SALINITY, SODICITY AND FLOODING TOLERANCE OF SELECTED PLANT SPECIES OF THE NORTHERN CHEYENNE RESERVATION

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Preface

This document was prepared in response to numerous questions raised regarding the tolerance and/or sensitivity of native and culturally significant plants on the Northern Cheyenne Reservation to salinity, sodicity, and flooding that might be a consequence of natural gas exploration and extraction in southeast Montana. Initially, a list of native and culturally significant plant species was obtained from the Department of Environmental Protection, Northern Cheyenne Tribe. A thorough search of references dealing with salinity, sodicity, flooding, and pH tolerances for the plants in question was then undertaken, with journals, reference books and Internet sources all providing pertinent information. The goal was to gain an accurate prediction as to how native and culturally significant plants would be likely to respond to increases in salinity, sodicity, flooding, and pH/ alkalinity, all possible consequences of proposed natural gas extraction in southeast Montana. Where no data were found for a specific plant tolerance, indicator species were used. Indicator species were either plants in the same genus or plants commonly found in the same habitats or communities as the plant in question. Some of the primary sources used were Ayers and Westcot's 1976 "Water Quality for Agriculture", E.V. Maas' 1993 "Testing crops for salinity tolerance", Frank F. Munshower's Forbs, Shrubs, and Trees for Revegetation of Disturbed Lands in the Northern Great Plains and Adjacent Areas with comments about some wetland species, James Small's 1946 pH and Plants: An Introduction for Beginners, K.K. Tanji's Agricultural Salinity Assessment and Management, The United States Department of

Agriculture website, Utah State University's Extension Service, and B. Wolf's The Fertile Triangle.

Scientific Basis

Salinity: A multitude of references have been published within the scientific literature assigning various ranges of soil solution salinity to categories of salt tolerant plants. Using these ratings systems, most plant species are assigned to categories such as degree of sensitivity or degree of tolerance to salinity. For purposes of reference, Table 1 presents two frequently cited salt tolerance rating systems (Miller and Donahue, 1995; Maas, 1993). Using the composite information from these two references, a general rating system was prepared for use in this report. Plant species identified in this report as "sensitive" were those determined to be adversely affected by EC_e values < 2 dS/m. At the other extreme, plant species reportedly tolerant and capable of reasonably normal growth under conditions of EC_e values > 6 dS/m were rated as tolerant. For further purposes of reference, a saline soil is generally considered to be one with an EC_e (saturated paste extract) greater than 3.0 dS/m (Miller and Donahue, 1995).

Table 1. Salinity Tolerance Ratings

Miller and Donahue, 1995	Maas,1993 EC_e[1] (dS/m)	This report	Symbol-
0-2 few plants affected	< 1.5 sensitive	< 2 sensitve	S
2-4 some sensitive plants affected	1.5 – 3.0 moderately sensitive	2-4 moderately sensitive	MS
4-8 many plants affected	3-6 moderately tolerant	4-6 moderately tolerant	MT
8-16 most crop plants affected	6-10 tolerant	>6 tolerant	T

>16 few plants tolerant >10 very tolerant

[1]EC_e = salinity of saturated paste extract, dS/m

For purposes of this assessment, plant species determined to be adversely affected by salinity values < 2 dS/m were rated as sensitive; those adversely affected by salinity values between 2 and 4 dS/m were rated as moderately sensitive; those affected by salinity values between 4 and 6 dS/m were rated at moderately tolerant; plant species tolerant to EC > 6 dS/m were rated as tolerant.

Sodium Tolerance Ratings: The scientific literature contains few specific references to individual plant species' tolerances to sodicity, which may be expressed as SAR (sodium adsorption ration), ESP (exchangeable sodium percentage) or specific sodium concentration. Sodium is known to have an adverse effect on most plant tissue when in direct contact with leaves at high concentrations. Generally, however, effects of sodium on plant performance are indirect and a response to sodium-induced alterations in soil physical and chemical properties. For purposes of reporting herein, species exhibiting a high degree of sensitivity to sodium are listed as extremely sensitive (ES). Other species may be affected indirectly by sodium, through a change in soil physical structure. Species reportedly very tolerant of sodium (able to tolerate ESP of as much as 60%) are identified as VT. Where no ratings is presented, data were not available to justify a rating. Shainberg and Oster (1978) report that all deciduous fruits are extremely sensitive to sodium, with ESP 2 –10 % having a negative impact on plants and fruit production. Primary sodium toxicity symptoms are leaf burn and leaf wilting. In

general, it is not uncommon for sodium toxicity to occur when flood irrigation water has an SAR as low as 4.5 and/or spray irrigation water that wets the foliage has a sodium content > 70 mg/L or SAR >3.0 (DPI website, 2002).

Flooding Tolerance Ratings: (conventions used in this report)

Intolerant – unable to withstand flooding for more than a few days

Moderately Tolerant – able to withstand short-term flooding, approximately two weeks in duration, but not long term flooding

Tolerant – able to withstand relatively long flooding, up to a year or more, but may still be damaged by consecutive years of flooding

pH/Alkalinity Tolerance Ratings: (conventions used in this report) Ideal pH ranges are given. While plant species may be able to survive outside of the given ranges, they are likely to be negatively impacted, either through direct physical damage or through competition with species better adapted to the given pH.

Summary of Findings

The following table (Table 2) provides a summary of the primary information in the text, specifically plant tolerances to salinity, given as an overall sensitivity rating and threshold EC_e value (where salinity begins to have a negative impact), sodicity, flooding, and pH. The text itself provides a complete listing of all relevant data pertaining to the above criteria, as well as general habitat descriptions and other relevant information.

Table 2. Summary of sensitivity rating of thirty one native and culturally significant plant species of the Northern Cheyenne Reservation to soil solution salinity (EC_e), exchangeable sodium percentage, flooding, and changes in soil pH.

		SALINITY		SODIUM	FLOODING	pH range
		Rating	Acceptable Upper Limit EC_e (sat) dS/m	Tolerance/ Rating	Rating Inundation Limits	
1. June/ Service Berry	*Amelanchier alnifolia*	S	2.0	ES; ESP 2-10 SAR 1.6-8.0	MT short term, 2 weeks	no data
2. Red Osier Dogwood	*Cornus stolinifera*	S	2.0	no data available	MT short term, 2 weeks	6.5-7.9
3. Common spikerush	*Eleocharis palustris*	MS	4.0	no data available	T long term, 1 year +; not tolerant to permanent flooding	4.8-7.9
4. Horsetail, Field	*Equisetum arvense*	MS	4.0	no data available	T long term, 1 year +; not tolerant to permanent flooding	4.8-7.2
5. Wild licorice/American	*Glycyrrhiza lepidota*	MT	6.0	VT; ESP 60 SAR 48	T long term, 1 year +; not tolerant to permanent flooding	4.8-7.2
6. Goose Berry, red shoot	*Ribes setosum*	S	2.0	ES: ESP: 2-10 SAR 1.6 - 8	T long term, 1 year +; not tolerant to permanent flooding	4.8-7.9
7. Mint/ Field	*Mentha arvensis*	S/MS	2.0	ES: ESP 2-10 SAR 1.6-8	no data available	4.8-7.9
8. Horsemint/ W. Bergamot	*Monarda fistulosa*	MS	4.0	no data available	no data available	5.5-7.9
9. Water Plant/ Water Cress	*Nasturium officinale*	MS	4.0	no data available	T long term, 1 year +; not tolerant to permanent flooding	4.8-7.2

10. Sweet Medicine	*Oxtropis lamnbertii*	MS	4.0	no data available	no data available	5.5-7.9
11. Chokecherry	*Prunus virginiana*	S	2.0	ES: ESP 2-10 SAR 1.6 – 8	I very short term, < 2 weeks	4.8-7.9
12. Cottonwood, G. Plains	*Populus deltoides*	MS	4.0	no data available	T long term, 1 year +; not tolerant to permanent flooding	4.8-7.9
13. Box elder	*Acer negundo*	MT	6.0	no data available	T long term, 1 year +; not tolerant to permanent flooding	4.8-7.9
14. Green ash	*Fraxinus Pennsylvania*	MT	6.0	no data available	T long term, 1 year +; not tolerant to permanent flooding	6.5-7.9
15. Sand bar willow	*Salix exigua*	MS	4.0	no data available	T long term, 1 year +; not tolerant to permanent flooding	4.8-7.9
16. Snow Berry	*Symphoricarpos occidentalis*	MS	4.0	ES: ESP 2-10 SAR 1.6 -1.8	I long term, 1 year +; not tolerant to permanent flooding	4.8-7.9
17. Cattail	*Typha latifolia*	MS	4.0	no data available	T long term, 1 year +; not tolerant to permanent flooding	4.8-7.9
18. Wild plum	*Prunus Americana*	S	2.0	ES:ESP 2-10 SAR 1.6-8	T long term, 1 year +; not tolerant to permanent flooding	no data
19. Sweet grass	*Hierochloe odorota*	MS	4.0	no data available	no data available	4.8-7.2
20. Quaking aspen	*Populus tremuloides*	S	2.0	no data available	T long term, 1 year +; not tolerant to	no data
21. Saw beak sedge	*Carex stipata*	MS	4.0	no data available	T long term, 1 year	5.0-7.9

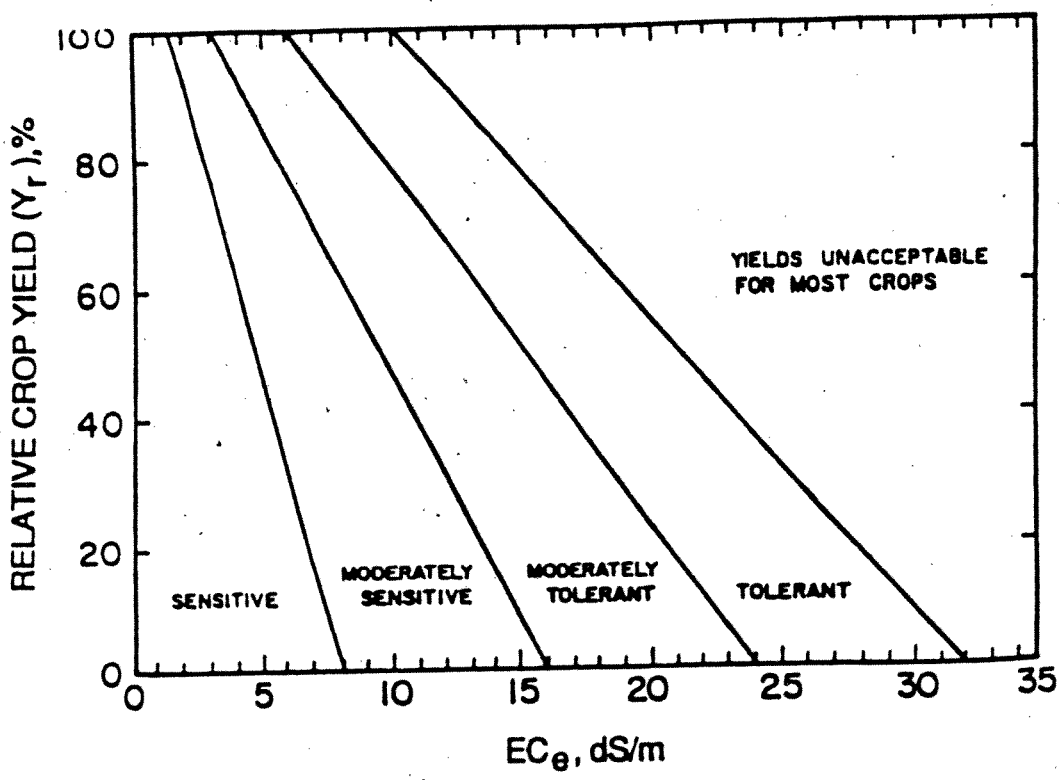
					not tolerant to permanent flooding	
22. Leafy aster	*Aster foliactus*	S	2.0	no data available	T long term, 1 year +; not tolerant to permanent flooding	4.8-7.2
23. Stinging nettle	*Urtica dioica*	MS	4.0	no data available	I very short term, < 2 weeks	4.8-7.2
24. Bulrush	*Scirpus nevadensis*	MT/T	6.0	no data available	T long term, 1 year not tolerant to permanent flooding	4.8-7.9
25. Arrow leaf	*Sagittaria latifolia*	MS	4.0	no data available	T long term, 1 year +; not tolerant to permanent flooding	4.8-7.9
26. Golden currant	*Ribes aureum*	MS	4.0	ES: ESP 2-10 SAR 1.6-8	no available data	4.8-7.9
27. Skunkbush sumac	*Rhus trixobata*	MT	6.0	no available data	MT short term, 2 weeks	6.5-7.9
28. Milkweed, showy	*Asclepias speciosa*	MS	4.0	no avaible data	I very short term, < 2 weeks	4.8-7.2
29. Western yarrow	*Achillea millelolium*	MS	4.0	no available data	I very short term < 2 weeks	4.8-7.9
30. Raspberry, red	*Rubes idaue*	S	2.0	ES: ESP 2-10 SAR 1.6-8	no available data	4.8-7.9
31. Rose Bush	*Rosa arkans*	MS	4.0	no available data	MT short term, 2 week	4.8-7.9

Explanations and Descriptions of Plant Responses to Salinity, Sodicity, pH/Alkalinity, and Bicarbonates

Salinity: The quality of water plants are exposed to has a direct impact on their survival, growth, and overall health. This is particularly true in regard to salinity. Published research supports the premise that the salinity of water plants will actually have available to utilize, the soil EC, EC_e, or EC_{sat} (saturated paste extract), is on average as much as three times the salinity of applied irrigation water due to evapotranspiration (Ayers and Westcot, 1976). Schafer (1983b) reports an increase in EC_{sat} of as much as 5 dS/m for each dS/m of applied water. Hence it is important to distinguish the condition being referred to with regard to salt tolerance, i.e. salinity of applied water or salinity of the soil solution. Most salinity tolerance listings, including those outlined here, use soil saturated paste extract EC measurements, referred to as EC_e or EC_{sat}.

An extensive amount of research has been published regarding cultivated crop species' tolerances to salinity. Less data are available for plants normally considered non-agricultural. Figure 1 illustrates the relative crop yield of plants of varying sensitivity to soil water salinity, EC_e. Shainberg and Oster (1978) identified five categories of plants with respect to salinity tolerance. In their rating system, sensitive plants demonstrated reductions in performance at EC_e values as low as 1.5 dS/m and death occurred in the sensitive species at EC_e = 8.0 dS/m. At the other extreme, plants rated as tolerant did not demonstrate measurable yield reductions until EC_e exceeded 6 dS/m and 100 % reduction did not occur until EC_e reached 32 dS/m. This same rating system was subsequently reported by Maas (1993) and constitutes part of the report

Figure 1: Relative crop yield as affected by soil salinity



(Shainberg and Oster, 1978)

contained herein. Generally most agricultural plants demonstrate some degree of impairment when EC_e exceeds 8 dS/m (Schafer, 1983a).

The most likely effect of salinity on plants is a general stunting of growth. Increased salinity requires plants to expend more energy to obtain water from the soil, thereby reducing the amount of energy available for growth. **Moderately salt-stressed plants usually appear normal, although their leaves may be darker green, thicker and more succulent than non-stressed plants. Visual symptoms (leaf burn, necrosis, and defoliation) sometimes occur, particularly in woody species. At high levels, salinity can cause physical damage and mortality. Plant sensitivity to salinity changes throughout the growing season. While most crops are relatively tolerant to salinity during germination, young developing seedlings are particularly susceptible to salinity damage during emergence and early juvenile development.** After they are established, plants generally become increasingly tolerant to salinity in later growth stages (Maas, 1993).

A primary effect of salinity is that it delays germination and seedling development. This delay may prove fatal if the salt-stressed seedlings encounter additional stresses, such as water stress, extreme temperature fluctuations and/ or soil crusting. Additionally, because of evaporation at the soil surface, the salt concentration in the seedbed is often higher than deeper down in the soil profile. Hence, roots of emerging seedlings are exposed to a greater degree of stress than that indicated by usual salinity measurements which are generally derived from composite soil samples taken throughout the soil profile (Western Fertilizer Handbook,1995). Plant loss during this

seedling stage can reduce the plant population density to suboptimal levels and significantly reduce yields (Maas, 1993).

Sodium: Two potential risks of elevated sodium levels in the soil solution are well documented in the scientific literature. The first is the direct toxic effect of sodium, which can result in leaf burn, defoliation, or death (Western Fertilizer Handbook, 1995). The second is the effect that alteration of soil physical structure may have on plant growth. This second risk is an indirect one, due to sodium-induced disperson, but one which has potential to impact plant growth and development (Ayers and Westcot, 1976; Hansen et al., 1999; Miller and Donahue, 1995). If SAR of the soil solution or ESP values of the soil exchange complex (a measurement of the relative concentrations of sodium to calcium and magnesium) become sufficiently elevated, soils, particularly those high in clay content, may disperse. When this soil reforms, a concrete-like surface crust is generally formed. This causes a decline in hydraulic conductivity, reduced water infiltration, and the potential for increased runoff. This physical condition may also make seedling establishment very difficult, if not impossible (Shainberg and Letey, 1984).

These dispersed conditions, common to sodic soils, also make it difficult for plant roots to obtain water and nutrients. Sodic soils are likely to become and remain waterlogged. This reduces drainage, and may lead to anaerobic conditions. If anaerobic conditions persist for any length of time, generally more than a few days, roots are unable to gain sufficient oxygen, leading to reduced plant growth, plant injury and very likely eventual death (Western Fertilizer Handbook, 1995).

Additionally, a significant decline in drainage often leads to saline conditions. If water containing salts is not allowed to drain beneath the root zone, the salt concentration of the remaining water will continue to increase as plants take up water, by transpiration, and water is lost to the atmosphere by evaporation (Western Fertilizer Handbook, 1995). (For more information on sodic soils, see "Basics of EC/ SAR Effects on Soil Physical Properties on MSU- Bozeman's Water Quality Web Page: http:waterquality.montana.edu.)

Tisdale (1985) proposed that reductions in crop yield could be assigned to one of four categories of sodic soil, along with a corresponding ESP (%) and SAR (Table 3). As previously noted, plants are not generally evaluated with respect to sensitivity to either SAR or ESP, in as much as these two diagnostics are generally specific to soil physical responses

Table 3: Typical reductions in crop yields at various exchangeable sodium percentages (ESP) (Tisdale, 1985)

Type of Soil	*ESP (%*	*SAR Average*	*Decrease in Crop Yield (%)*
slightly sodic	7-15	<12	20 – 40
moderately sodic	15 – 20	12-16	40 – 60
very sodic	20 – 30	16-24	60 – 80
extremely sodic	> 30	> 24	> 80

pH/Alkalinity: The presence of carbonates and bicarbonates increases soil solution alkalinity. However, the direct effect of alkalinity on plant performance is not well known. It is well documented that most plant species demonstrate optimal

performance within defined soil acidity/ alkalinity conditions. A sharp increase in alkalinity may cause a shift in the plant community, as plants more adapted to acidic conditions get outcompeted. Similarly, a shift toward acidic conditions will favor plants favorable to acid soils. However, it is more likely that salinity and sodicity will cause a shift in community structure and composition (Western Fertilizer Handbook, 1995). In general, most native plants and cultural plants in arid and semi-arid environments are adapted to slightly, moderately, or strongly alkaline conditions (Munshower, 1998).

Bicarbonates: Carbonates and bicarbonate salts are common in waters and soils of eastern Montana (Schafer, 1983a). The known effect of bicarbonates on plants is the potential for leaf burn when bicarbonate rich water at sufficiently elevated levels comes in direct contact with growing leaf tissue (ATTRA website, 2002). However, it is unlikely that bicarbonates will have a negative impact on native wetland plants. Only a few very sensitive crops are negatively affected by bicarbonates, and levels high enough to adversely affect plants are unlikely to occur under normal irrigation with good drainage. Under conditions of continuous flooding or frequent inundation, this situation could change (Western Fertilizer Handbook, 1995).

APPENDIX

Detailed description of tolerances, sensitivities and pecularities of selected native plant occurring on the Northern Cheyenne Reservation

1) June/Service Berry (*Amelanchier alnifolia*): June/ Service Berry is typically found in thickets in association with other shrubs (*Prunus* sp., *Cratuegus* sp.), in coulees, drainage bottoms and moist grasslands (Munshower, 1995).

Salinity Tolerance

Poor (Munshower, 1995) (Only qualatative ratings were given in Dr. Frank F. Munshower's ratings. Hence plants which occupy similar habitats and community types were used as indicator species in order to obtain quantitative ratings.) (Ribus sp. was used as an indicator species because of similar habitat and general plant structure) (Maas, 1993).
threshold EC_e – 1.5 dS/m (yield reduction occurs at EC_e greater than this value)
% decrease in yield - 22 % for each 1 dS/m increase in EC_e
Rating – sensitive to salinity – see Figure 1 (Maas, 1993).

Sodium Tolerance (ESP)

extremely sensitive (all deciduous fruits) (ESP 2-10 has a negative impact) A reduction in growth response under field conditions. Sodium toxicity symptoms (leaf burn, leaf wilting) even at low ESP values (Shainberg and Oster, 1978). Very sensitive to sodium; may show its toxic effect when flood irrigation water has an SAR as low as 4.5 and/or spray irrigation water that wets the foliage has a sodium content > 70 mg/L or SAR >3.0 (DPI website, 2002).

Flooding Tolerance

Poor – moderate (Munshower, 1995).

2) Red Osier Dogwood (*Cornus stolinifera*): Dogwood grows best in well-drained soils but is commonly found in riparian areas, moist woodlands, streambanks and other mesic sites. Essential requirement is well-drained rooting medium and abundance of oxygen in root zone (Munshower, 1995).

Salinity Tolerance

Sensitive >2dS/m soil EC (EC_e) will cause damage (yield reduction, injury) (Wolf, 1999).

Fair (Munshower, 1995)

Flooding Tolerance

Intolerant: (Flowering dogwood (*Cornus florida*) was used as an indicator species.) 4 – 10 inches of water for ten days leads to defoliation or death (U.S. Department of Agriculture Website). Red osier dogwood is considered

moderately tolerant to periodic flooding in rapidly drained soils. Good (Munshower, 1995). The discrepancy in ratings indicates that dogwood will tolerate water but not continuous flooding/ anaerobic conditions.

pH/ Alkalinity Tolerance
Cornus sp.: alka-tolerant; will tolerate pH 6.5 – 7.9 (Small, 1946)

3) Common spike rush (*Eleocharis palustris)*: Often found in fens and riparian areas, and in association with members of the *Salix* family. Because of their common association with *Salix*, similar habitat and responses, the genus *Salix* (willow) was used as an indicator where quantitative ratings are given (Munshower's ratings are for *Eleocharis palustris)* (USGS website, 2002).

Salinity Tolerance

Sensitive	(injury at > 2 dS/m EC_e) (arctic blue willow as indicator species)
Moderately Tolerant	(injury at 4- 6 dS/m EC_e) (golden willow as indicator species) (Wolf, 1999).
Good	(Munshower, 1995)

Flooding Tolerance

Tolerant (black willow (*Salix nigra*) used as an indicator species): able to survive deep, prolonged flooding for more than one year (Wolf, 1999). Very good (Munshower, 1998).

pH/alkalinity Tolerance
Spike rush is a calciphile (plants that prefer alkaline environments) (U.S. Department of Agriculture Website, 2002.); alka-tolerant (*Salix* sp. as indicator) (pH above 4.8/5.2 up to 7.5/9 or above) (Small, 1946).

4) Horsetail/ Field (*Equisetum arvense)*: Horsetail is also commonly found with members of the *Salix* family, often in marshes or other mesic sites. Because of similar habitat and responses to flooding/salinity, S*alix* was used as an indicator (Wild Rivers Commission Webpage, 2002).

Salinity Tolerance

Sensitive/ Moderately Tolerant	(injury at > 2 dS/m EC_e) (arctic blue willow as indicator species)/ (injury at 4- 6 dS/m EC_e) (golden willow as indicator) species) (Wolf, 1999).

Flooding Tolerance

Tolerant (black willow (*Salix nigra)* used as an indicator species) able to survive deep, prolonged flooding for more than one year (U.S. Department of Agriculture Website, 2002).

pH/ alkalinity tolerance
Mesophilous (pH 4.8 up to pH 7.0/7.2) (*Equisetum* sp.) (Small, 1946). Not likely to tolerate extremely alkaline conditions.

5) Wild licorice/American (*Glycyrrhiza lepidota)*: Wild licorice is often found associated with members of the wheat (*Agropyron)* family. Both are found in grasslands and open plains and do relatively well in mesic conditions (Wolf, 1999). Additionally, wild licorice is often found with green ash as part of the overstory, and ferns as part of the understory (National Park Service website, 2002).

Salinity Tolerance
Moderately tolerant to salinity – see Figure 1. (standard crested wheatgrass, *Agropyron sibiricum)* was used as an indicator) threshold EC_e – 3.5 dS/m % decrease in yield – 4 % for each 1 dS/m increase in EC_e above threshold (Maas, 1993).

Sodium (ESP) Tolerance
Most Tolerant (Agropyron sp. used as indicator) (ESP > 60 negatively impacts plant (stunted growth, usually due to adverse physical conditions of soil) (Shainberg and Oster, 1978).

Flooding Tolerance
Tolerant/ Green ash (*Fraxinus pennsylvania* as indicator) (able to survive deep flooding for one growing season, with significant mortality occurring if flooding is repeated the following year)
Very tolerant (able to survive deep, prolonged flooding for more than one year) (U.S. Department of Agriculture website, 2002). Good (Munshower, 1995).

pH/alkalinity Tolerance
Ferns in general: mesophilous (pH 4.8 up to 7.0/2) not likely to tolerate extreme alkaline conditions (Small, 1946).

6) **Goose berry, red shoot (*Ribes setosum*):** Gooseberry is either found in thickets or as individual plants, commonly on disturbed sites or along streambanks (Munshower, 1995).

Salinity Tolerance
Sensitive – see Figure 1 Ribes sp.: (Tanji, 1981).

Sodium Tolerance (ESP)
Extremely sensitive (ESP 2-10 will cause damage) (Shainberg and Oster, 1978). Very sensitive to sodium; may show its toxic affect when flood irrigation water has an SAR as low as 4.5 and/or spray irrigation water that wets the foliage has a sodium content > 70 mg/L or SAR >3.0 (DPI website, 2002).

pH/ Alkalinity Tolerance
Ribes sp.: alka-tolerant (above pH 4.8/ 5.2 up to 7.5/9 pH or above) (Small, 1946).

7) Mint/ Field (*Mentha arvensis*): Mint is commonly found in wetlands, floodplains or other relatively moist environments. For this reason, *Salix* sp. was used as an indicator (U.S. Department of Agriculture website, 2002).

Salinity Tolerance

Sensitive/	(injury at > 2 dS/m EC_e) (arctic blue willow as indicator species)
Moderately tolerant	(injury at 4-6 dS/m EC_e) (Golden willow as indicator species) (Wolf, 1999).

Flooding Tolerance

Tolerant	able to survive deep, prolonged flooding for more than one year (black willow (*Salix nigra*) as indicator species) (U.S. Department of Agriculture website, 2002).

pH/ Alkalinity Tolerance
alka-tolerant (above pH 4.8/ 5.2 up to 7.5/9) *Salix* sp. (Small, 1946).

8) Horsemint/W. Bergamot (*Monarda fistulosa*): Horsemint is often found in grasslands environments. Commonly associated species are aster, festuca, bromus and Elymus (Interactive Biodiversity Information System website, 2002).

Salinity Tolerance
Moderately sensitive tall Fescue (*Festuca elatior)* used as indicator species.

threshold EC_e	10% yield loss	25% yield loss	0% survival
3.9	5.8	9.0	46.0

(Shainberg and Oster, 1978).

pH/ alkalinity Tolerance
alka-tolerant (5.5/9 - 7.5/9 pH) (tall Fescue as indicator species) (Small, 1946).

9) Water Plant/ WaterCress (*Nasturium officinale*): Both *Carex* and *Salix* were used as indicator species, as all three species typically grow in moist environments such as riparian areas, floodplains, and wetlands (Centreconnect website, 2002).

Salinity Tolerance

Sensitive/	(injury at > 2 dS/m EC_e) (arctic blue willow as indicator species)
Moderately tolerant)	(injury at 4-6 dS/m EC_e) (Golden willow as indicator species) (Wolf, 1999).

Flooding Tolerance

Tolerant — able to survive deep, prolonged flooding for more than one year (black willow (*Salix nigra)* as indicator species) (U.S. Department of Agriculture website, 2002).

pH/ alkalinity Tolerance

mesophilous (pH 4.8 up to pH 7.0/2) *(Carex* sp. used as indicator) (Small, 1946).

10) Sweet Medicine (*Oxtropis lamnbertii)*: Sweet medicine is often found in association with *Festuca* sp., and therefore tall Fescue was used as an indicator species (U.S. Department of Agriculture website, 2002).

Salinity Tolerance

Moderately sensitive

Threshold EC_e	10% yield loss	25% yield loss	50% yield loss
3.9	5.8	8.6	13.3

(Shainberg and Oster, 1978)

pH/ alkalinity Tolerance

alka-tolerant (5.5/9 - 7.5/9 pH) (Small, 1946)

11) Choke Cherry (*Prunus virgiana)*: Choke cherry is found in coulees and other damp areas in association with cottonwoods, willows, maples, aspen, service berry and snowberry (Munshower, 1995).

Salinity Tolerance

Sensitive/ (see graph) (Tanji, 1981).
moderately sensitive (injury at 2- 4 dS/m EC_e) (Wolf, 1999).

Threshold value (EC_e in dS/m)	10% yield loss	25% yield loss	50% yield loss
.9	1.9	2.2	3.1

(Utah State University Extension website, 2002)

Sodium Tolerance (ESP)

extremely sensitive — (ESP of 2-10 will cause injury) very sensitive to sodium; may show its toxic affect when flood irrigation water has an SAR as low as 4.5 and/or spray irrigation water that wets the foliage has a sodium content >70 mg/L or SAR >3.0 (DPI website, 2002).

Flooding Tolerance

Intolerant — (black cherry (*prunus serotina)* was used as an indicator species): (4-10 inches of water for 10 days will cause defoliation or death) (U.S. Department of Agriculture website, 2002). Poor to prolonged flooding but performs well on briefly flooded sites (Munshower, 1995).

pH/ alkalinity Tolerance

Prunus sp.: alka-tolerant (above pH 4.8/5.2 up to or above 7.5/9) (Small, 1946)

12) Cottonwood (*Populus deltoides)*: Cottonwood is frequently a pioneer on wet, disturbed sites and is the most common Plains riparian tree species. Cottonwood is commonly found on alluvial terraces of streams/ rivers, around lakes and ponds, or in almost any moist subirrigated area (Munshower, 1995).

Salinity Tolerance
Moderately sensitive (2-4 dS/m EC_e will cause damage) (Wolf, 1999).
Fair (Munshower, 1995).

Flooding tolerance
Tolerant: able to survive deep flooding for one growing season, with significant mortality occurring if flooding is repeated the following year (U.S. Department of Agriculture website, 2002).

pH/Alkalinity Tolerance
alka-tolerant (above pH 4.8/5.2 up to 7.5/9 or above) (*Salix* sp. (willow) was used as an indicator species because of similar habitat and growth strategies) (U.S. Department of Agriculture website, 2002; Small, 1946). Very good (Munshower, 1995).

13) Box Elder (*Acer negundo*): Box elder is commonly found in coulee bottoms, along streams, or in riparian habitats (Munshower, 1995).

Salinity Tolerance
moderately tolerant: 4-6 dS/m EC_e will cause injury (Wolf, 1999)

Flooding Tolerance
Tolerant able to survive deep flooding for one growing season, with significant mortality occurring if flooding is repeated the following year (U.S. Department of Agriculture website, 2002).

pH/ Alkalinity Tolerance
mesophilous (pH 4.8 - 7.0.2)/ alka-tolerant (above pH 4.8/5.2 up to 7.5/9) (Small, 1946)

14) Green Ash (*Fraxinus pennsylvania)*
Salinity Tolerance
Moderately tolerant injury at 4– 6 dS/m EC_e (Wolf, 1999)

Flooding Tolerance
Tolerant/ (able to survive deep flooding for one growing season, with significant mortality occurring if flooding is repeated the following year)
Very tolerant (able to survive deep, prolonged flooding for more than one year) (U.S. Department of Agriculture website, 2002).

pH/ Alkalinity Tolerance
Alka-tolerant (6.5/9 – 7.5/9) – *Fraxinus* sp. (Small, 1946).

15) Sand bar Willow (*Salix exigua)*: Willow readily invades disturbed wet sites if adjacent area has parent stock. Commonly used for rehabilitation along waterways, willow is a common riparian and floodplain Plains species (Munshower, 1995).

Salinity Tolerance

Sensitive/ (injury at > 2 dS/m EC_e) (arctic blue willow as indicator species)
Moderately tolerant (injury at 4-6 dS/m EC) (Golden willow as indicator species) (Wolf, 1999). Usually moderate but some species reveal fair – good tolerance (Munshower, 1995).

Flooding Tolerance

Tolerant able to survive deep, prolonged flooding for more than one year (black willow (*Salix nigra)* as indicator species) (U.S. Department of Agriculture website, 2002). Very good (Munshower, 1995).

pH/ Alkalinity Tolerance

alka-tolerant (above pH 4.8/ 5.2 up to 7.5/9) *Salix* sp. (Small, 1946).

16) Snow berry (*Symphoricarpos occidentalis)*: Snowberry is commonly found in moist environments, often in association with *Salix* sp. (U.S. Department of Agriculture website, 2002). Often found in riparian areas and floodplians as well as run-in areas where water collects and in soils with above average water holding capacity (Munshower, 1995).

Salinity Tolerance

Sensitive (Munshower, 1995)
Moderate – fair (injury at > 2 dS/m EC_e) (arctic blue willow as indicator speciies)
Moderately tolerant (injury at 4-6 dS/m EC_e) (Golden willow as indicator species) (Wolf, 1999).

Sodium Tolerance (ESP)

Extremely sensitive (ESP 2-10 will cause injury) (Shainberg and Oster, 1978). very sensitive to sodium; may show its toxic affect when flood irrigation water has an SAR as low as 4.5 and/or spray irrigation water that wets the foliage has a sodium content > 70 mg/L or SAR >3.0 (DPI website, 2002).

Flooding Tolerance

Tolerant able to survive deep, prolonged flooding for more than one year (black willow (*Salix nigra* as indicator species) (U.S. Department of Agriculture website, 2002). Fair – good. Can tolerate imperfectly drained soils and some flooding but not prolonged flooding (Munshower, 1995).

pH/ Alkalinity Tolerance

alka-tolerant (above pH 4.8/ 5.2 up to 7.5/9) *Salix* sp. (Small, 1946)

17) Cattail (*Typha latifolia*): Cattail is typically found in moist areas such as riparian areas, floodplains, and surrounding lakes. Because of a shared habitat, *Salix* sp. was used as an indicator (U.S. Department of Agriculture website, 2002).

Salinity Tolerance

Sensitive/ (injury at > 2 dS/m EC_e) (arctic blue willow as indicator species)/
Moderately tolerant (injury at 4-6 dS/m EC_e) (Golden willow as indicator species) (Wolf, 1999).

Flooding Tolerance

Tolerant able to survive deep, prolonged flooding for more than one year (black willow (*Salix nigra)* as indicator species) (U.S. Department of Agriculture website, 2002).

pH/ Alkalinity Tolerance

alka-tolerant (above pH 4.8/ 5.2 up to 7.5/9) *Salix* sp. (Small, 1946).

18) Wild Plum (*Prunus americana*): Wild plum is found in association with willow, alder, aspen and dogwood in riparian habitats, wooded draws and thickets (Munshower, 1995).

Salinity Tolerance

Sensitive Threshold EC_e 10 % reduction 25% reduction 50% reduction maxEC_e
1.5 , 7% LR 2.1, 10% LR 2.9, 14% LR 4.3, 20% LR 7.0
(all values in dS/m; LR = leaching requirement) (Ayers and Westcot, 1976; Maas, 1993, Western Fertilizer Handbook, 1995).

Moderate – fair (Munshower, 1995).

Sodium Tolerance (ESP and sodium concentration)

ESP – extremely sensitive (2-10 ESP will cause injury) (Shainberg and Oster, 1978). Sodium concentration < 5 mol/m^3 may cause foliar injury (susceptibility based on direct accumulation of salts through leaves) (Shainberg and Oster, 1978). Very sensitive to sodium; may show its toxic affect when flood irrigation water has an SAR as low as 4.5 and/or spray irrigation water that wets the foliage has a sodium content >7.0 mg/L or SAR >3.0 (DPI website, 2002).

Flooding Tolerance

Fair, poor to prolonged flooding (Munshower, 1995).

19) Sweet grass (*Hierochloe odorata*): Sweet grass is commonly found in low, moist areas, often in association with *Agropyron* and *Carex,* both of which were used as indicator species (U.S. Department of Agriculture website, 2002).

Salinity Tolerance

Moderately sensitive (Standard crested wheat grass (*Agropyron trachycaulum)* used as indicator species)

threshold EC_e	slope %/dS/m	Rating
3.5	4.0	moderately tolerant (see graph)

(U.S. Department of Agriculture website, 2002).

pH/ alkalinity Tolerance
mesophilous *(Carex* sp. used as indicator) (pH 4.8 up to pH 7.0/2) (Small, 1946)

20) Quaking aspen (*Populus tremuloides)*: Quaking aspen is a shallow rooted species, with strong lateral roots forming in the top 18 inches of the soil profile. Stands indicate water within five feet. Quaking aspen is found in damp and wet sites, primarily in foothills and mountains (Munshower, 1995).

Salinity Tolerance
Poor (Munshower, 1995).

Flooding Tolerance
Very good to high water table and good to flooding (Munshower, 1995).

21) Saw beak sedge (*Carex stipata)*: Saw beak sedge is common in moist riparian, floodplain, and wetland areas, and is often found growing in association with Kentucky bluegrass (*Poa pratensis),* which was used as an indicator species. (Watershed.org website, 2002). *Salix* sp. was also used as an indicator.

Salinity Tolerance
Sensitive Low Tolerance (EC_e > 3 dS/m will cause damage (Kentucky bluegrass *(Poa pratensis)* used as indicator species (Utah State University Extension website, 2002). (Nebraska Fair Sedge (*Carex nebraskensis)* used as indicator) (Munshower, 1995).

Flooding Tolerance
Tolerant able to survive deep, prolonged flooding for more than one year (black willow (*Salix nigra)* as indicator species) (U.S. Department of Agriculture website, 2002). Very good to both flooding and high water table (Munshower, 1995).

pH/ alkalinity Tolerance
alka- tolerant (5.0/4 pH - 7.5/9) (Kentucky bluegrass *(Poa pratensis)* used as indicator species) (Small, 1946).

22) Leafy aster (*Aster foliactus)*: Leafy aster is commonly found in mesic meadows, often in association with *Carex* and *Salix* sp., both of which were used as an indicators (EPA website, 2002).

Salinity Tolerance
Low tolerance (EC_e > 2.0 dS/m will cause damage) (China aster used as indicator species) (Utah State University Extension Service website, 2002).

Flooding Tolerance

Tolerant — able to survive deep, prolonged flooding for more than one year (black willow (*Salix nigra* as indicator species) (U.S. Department of Agriculture website, 2002).

pH/ alkalinity Tolerance

mesophilous (pH 4.8 up to pH 7.0/2) (*Carex* sp. used as indicator) (Small, 1946).

23) Stinging nettle (*Urtica dioica)*: Stinging nettle is often found in oak- savanah environments, often in association with cottonwood, oak, and pine (U.S. Department of Agriculture website, 2002).

Salinity Tolerance

Moderately sensitive — (2-3 dS/m) when oaks (Bur, Gambel, Shingle used as indicators)(3-4 dS/m) when cottonwoods used as indicator (Utah State Extension webpage, 2002).

Flooding Tolerance

Intolerant — (Red oak as indicator) (4 to 10 inches of water for 10 days results in defoliation or death) U.S. Department of Agriculture website, 2002).

pH/Alkalinity Tolerance

mesophilous — (pH 4.8 up to PH 7.0/2) (both oaks and pines used as indicators) (Small, 1946).

24) Bulrush (*Scirpus nevadensis)*: Bulrush is often found in riparian areas, floodplains, and wetlands, often in association with *Carex* and *Salix* sp. (U.S. Department of Agriculture website, 2002). Bulrush is tolerant of brackish, saline, and alkaline sites and is always found in standing water, often around the periphery of lakes/ponds and on muddy shores (Munshower, 1995).

Salinity Tolerance

Moderately tolerant — (injury at 4-6 dS/m EC_e) (Golden willow as indicator species) (U.S. Department of Agriculture website, 2002).

Very good — (Munshower, 1995).

Flooding Tolerance

Tolerant — able to survive deep, prolonged flooding for more than one year (black willow (*Salix nigra)* as indicator species) (U.S. Department of Agriculture website, 2002).Very good (Munshower, 1995).

pH/ Alkalinity Tolerance

Mesophilous/ Alka-tolerant — (pH 4.8/5.2 up to 7.0/2), (*Scirpus trichophorus* as indicator) (6.5/9 – 7.5/9 pH), (*Scirpus silvatica* as indicator species) (Small, 1946).

25) Arrow leaf (*sagittaria latifolia)*: Arrow leaf is generally found in saturated riparian, floodplain, and wetland environments, often in association with *Salix* sp., which was used as an indicator (U.S. Department of Agriculture website, 2002).

Salinity Tolerance

Sensitive/ (injury at > 2 dS/m EC_e) (arctic blue willow as indicator species)
Moderately tolerant (injury at 4-6 dS/m EC_e) (Golden willow as indicator species) (Wolf, 1999).

Flooding Tolerance

Tolerant able to survive deep, prolonged flooding for more than one year (black willow *(Salix nigra)* as indicator species) (U.S. Department of Agriculture website, 2002).

pH/ Alkalinity Tolerance

alka-tolerant (above pH 4.8/ 5.2 up to 7.5/9) *Salix* sp. (Small, 1946).

26) Golden currant (*Ribes aureum)*: Golden currant is commonly found on disturbed soils and along streamsides and streambanks (Munshower, 1995).

Salinity Tolerance

Sensitive Probabably poor (Munshower, 1995)
Moderately tolerant (injury at 4 –6 dS/m) Black and European currant used as indicator species (Maas, 1993).
Ribes sp.: threshold EC_e = 1.5 dS/m, slope %/dS/m = 22.0 (Maas, 1993)

Sodium Tolerance (ESP)

Extremely sensitive (2 –10 ESP will cause damage) (Shainberg and Oster, 1978). Very sensitive to sodium; may show its toxic affect when flood irrigation water has an SAR as low as 4.5 and/or spray irrigation water that wets the foliage has a sodium content > 70 mg/L or SAR >3.0 (DPI website, 2002).

Flooding Tolerance

Poor – moderate (Munshower, 1995)

pH/Alkalinity Tolerance

Alka-tolerant (above pH 4.8/ 5.2 up to 7.5/9 or above) (Small, 1946). Slightly acidic – slightly basic (Munshower, 1995).

27) Skunkbush Sumac (*Rhus Trixobata)*: Skunkbush is usually found growing in coarse-textured soils from prairies to foothills (Munshower, 1995). Skunkbush sumac is often found in association with mountain ash, snowberry, and elderberry, often in relatively moist environments. Green ash was used as an indicator species (Wildlife Habitat Management Institute Webpage, 2002).

Salinity Tolerance

Moderately tolerant — Injury at 4– 6 dS/m EC_e (Wolf, 1999). Fair – good (Munshower, 1995).

Sodium Tolerance

extremely sensitive — (2-10 ESP will cause damage)/ very sensitive to sodium; may show its toxic affect when flood irrigation water has an SAR as low as 4.5 and/or spray irrigation water that wets the foliage has a sodium content > 70 mg/L or SAR >3.0 (DPI website, 2002).

Flooding Tolerance

Tolerant/ — (able to survive deep flooding for one growing season, with significant mortality occurring if flooding is repeated the following year)

Very tolerant — (able to survive deep, prolonged flooding for more than one year) U.S. Department of Agriculture website, 2002). Poor (Munshower, 1995).

pH/ Alkalinity Tolerance

Alka-tolerant (*Fraxinus* sp.) (6.5/9 – 7.5/9 pH) (Small, 1946)

28) Milkweed, showy (*Asclepias speciosa)*: Showy milkweed is often found in association with oak, which was used as an indicator species (U.S. Department of Agriculture website, 2002).

Salinity Tolerance

Moderately tolerant — (Oaks (Bur, Gambel, Shingle) used as indicators) (2-3 EC_e dS/m threshold) (Utah State University Extension webpage, 2002).

Flooding Tolerance

Intolerant — (Red oak (*Quercus rubra* used as indicator) (4 - 10 inches of water for 10 days results in defoliation or death) (U.S. Department of Agriculture website, 2002).

pH/alkalinity

mesophilous (*Quercus* sp. used as indicator) (pH 4.8 up to pH 7.0/2) (Small, 1946).

29) Western yarrow (*Achilliea millelolium)*: Western yarrow is found on disturbed/ overgrazed sites, as well as dry, sunny range sites from prairie to alpine environments (Munshower, 1995). Yarrow is commonly found in association with Rocky mountain maple (*Acer rubra),* hence *Acer* sp. was used as an indicator (U.S. Department of Agriculture website, 2002).

Salinity Tolerance

Moderately sensitive — Good (Munshower, 1995.); (3-4 dS/m threshold) (Maples (Norway, Hedge) used as indicators (Utah State University Extension webpage, 2002).

Flooding Tolerance

Intolerant (4 - 10 inches of water for 10 days results in defoliation or death) (Red oak (*Quercus rubra)* used as indicator*)* (U.S. Department of Agriculture website, 2002). Moderate – fair (Munshower, 1995).

pH/alkalinity

Mesophilous (pH 4.8 up to pH 7.0/2)/ alka-tolerant (pH 4.8/5.2 up to 7.5/9 or above) (*Acer* sp. used as indicator (Small, 1946).

30) Raspberry, red (*Rubes idaue)*

Salinity Tolerance

	0% reduction	10% reduction	25% reduction	50% reduction	max EC_e
Sensitive	1.0, 6% LR	1.4, 9% LR	2.1, 13% L	3.2, 19% LR	5.5

(Ayers and Westcot, 1976; Western Fertilizer Handbook, 1995).

Sodium Tolerance (ESP)

Extremely sensitive (2-10 ESP will cause damage) (Shainberg and Oster, 1978); Very sensitive to sodium; may show its toxic affect when flood irrigation water has an SAR as low as 4.5 and/or spray irrigation water that wets the foliage has a sodium content > 70 mg/L or SAR >3.0 (DPI website, 2002).

pH/alkalinity

alka-tolerant (above pH 4.8/5.2 up to 7.5/9 or above) Ribes sp. (Small, 1946).

31) Rose bush (*Rosa arkansa)* Rose bush is generally found on more mesic sites, but will persist in disturbed or open rangeland habitats (Munshower, 1995).

Salinity Tolerance

Moderate – fair (Rose, common used as indicator species) (Munshower, 1995).

Moderately sensitive (injury at 2 – 4 dS/m) (Wolf, 1999). Maximum permissible EC_e = 2 – 3 dS/m (Tanji, 1981; Chabbra, 1996).

Flooding Tolerance

Some varieties will tolerate high water tables (Munshower, 1995).

pH/Alkalinity Tolerance

Alka-tolerant (above pH 4.8/5.2 up to 7.5/9 or above) (Small, 1946).

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Northern Cheyenne Reservation
Wetlands Conservation Plan
Culturally Significant Wetland Plant Species

Figure 24.

PLANT SPECIES	SCIENTIFIC NAME	WETLANDS INDICATOR	PROFILE LAYER	CHEYENNE NAME	TRADITIONAL USE
June / Service Berry	*Amelanchier alnifolia*	FAC_, UPL	Shrub	HE TAN I MINS	Food and Medicinal
Red Osier Dogwood	*Cornus stolonifera*	FAC, FAC+	Shrub	MA'KOOMEEHESO	Ritual
Common Spike Rush	*Eleocharis palustris*	OBL	Herbaceous	HEXOVAO'ESTSE	Basket Making
HorseTail / Field	*Equisetum arvense*	FACU, FACW	Herbaceous	MO''EHNO''HAMEMOXESENE	Medicinal
Wild Licorice / American	*Glycyrrhiza lepidota*	UPL, FAC+	Herbaceous	MA'KOOMEEHESO	Food
Goose Berry, Red Shoot	*Ribes setosum*	FACW?	Herbaceous	HESKIVEHESTAAHRSEMEN''E	Food
Mint / Field	*Mentha arvensis*	FAC, FACW	Herbaceous	HE HE OTSE WATSE	Medicinal
Horsemint / West Bergamot	*Monarda fistulosa*	UPL, FAC+	Herbaceous	WI'US KI MOHK' SHIN	Ritual
Water Plant / Cress	*Nasturtium officinale*	OBL	Herbaceous	MA PE VOTZ	Food and Medicinal
Sweet Medicine	*Oxtropis (lamnbertii)*	UPL, FACU	Herbaceous	WI' KE ISSE E YO	Medicinal
Chokecherry	*Prunus virginiana*	FACU	Shrub	MINS	Food, Medicinal, and Ritual
Cottonwood, Great Plains	*Populus deltoides*	FAC, FACW	Canopy	XAMAEHOOHTSESTSE	Ritual
Box Elder, Ashleaf Maple	*Acer negundo*	FAC, FACW	Canopy	MESKEMAHMA	Ritual
Green Ash	*Fraxinus pennslyvania*	FAC, FACW	Canopy	MOTO'EO'O	Ritual
Quaking Aspen	*Populus tremuloides*	FAC, FACW	Canopy	WESS KIA'	Ritual
Sand Bar Willow	*Salix exigua*	FACW, OBL	Shrub	MAXE MENO'KO	Ritual and Medicinal
Snow Berry	*Symphoricarpos occidentalis*	FACU	Herbaceous	MEME NO OTSE	Whistle making
Cattails	*Typha latifolia*	OBL	Herbaceous	VETANO ESTSE	Food and Household
Wild Plum	*Prunus americana*	FACW	Shrub	MAXE MINS	Food
Sweet Grass	*Heirochloe odorata*	FACW	Herbaceous	VE HO OHTSE	Ritual
Saw Beak Sedge	*Carex stipata*	OBL	Herbaceous	HESH'KO'VOV'OTSE	Ritual
Leafy Aster	*Aster foliacius*	FACW	Herbaceous	STO'WAHTS IS SE E YO	Medicinal
Stinging Nettle	*Urtica dioica*	FACW	Herbaceous	HO TOM MOTSE	Medicinal
Bulrush	*Scirpus nevadensis*	OBL	Herbaceous	MO MUM STATS	Ritual and Food
Arrow Leaf	*Sagittaria latifolia*	OBL	Herbaceous	HE' TUN E HESSE" YO	Food
Golden Currant	*Ribes aureum*	FAC-, FACW	Shrub	HE WOV HW STA STI MINTSE	Food
Skunkbush Sumac	*Rhus Tribobata*	FAC?	Herbaceous	NO A HE YONTSE	Tobacco
Milkweed, Showy	*Asclepias speciosa*	FAC, FACW	Herbaceous	MA' BONAI' WOTSE	Food and Ritual
Western Yarrow	*Achilliea millefolium*	FACU	Herbaceous	HE' HAEHE SEEO' OTSE	Medicinal
Raspberry, Red	*Rubes idaues*	UPL, FAC	Herbaceous	WIS KE E MINS	Food
Rose Bush	*Rosa arkansana*	FAC?	Shrub	HIH' NIN	Medicinal

OBL = Obligate
FAC = Facultative
UPL = Upland