas (Idaho Creek, probably) leaving 25% or more of the stand, but confined as much as possible to the smaller diameters.

3. The establishment of wind recording stations in typical locations within each of the several potential timber sale areas for the study of storm, wind currents and probable effects on reserved stands where areas are logged. This seems to be especially desirable because of the greater windfall losses occurring here as compared with elsewhere.

PICTURES
(note that poor-quality photocopies of the pictures are available with this report)

#1 - Windfalls on Pw-1 Plot (lee slope). See East edge map.

Looking southwest across southeastern part of plot. Twenty-six out of a possible 32 windfalls can be counted in picture. (Smoke from brush burning in background.)

#2 - Looking northeast down lee slope from crest of low ridge into edge of virgin timber, showing group of seventeen 1913 windfalls ranging from 16" to 34" d.b.h. Forty #86.

#3 - Two yellow pines 28" and 32", broken off at 30' and 40'. Eighteen-inch yellow pine wind bent to angle 30^{o}, looking northeast on lee slope, lee flank edge of virgin timber, parallel to wind direction and with all protection removed for 5 or more chains to windward.

#4 - Looking southeast on lee crest of 150-ft. ridge. Forty #114.

Six yellow pines 14" to 26" d.b.h.; 1 Douglas fir 30". Windfalls of 1914.

#5 - Looking north on ridge, Forty #115.

Three broken off, 5 uprooted, and several wind-bent trees, showing havoc wrought in groups. All mature trees of large diameter should not have been left. (Starker)

#6 - Looking southwest on Forty #114.

Protected group in gulch which is deeper and slopes steeper than indicated in picture. Intact group of 48 trees above 12" d.b.h., 38 thrown.

#7 - Looking north on Forty #125.

On low ridge, partially exposed. Windward edge, large intact group, showing one broken off, five uprooted (37 windfalls in this group).

#8 - Looking east and southeast into Pw-2 Plot, Forty #92.

On the plot of 10 acres, 3 trees are broken off, 10 windthrown and 11 badly bent by wind. This is a typical example of selection cutting of 15% to 25% reserved in even distribution.

#9 and #10 - Examples of extremes in soil character. #9 - 24" tree spread of roots torn up 10'x18'. Soil 1 ft. loam, 2 ft. broken solid rock penetrated by roots. #10 - 30" d.b.h. yellow pine crown L.M.D. Earth uprooted 12'x12'x4' thick; 2 ft. sandy loam, 2 ft. decomposed rocky loam, merging into solid rock beneath.