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Characterization of Sandbar[1] Willow Stems for Erosion Control Applications

by John Tingle and Chris Hoag

BACKGROUND: Reservoir shoreline erosion is a problem of national scope (Allen and Tingle 1993). Traditionally, the U.S. Army Corps of Engineers has tended to treat its eroding shorelines by using concrete structures, stone riprap, and other engineering "hard fixes" to halt this soil loss. In recent years, other techniques have been employed using woody and herbaceous vegetation alone or in combination with traditional hard fixes to stabilize eroding shorelines and to absorb or attenuate wave energy. In low-energy environments (average wave heights less than 0.46 m to 0.61 m (1.5 ft to 2 ft)), simple structures constructed from locally available willows can armor shorelines effectively and act as barriers to dampen or reduce wave action.[2] Examples of simple structures include brush mattresses, branch box breakwaters, and brush layering.

Some structures, such as fascines or wattling bundles, are constructed by arranging and bundling cut willow stems (Allen and Tingle 1993; Gray and Sotir 1996; Henderson and Shields 1984; Allen and Klimas 1986). However, physical characteristics of the willow trees from which the fascines are created and the number of stems needed to construct a fascine are poorly documented. This study is an effort to provide some of the information needed to fill this data gap.

Fascines are bundles of willow stems, roughly cigar-shaped, approximately 102 mm to 203 mm (4 in. to 8 in.) in diameter and 2.4 m to 3.7 m (8 ft to 12 ft) long, tightly bound together with wire or twine (Figure 1). Because little quantitative information is available for shrubby species of willow, such questions as "How much willow will be needed per meter of treated shoreline for various bank stabilization techniques," are common. The objective of this study is to describe narrowleaf or sandbar willow (*Salix exigua* Nutt.) stems to aid in estimation of the quantity of this material needed to accomplish shoreline erosion control.

INTRODUCTION: Willows are among the largest and most widely distributed group of woody plants in Idaho (Brunsfeld and Johnson 1985), and ostensibly in the United States. Because of the identification difficulties with willow species (i.e., differentiation based on characteristics of flowers and fruits, which are absent during much of the year), Brunsfeld and Johnson (1985) extensively studied the willows of Idaho. Consequently, for this study, the "Field Guide to the Willows of East-Central Idaho" (Brunsfeld and Johnson 1985) and The National PLANTS Database (U.S. Department of Agriculture (USDA) 2001) were chosen as the primary references for describing narrowleaf willow, *Salix exigua* Nutt. The National PLANTS Database symbol for narrowleaf willow is SAEX (USDA 2001).

1 At the time this research was conducted, the common name for this species, *Salix exigua* Nutt., was sandbar willow. Since that time, *Salix exigua* has been designated as narrowleaf willow.

2 Personal Communication, Hollis Allen, Biologist, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

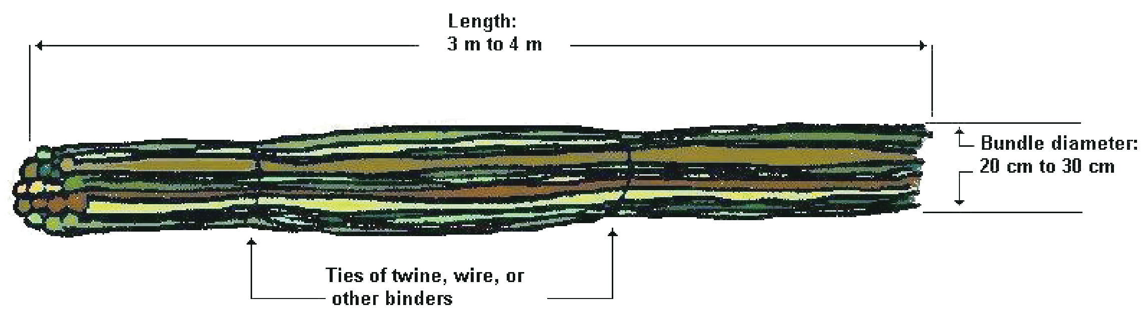

Figure 1. Schematic diagram of a fascine (wattling) bundle (U.S. Department of Agriculture 1999d)

Figure 2. *Salix exigua* Nutt. perennial, native, woody tree; © USDA, NRCS, 1995-Midwestern

Salix exigua (Figure 2) is a common native woody plant widely distributed in the United States (Figure 3). It is described as a suckering shrub, 0.9 m to 7.6 m (3 ft to 25 ft) tall (Figure 4), found throughout the western contiguous United States (USDA 2001). It is dioecious.[1] The leaves are very narrow with serrated edges, 50 to 127 mm (2 to 5 in.) long, lance-shaped, and pointed at both ends, with margins that have shallow, widely spaced teeth. The leaves are green and smooth on both surfaces or sometimes silvery-silky (USDA 1999b).

When this species becomes established, it quickly forms thickets on sand or gravel deposits along streams, roadside ditches, sloughs, and other places that frequently flood (Figure 5). *Salix exigua* is adapted to sandy soils in stream, river, and shoreline sites, but is not well adapted to other sites (USDA 1999a). In Idaho, *Salix exigua* has been found on sand and gravel bars up to the high-water line, and it is often the only shrub that survives annual flooding (Brunsfeld and Johnson 1985). The ability to withstand both (relatively) dry and flood conditions makes this plant extremely valuable for shoreline stabilization purposes.

METHODS: To describe the physical characteristics of *Salix exigua* stems, individual trees were measured in Oregon (Grant, Umatilla, and Union Counties) and Idaho (Bannock, Bingham, Blaine, Bonneville, Cassia, Minidoka, Oneida, Power, and Teton Counties) (Figures 6 and 7). Total tree height and stem diameter at ground level were measured. Elevations of the sites at which willows were harvested or measured in Oregon ranged from about 975 m (3,200 ft)[2] (Grant County) to about 853 m (2,800 ft) (Union County). In Idaho elevations ranged from approximately 1,280 m

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1 Male and female flowers are found on separate plants.

2 Elevations were estimated by inspection of U.S. Geological Survey Maps (North American Vertical Datum of 1927).

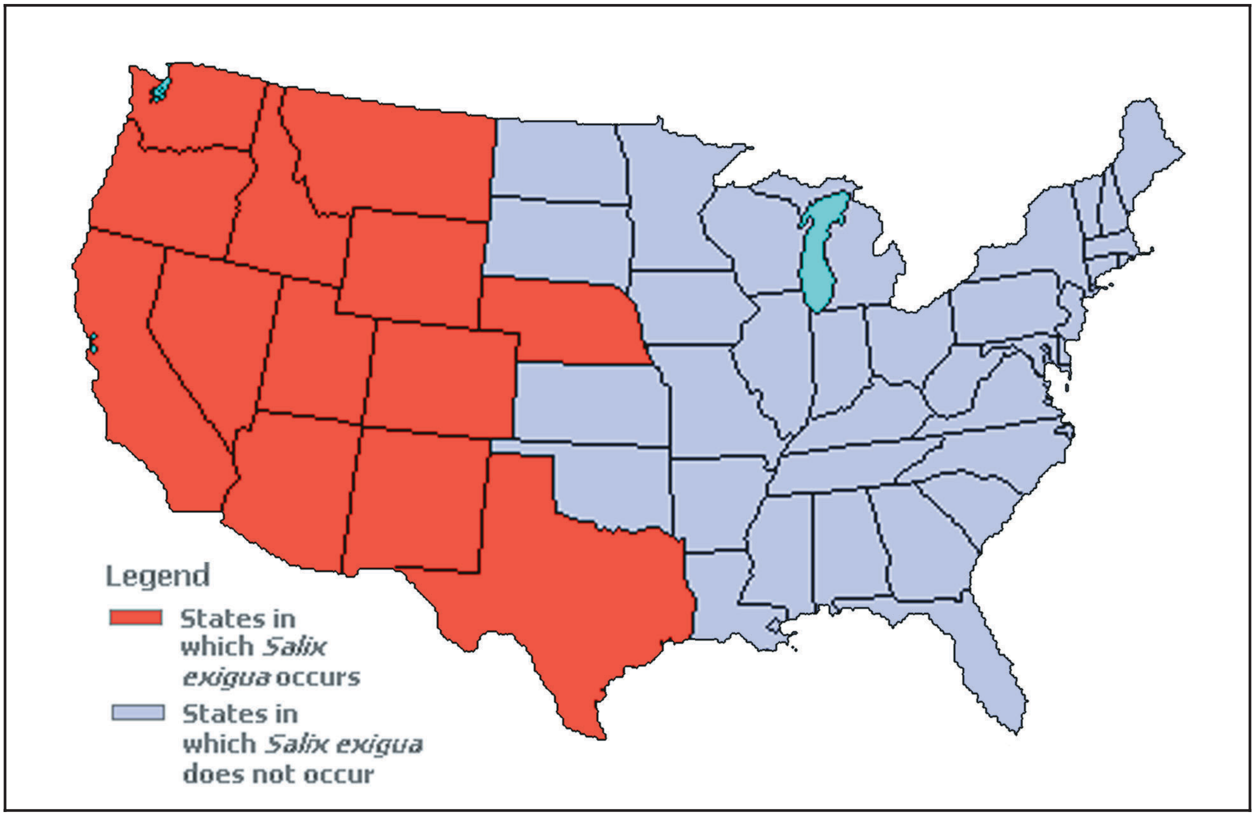

Figure 3. National distribution of *Salix exigua* by state (USDA 1999d)

Figure 4. *Salix exigua* approximately 8 m (25 ft) tall

Figure 5. *Salix exigua* growing on a streambed of mainly gravel

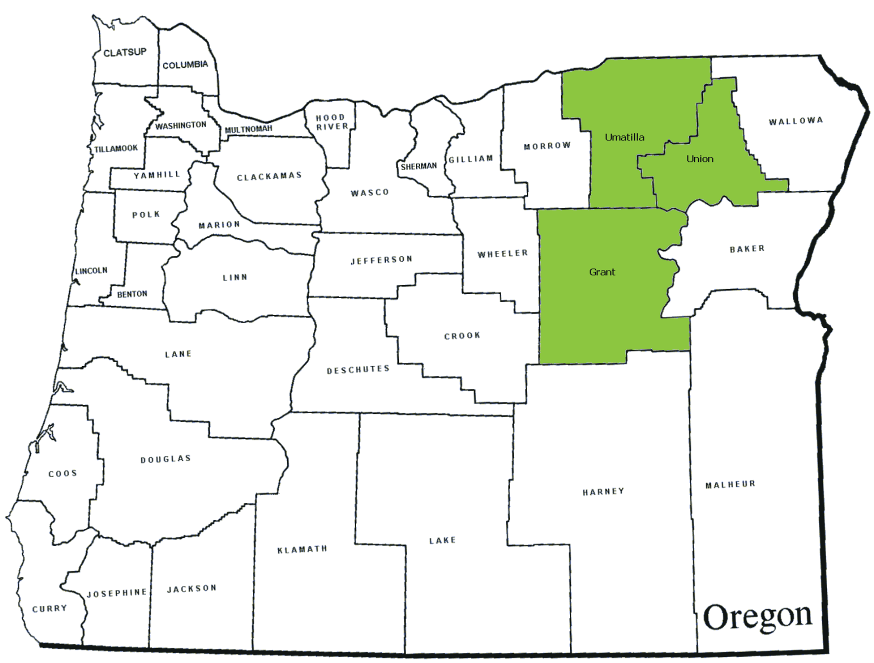

Figure 6. Counties of Oregon in which *Salix exigua* was sampled

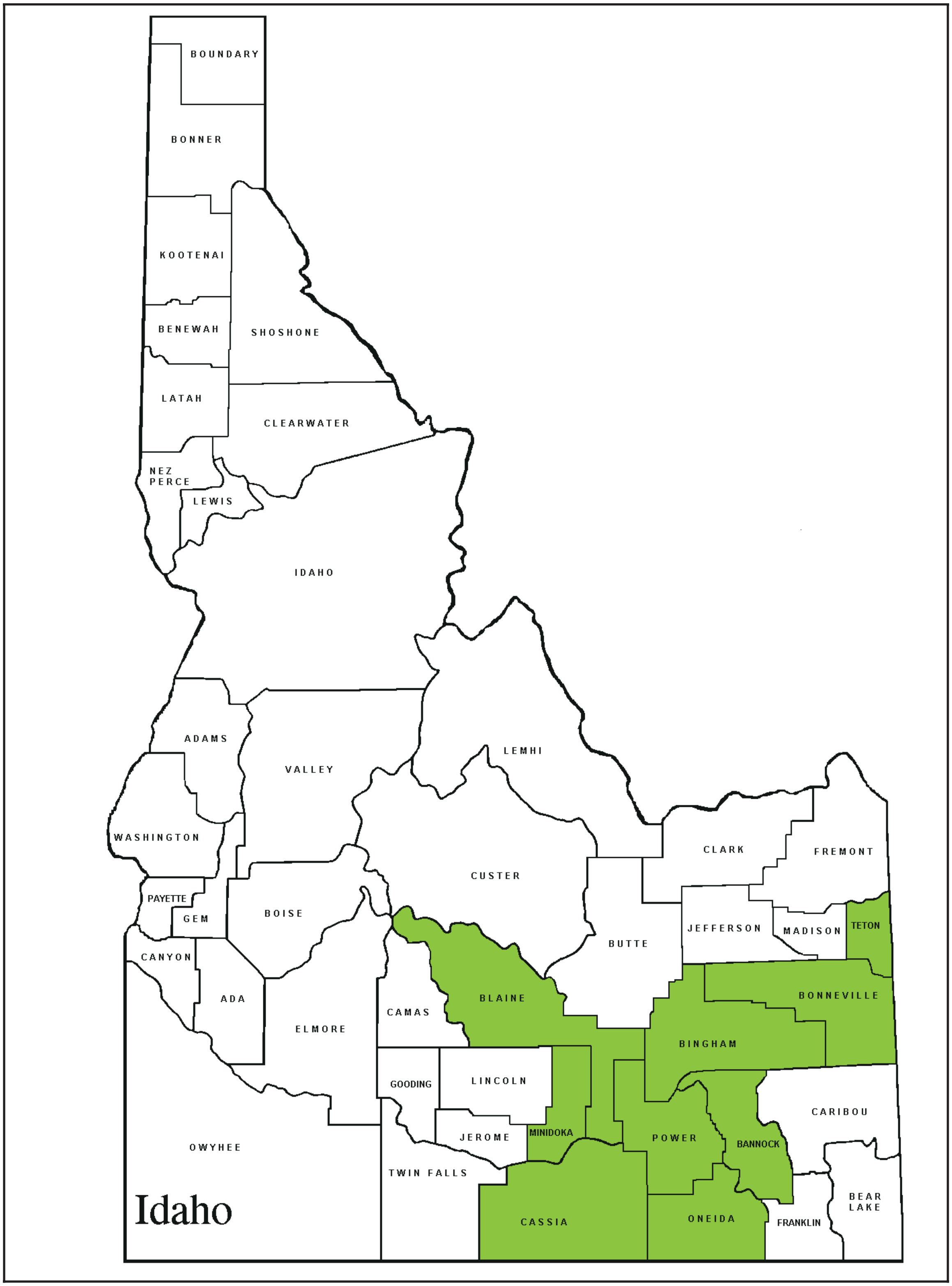

Figure 7. Counties in Idaho in which *Salix exigua* was sampled

(4,200 ft) near Minidoka Dam in Minidoka County to about 1,768 m (5,800 ft) in Teton County. These elevations fall within the lower elevation range of willows as defined by Brunsfeld (Brunsfeld and Johnson 1985). At these lower elevations, there is less likelihood of confusing *Salix exigua* with *Salix melanopsis* (*Salix exigua* ssp. *melanopsis*)[1]. Data in Oregon were collected in early April 1999, and July, August, and September 1999 in Idaho.

Willow dimension data came from three sources:

- At John Day and LaGrande, Oregon, respectively, trees were harvested in advance of two Natural Resources Conservation Service (NRCS) streambank erosion control workshops. These tree stems were measured at the workshop field demonstration sites using students to assist with the measuring procedures.
- As the investigators traveled between John Day and LaGrande, stands of willow were randomly selected for measurement on road shoulders and along streambanks. These measurements were taken on live trees.
- Trees in Idaho were measured by summer personnel hired by the NRCS specifically to perform this work. Stem measurements in Idaho were taken on live trees.

Willow trees for the two Oregon workshops were harvested by volunteer labor within a week of the workshops and stored submerged in water. Willows were harvested as near the demonstration sites as possible. No restrictions or guidance was provided to volunteers as to size of trees to harvest for the workshops. Therefore, stem selection was completely ad libitum by the volunteers. Stems were cut 13 to 152 mm (0.5 to 6 in.) above the ground.

Diameter classes for this study were arbitrarily set beginning with 6.35 mm (0.25 in.) and incremented by 6.35 mm (0.25 in.) per diameter class (Table 1). At workshop field demonstration locations, diameters were measured by inserting stem butts into holes predrilled into a piece of lumber (Figure 8). The diameters were assigned to diameter classes determined by the smallest diameter hole into which the stem would fit. For example, a stem that was actually 15.2 mm (0.6 in.) in diameter was tallied in the 19-mm (0.75-in.) class. Length to the nearest 0.30 m (1 ft) was measured by holding each stem near a measuring tape that had been either attached to a nearby fence or staked to the ground.

A limited number of "grab" samples at the demonstration sites were fashioned into fascines to determine the number of stems required for fascine construction. In addition, a small sample of stems was weighed individually with a spring scale during the Oregon workshop at the John Day site. At the LaGrande site, smaller bundles of willow, called vertical bundles, also were constructed from grab samples of stems.

Vertical bundles, although the same length, are approximately half the diameter of fascines. They are installed in streambanks by digging a vertical trench into the back face deep enough to contain the bundle. The bundle is then staked in place and covered with compacted soil.

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1 Personal Communication, 13 October 1999, Dr. Steven J. Brunsfeld, Professor, Department of Forest Resources, University of Idaho, Moscow, ID.

Table 1
Basal Stem Diameter Classes of Sampled Trees

Diameter Classes			
mm	**inches**	**mm**	inches
≤6.0	≤0.25	>38.1 and ≤44.5	>1.50 and ≤1.75
>6.0 and ≤12.7	>0.25 and ≤0.50	>44.5 and ≤50.8	>1.75 and ≤2.00
>12.7 and ≤19.1	>0.50 and ≤0.75	>50.8 and ≤57.2	>2.00 and ≤2.25
>19.1 and ≤ 25.4	>0.75 and ≤1.00	>57.2 and ≤63.5	>2.25 and ≤2.50
>25.4 and ≤31.8	>1.00 and ≤1.25	>63.5	>2.50
>31.8 and ≤38.1	>1.25 and ≤1.50		

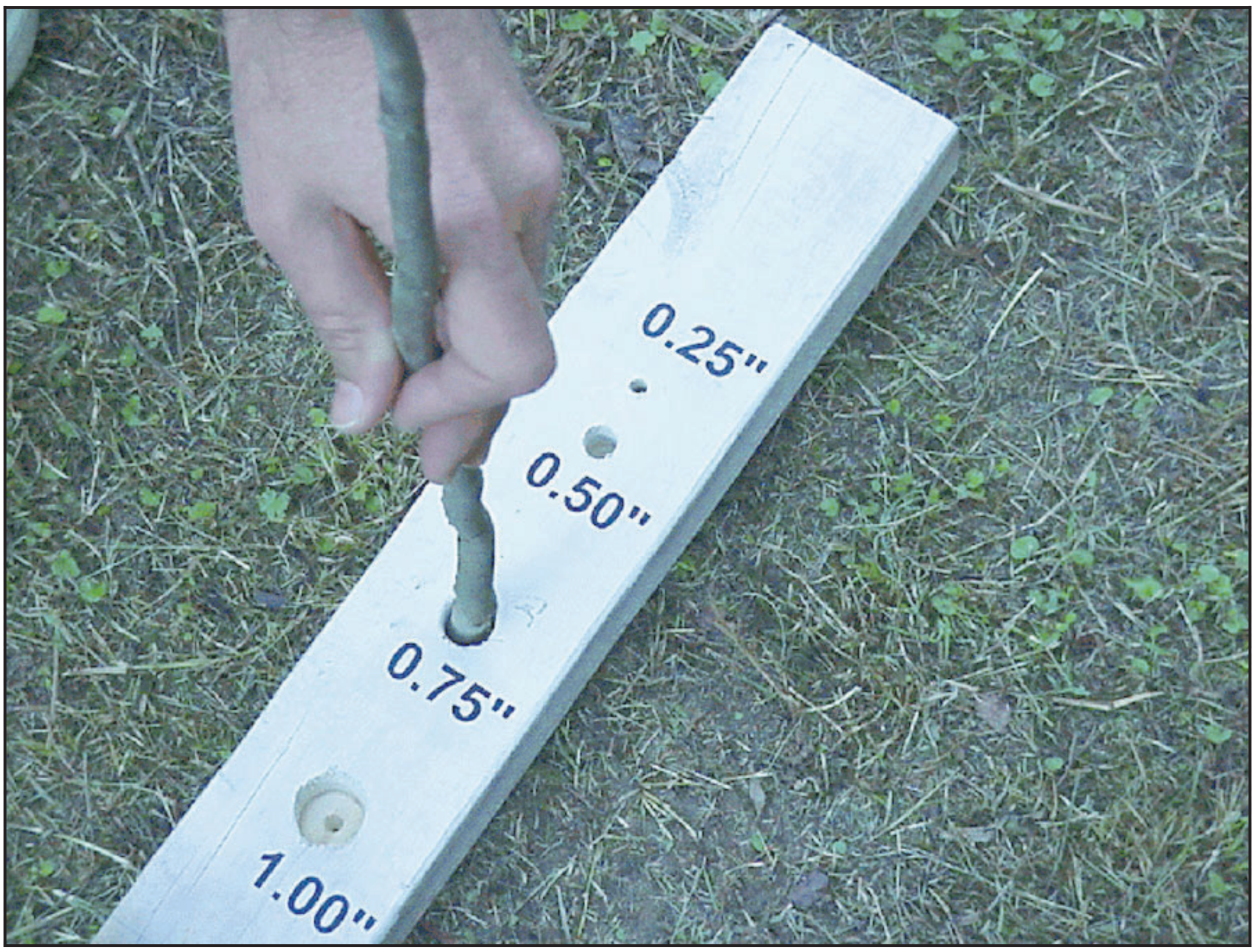

Figure 8. Stem diameter measurement by insertion into holes of known diameters

Figure 9. Heights and diameters of all stems within a 1-m by 1-m frame were determined. The rod stands in the middle of the frame

Stands of willows encountered between workshop sites in Oregon (John Day and LaGrande) and all samples in Idaho were measured regardless of tree size. A 1-m by 1-m sampling frame was placed on the ground, and all trees within this frame were measured at ground level using calipers. Heights were measured to the nearest 0.30 m (1.0 ft) by holding a surveying stadia rod beside each tree (Figure 9). Diameters were summarized in the same diameter classes[1] as the cut stems.

All data were processed, statistics were calculated, and simple linear regression graphs were prepared using Microsoft Excel software (Office 97). In the linear regression calculations, height was selected for the independent variable and basal diameter was selected for the dependent variable. The rationale for this choice was that average stand height is relatively easily estimated (or sampled) whereas measuring diameters of the stems at or near the ground is more physically difficult for the sampler.

RESULTS AND DISCUSSION:

Oregon. A total of 977 willow stems were measured: 438 at the John Day workshop, 156 at the LaGrande workshop, and 383 at random stops along the highway while traveling between the two workshops. Stem diameters ranged from 6.4 mm (0.25 in.) to 50.8m (2 in.), and tree height ranged from 0.5 m to 5.99 m (1.6 ft to 19.7 ft). Seventy-five percent (n = 729) of the stem diameters were between 12.7 mm (0.50 in.) and 31.8 mm (1.25 in.). Twenty-three percent (n = 223) of the stem diameters were less than 12.7 mm (0.5 in.), and about 3 percent (n = 25) of the stem diameters were greater than 31.8 mm (1.25 in.). Average stem diameters and mass are summarized by height classes (Table 2).

For all measured trees in Oregon, the average basal diameter was 17.1 mm (0.67 in.), and the average height was 2.42 m (7.91 ft). The average number of stems per square meter was 14.5. This equates to approximately 145,000 stems per hectare (ha) or 58,700 stems/acre.[2]

At the workshops, 32 to 42 stems (average diameter = 17.0 mm (0.67 in.) and average height = 24.1 m (7.91 ft)) were required to construct a 203.2-mm by 3.05-m (8-in. by 10-ft) fascine, and 8 to 15 stems were required to create a 101.6-mm by 3.05-m (4-in. by 10-ft) vertical bundle.

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1 Field workers in Idaho measured and recorded trees smaller than 6.4 mm (0.25 in.) and larger than 50.8 mm (2.0 in.).

2 One hectare equals 2.47 acres.

Table 2
Physical Characteristics of *Salix exigua* Measured in Oregon during April 1999

Measurements by Height Class					Stem Count		Number of Stems per Sample Plot (1 m²)	
Height Class m (ft)	Average Basal Stem Diameter mm (in.)	n	Average Mass grams	n	Vertical Bundle	Fascine	Stem Count	Replications (number of plots) with This Count
0.61 (2)	6.4 (0.25)	2	—	—	9	40	7	1
0.91 (3)	9.1 (0.36)	40	—	—	14	42	9	4
1.22 (4)	12.2 (0.48)	26	—	—	15	32	10	5
1.52 (5)	13.5 (0.53)	60	100	2	15	—	11	1
1.83 (6)	14.5 (0.57)	130	157	3	8	—	12	4
2.13 (7)	13.5 (0.53)	208	180	1	8	—	14	3
2.44 (8)	16.3 (0.64)	156	220	1	14	—	15	1
2.74 (9)	19.1 (0.75)	119	583	3	14	—	16	2
3.05 (10)	22.1 (0.87)	99	400	1	11	—	17	1
3.35 (11)	25.4 (1.00)	56	730	1	10	—	18	1
3.66 (12)	26.2 (1.03)	36	700	1	9	—	20	2
3.96 (13)	23.9 (0.94)	24	—	—	10	—	22	1
4.27 (14)	26.9 (1.06)	9	—	—	—	—	23	1
4.57 (15)	26.9 (1.06)	4	—	—	—	—	24	2
4.88 (16)	25.4 (1.00)	2	—	—	—	—	26	1
5.18 (17)	27.4 (1.08)	3	—	—	—	—	—	—
5.49 (18)	31.8 (1.25)	1	—	—	—	—	—	—
5.79 (19)	—	—	—	—	—	—	—	—
6.10 (20)	25.4 (1.00)	2	—	—	Averages			—
Sum		977		13	11	38	14.5	

Linear regression of the Oregon data produced a prediction equation of

$$y = 0.3577 + 0.5583x \tag{1}$$

This means that the estimated diameter y is equal to the constant, 0.3577, added to the product of a tree of height x and the coefficient, 0.5583. The R^2, the proportion of the total sums of squares attributable to tree height, is 0.2725, and the R value is 0.5220.

Idaho. A total of 3,794 willows were measured in Idaho. Diameters ranged from 3.2 mm to 127 mm (0.125 in. to 5.0 in.). Seventy percent (n = 2,672) of stem diameters were between 13.5 mm (0.50 in.) and 31.8 mm (1.25 in.). About 25 percent (n = 962) of stem diameters were less than 13.5 mm (0.50 in.), and the remaining approximately 4 percent (n = 160) of tree diameters were greater than 31.8 mm (1.25 in.).

For all stems the mean diameter was 17.3 mm (0.68 in.) and the mean height was 2.3 m (7.5 ft). However, when the stems larger than 50.8 mm (2.0 in.) were eliminated from the sample,[1] the sample size was reduced to 3,770 trees (Table 3). For this reduced sample, the mean diameter was 17 mm (0.67 in.) and the mean height was 2.28 m (7.48 ft). The number of stems per square meter averaged 16.6. On a per-ha basis, this was approximately 166,000 stems/ha or 67,178 stems/acre.

Linear regression of the Idaho data produced a prediction equation of

$$y = 0.0461 + 0.7249x \tag{2}$$

Table 3
Physical Characteristics of *Salix exigua* Measured in Idaho during July, August, and September 1999

Measurements by Height Class			Number of Stems per Sampled Plot (1 m^2)			
Height Class m (ft)	Average Basal Stem Diameter mm (in.)	n	Stem Count	Replications (number of plots) with This Count	Stem Count	Replications (number of plots) with This Count
0.30 (1)	15.5 (0.61)	21	3	1	26	4
0.61 (2)	17.8 (0.70)	135	4	1	27	1
0.92 (3)	16.3 (0.64)	304	5	5	28	4
1.22 (4)	19.1 (0.75)	290	6	6	29	4
1.52 (5)	15.2 (0.60)	394	7	3	30	2
1.83 (6)	17.0 (0.67)	359	8	5	31	1
2.13 (7)	17.0 (0.67)	400	9	10	34	3
2.44 (8)	18.0 (0.71)	436	10	13	36	2
2.74 (9)	17.3 (0.68)	382	11	13	37	1
3.05 (10)	15.5 (0.61)	379	12	11	41	1
3.35 (11)	18.5 (0.73)	289	13	8	46	1
3.66 (12)	19.8 (0.78)	148	14	6	47	1
3.96 (13)	19.1 (0.75)	111	15	13	48	1
4.27 (14)	21.3 (0.84)	65	16	6	61	1
4.57 (15)	19.8 (0.78)	36	17	6	—	—
4.88 (16)	16.8 (0.66)	17	18	4	—	—
5.18 (17)	16.0 (0.63)	13	19	6	—	—
5.49 (18)	14.7 (0.58)	6	20	3	—	—
5.79 (19)	16.0 (0.63)	3	21	4	—	—
6.10 (20)	12.7 (0.50)	2	22	4	—	—
6.40 (21)	12.7 (0.50)	1	23	3	—	—
6.71 (22)	12.7 (0.50)	2	24	1	—	—
7.01 (23)	12.7 (0.50)	1	25	1	—	—
	Sum	3,794			Average	16.6

1 Stems larger than 50.8 mm (2.0 in.) were excluded to standardize the Idaho data with the Oregon data (maximum diameter in Oregon was 50.8 mm).

This means that the estimated diameter y is equal to the constant 0.0461 added to the product of a tree of height x and the coefficient 0.7249. The R^2, the proportion of the total sums of squares attributable to tree height, is 0.5614, and the R value is 0.7493.

Idaho and Oregon. Since all sampled willow stands were from lower elevations in Idaho and Oregon, the intent was to pool the measurements without anticipating biological differences[1] (hybridizations, subspeciation, etc.).

From the regression equation for the Oregon sample:

$$y = 0.3577 + 0.5583x \quad (R^2 = 0.2561) \text{ (Figure 10)} \tag{3}$$

and from the regression equation for Idaho (with diameters limited to a 50.8-mm (2.00-in.) maximum[2]):

$$y = 0.0461 + 0.7249x \quad (R^2 = 0.5614) \text{ (Figure 11)} \tag{4}$$

A t-test was performed to assess the homogeneity of the b's (slopes of the respective regression lines) to determine if they estimated a common β. Using the formula:

$$t = \frac{b_1 - b_2}{\sqrt{s_p^2 \left(1/\sum x_{1j}^2 + 1/\sum x_{2j}^2 \right)}} \tag{5}$$

where

s_p^2 = estimate of variation about regression

x_{1j}, x_{2j} = values of x from the first and second samples, respectively

a t-value of 0.006943 was calculated. The slopes of the regressions were found to be not significantly different ($P < 0.001$); thus, the two data sets were combined for analysis.

Linear regression of the combined Idaho and Oregon data produced a prediction equation of

$$y = 0.0864 + 0.6993x \; (R^2 = 0.5032) \text{ (Figure 12)} \tag{6}$$

This means that the estimated diameter y is equal to the constant 0.0864 added to the product of tree height x and the coefficient 0.6993. The R^2, the proportion of the total sums of squares attributable to tree height is 0.5032, and the r value is 0.7094. From this equation, estimates of diameters from stem heights are displayed in Table 4.

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1 Personal Communication, 13 October 1999, Dr. Steven J. Brunsfeld, Professor, Department of Forest Resources, University of Idaho, Moscow, ID.

2 Idaho diameters were limited to 50.8 mm because this was the maximum diameter of the sampled stems in the Oregon data set.

Although the number of fascines and vertical bundles for which stem counts were determined is small, the average requirement was 38 stems per fascine 203.2 mm (8 in.) in diameter by 3.05 m (10 ft) long. Based on this estimate, to create 30.48 m (100 ft) of fascines, approximately 380 *Salix exigua* stems would be required. At an average 14.5 stems per m^2 in Oregon, this would mean harvesting approximately 26.2 m^2 (282 ft^2 or approximately 0.006 acre). In Idaho, at an average of 16.6 stems per m^2, 30.48 m (100 ft) of fascines would require harvesting about 22.9 m^2 (246.5 ft^2 or approximately 0.006 acre). On average, a vertical bundle 101.6 mm (4 in.) in diameter by 3.05 m (10 ft) long requires 11 stems, which in Oregon and in Idaho would require harvesting less than 1 m^2 of *Salix exigua*.

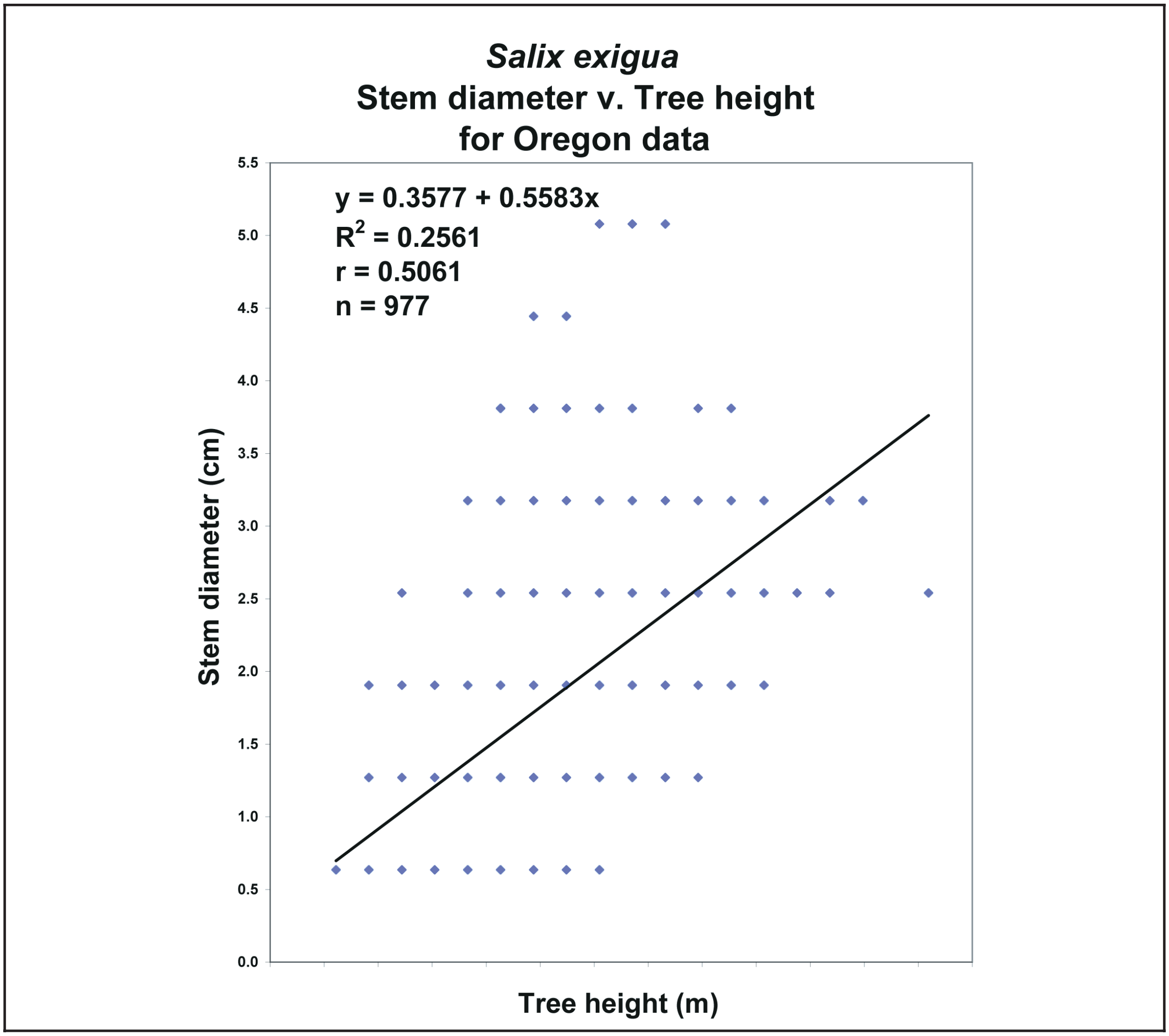

Figure 10. Graph of *Salix exigua* data measured in Oregon in April 1999 showing regression trend line

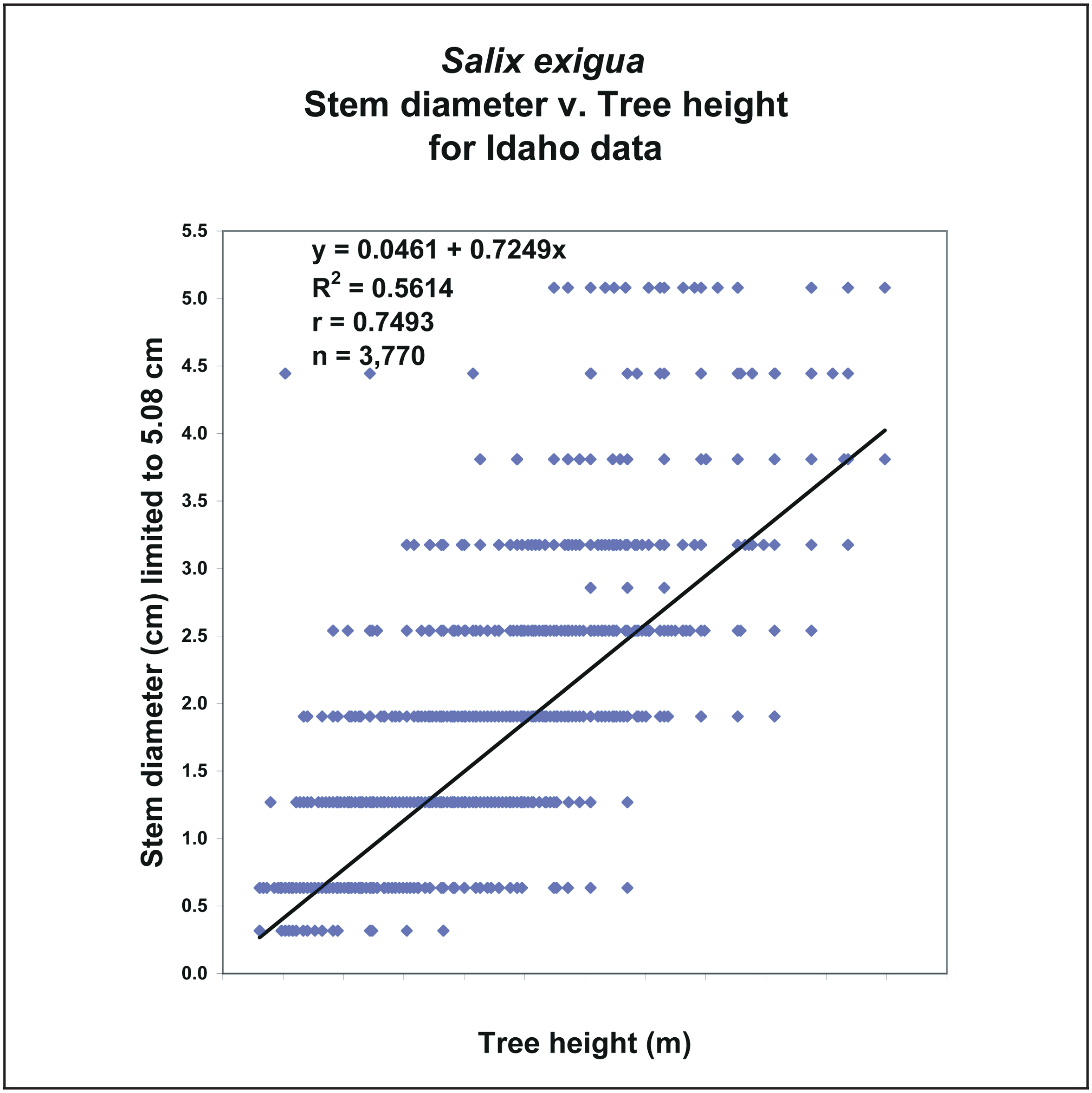

Figure 11. Graph of *Salix exigua* data measured in Idaho in July, August, and September 1999 showing regression trend line

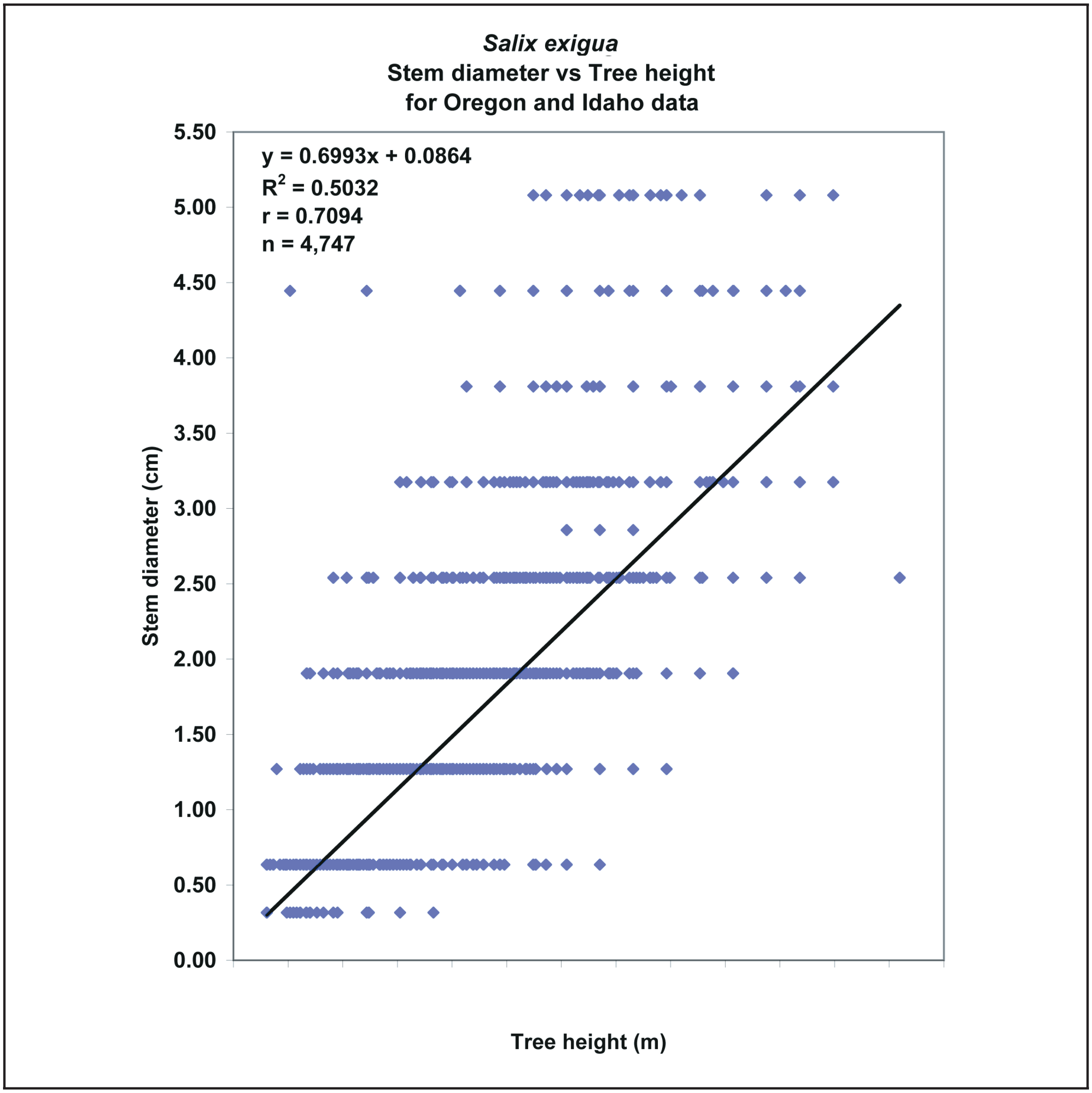

Figure 12. Graph of combined Oregon and Idaho *Salix exigua* data measured in April and July, August, and September 1999, respectively, showing regression trend line

Table 4
Estimated Stem Diameters of *Salix exigua* in Idaho and Oregon

Tree Height, m	Estimated Basal Stem Diameter, mm	Tree Height, m	Estimated Basal Stem Diameter, mm
1.0	7.9	3.5	25.3
1.5	11.4	4.0	28.8
2.0	14.9	4.5	32.3
2.5	18.3	5.0	35.8
3.0	21.8	5.5	39.3

Note: Estimates based on simple linear regression ($y = 0.0864 + 0.6993$ x) where y is estimated diameter and x is the average tree height.

HOW TO USE THIS INFORMATION; A HYPOTHETICAL CASE: A project manager in Idaho wants to construct 1,500 m of wattling bundles to treat an area of erosion on his lake near a boat landing. He knows the location of a sandbar on a stream on his project with *Salix exigua* growing on it. To schedule his crew efficiently, he wants to know how much willow to harvest and whether the sandbar contains sufficient willow material to meet his requirements or whether he will have to locate additional stands of willow.

- **Step 1.** Using a conventional measuring tape, a dot grid on aerial photographs, or Global Positioning System (GPS) equipment, determine the area of the willow stand on the sandbar (Figure 13).
- **Step 2.** By placing a sampling frame of known dimensions at several locations in the stand, determine the average number of stems of willow per unit area (square meters, square feet, etc.) (Figure 14).
- **Step 3.** With a stadia rod or other engineering equipment, make height measurements on approximately 10 m^2 (108 ft^2 or 0.002 acre) of standing trees, or the stem lengths of cut stems from approximately 10 m^2.
- **Step 4.** From the average height determined in Step 3 and the height-diameter relational information in Table 4, estimate the average diameter of the stems.
- **Step 5.** Based on the average length and diameter of the stems, determine the number of stems required to construct a wattling bundle. Since the average length of a wattling bundle is 3 m, the 1,500 m to be treated will require 500 bundles. The 500 bundles are multiplied by the number of stems per wattling bundle to get an estimate of the total number of stems.
- **Step 6.** From Step 2, determine the average number of stems per unit area on the sandbar. The number of stems per unit area is multiplied by the area (Step 1) to get an approximation of the number of stems available. This will then reveal whether the area contains sufficient willow to meet the project requirements (Step 5) or whether additional willow source(s) will be needed.

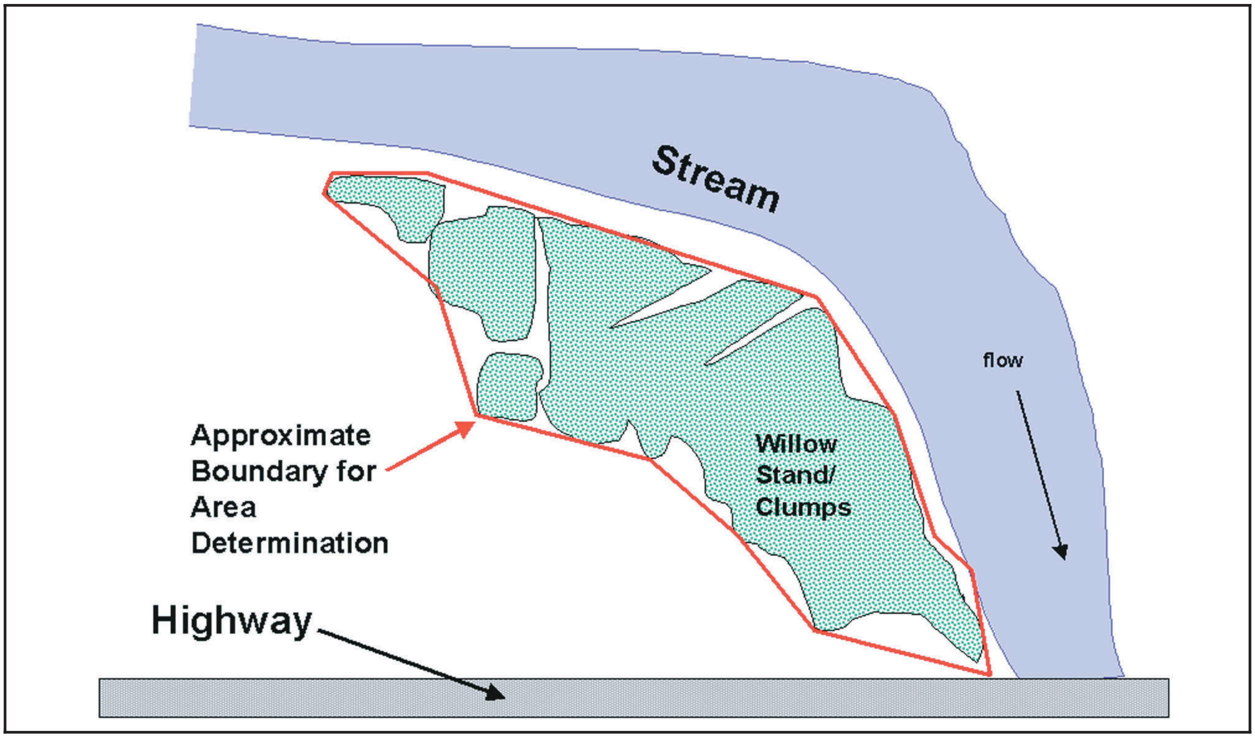

Figure 13. Hypothetical case: source of willow for erosion control

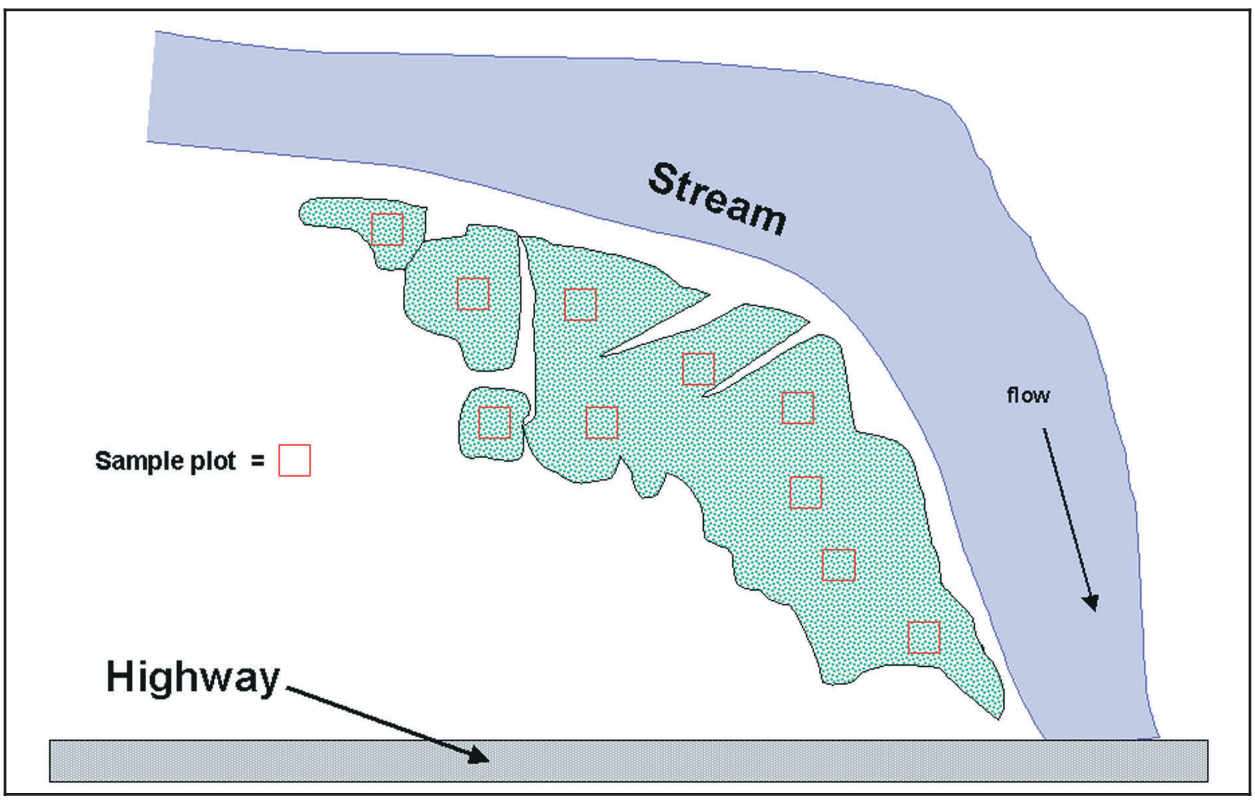

Figure 14. Samples are taken within the stand to determine mean number of stems per unit area

RECOMMENDATIONS FOR ADDITIONAL STUDY:

- Although an extensive number of *Salix exigua* stems were measured in Oregon and Idaho, only a limited number of erosion control components were constructed. Additional information is needed to more fully characterize structures commonly prepared for shoreline and streambank erosion control. Brush mattress, branch box breakwaters, and additional fascines and vertical bundles could be constructed, then dismantled and the components (stems) measured to more clearly establish the relationship between *Salix exigua* stem size and the quantity of stems necessary to prepare erosion control components.
- Additional weight/mass data are needed. Since willow is typically harvested near the site at which it will be used, weight and haul distance are generally not significant cost factors. However, knowing the stem dimensions and how those dimensions relate to stem weight could simplify the estimation process. For example, if the stand averaged 3.05 m (10 ft) tall and a fascine of this material required 40 stems/bundle that weighed 18.2 kg (40 lb), then 454.5 kg (1,000 lb) of 3.05-m stems would produce about 55 fascine bundles. Weight of cut stems could be easily and quickly determined with truck scales. Because of the formats of the workshops onto which this study was appended, it was not possible to collect such information.
- *Salix exigua* should be sampled in other portions of its native range with predefined criteria for the sizes of stems to be measured. Differences in site quality and in climate may produce *Salix exigua* stems of different physical characteristics from those described in this study.

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Tingle, J. L., and Hoag, C. (2001). "Characterization of narrowleaf willow stems for erosion control applications," *Water Quality Technical Notes Collection* (ERDC WQTN-MS-06), U.S. Army Engineer Research and Development Center, Vicksburg, MS. *www.wes.army.mil/el/elpubs/wqtncont.html*

REFERENCES

Allen, H. H., and Klimas, C. V. (1986). "Reservoir shoreline revegetation guidelines," Technical Report E-86-13, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Allen, H. H., and Tingle, J. L., ed. (1993). *Proceedings, U.S. Army Corps of Engineers Workshop on Reservoir Shoreline Erosion: A National Problem*, McAlester, OK, 26-30 October 1992. Miscellaneous Paper W-93-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Brunsfeld, S. J., and Johnson, F. D. (1985). "Field guide to the willows of east-central Idaho," Bulletin Number 39, Forest, Wildlife, and Range Experiment Station, University of Idaho, Moscow, ID.

Gray, D. H., and Sotir, R. B. (1996). *Biotechnical and soil bioengineering slope stabilization: A practical guide for erosion control.* John Wiley, New York.

Henderson, J. E., and Shields, F. D., Jr. (1984). "Environmental features for streambank protection projects," Technical Report E-84-11, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Steel, R., and Torrie, J. (1960). *Principles and procedures of statistics*. McGraw-Hill, New York.

U.S. Department of Agriculture. (1999a). "Plant Fact Sheet," Natural Resources Conservation Service, Plant Materials Program, *http://Plant-Materials.nrcs.usda.gov:90/pmc/shrubs/saex.html* (September 20, 1999).

U.S. Department of Agriculture. (1999b). "PLANTS - National database," Natural Resources Conservation Service. *http://plants.usda.gov/plantproj/plants/index.html* (September 20, 1999).

U.S. Department of Agriculture. (1999c). "The National PLANTS database," Natural Resources Conservation Service. *http://rndhouse.nrcs.usda.gov/plantproj/plants/* (October 25, 1999).

U.S. Department of Agriculture. (1999d). "Watershed Technology Electronic Catalog," Natural Resources Conservation Service. *http://www.wcc.nrcs.usda.gov/wtec/soilbio.html* (October 25, 1999).

U.S. Department of Agriculture. (2001). "The PLANTS database," Version 3.1, National Plant Data Center, Baton Rouge, LA, *http://plants.usda.gov/plants/cgi_bin/topics.cgi* (June 19, 2001).