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Survey of Aquatic Plants in Corps of Engineers Reservoirs

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By
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Summary

A survey of aquatic plants in a selected Corps of Engineers reservoirs in Oregon was conducted. Cottage Grove, Dorena, Fern Ridge, Dexter and Willow Creek Reservoirs contained abundant aquatic plants. *Potamogeton pectinatus* and *Potamogeton epihydrous* were the most common native plant species. *Myriophyllum aquaticum* and *Potamogeton crispus* were the most widespread nonnative plants. Species richness in the reservoirs was correlated with trophic status and basin morphology. Shallow reservoirs that included extensive areas of nutrient-rich sediments that were historic flood plain soils supported the greatest biomass and number of species. Mesotrophic reservoirs had lower species diversity. Oligotrophic reservoirs with steep basin morphology, nutrient-poor sediments, and large water level fluctuation did not support aquatic vascular plant populations.

An aquatic plant management program should be developed for the reservoirs. The program should focus on preventing introduction and spread of invasive aquatic plants and on rapid response procedures for new infestations. Those reservoirs that currently support aquatic macrophyte communities may be most susceptible to invasion and rapid spread of new introductions, however, even reservoirs that are currently free of aquatic plants may be invaded.

Early detection is critical to effective implementation of rapid response procedures for invasive aquatic plant control. Annual survey of the most productive reservoirs is recommended to document introduction of new species. Plant community

composition changes during the growing season, and multiple surveys during the growing season are preferred over one-time visits.

Management of established populations of invasive species in the reservoirs will be difficult. Where invasive plant abundance is limited in area and number management activities may be implemented to slow dispersal and perhaps eradicate the plants. Integrated pest management procedures should be followed to ensure effective and economical aquatic plant control.

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Introduction

U. S. Army Corps of Engineers (USACE) reservoirs are an important resource. They provide fish and wildlife habitat, recreation, and flood control. Recreation and residential development around reservoirs contributes to local economies and enhances property values and the quality of life in Oregon.

Nonnative aquatic plants have invaded many lakes and reservoirs in Oregon and the Pacific Northwest. Forty-three percent of the lakes and reservoirs on the Oregon Department of Environmental Quality's (ODEQ) list of water quality limited waterbodies (totaling over 118,500 acres) are listed because of aquatic weeds (ODEQ 1996). Many additional waterbodies are impacted by aquatic weeds but not listed because of lack of adequate data (ODEQ 1996).

Native aquatic plants stabilize sediments, provide structure that is habitat for fish and invertebrates, and play a major role in the cycling of nutrients in lakes and reservoirs. When invasive aquatic plants are introduced to an aquatic system, without natural controls on their growth and distribution, the plants can proliferate to the extent that the function and health of the ecosystem is degraded. (Carpenter and Lodge 1986).

Reservoir operation can influence aquatic plant populations and communities. Emergent plant species, such as cattail (*Typha* spp.) can colonize shallow water or damp soils along the shoreline, but are unlikely to survive large fluctuations in lake level (Mitchell, 1973). Species with floating or emergent leaves, such as some pondweeds (*Potamogeton* spp.) and pond lilies (*Nymphaea* spp.), cannot establish at depths greater than about 10 meters and may also be adversely affected by large lake level fluctuations. Floating species, such as water fern (*Salvinia* spp.), are independent of sediment attachment and are largely unaffected by changes in lake level, but low temperatures may prevent overwintering and high biomass accumulation.

Some aquatic plants are adapted to seasonal water level fluctuation typical of many Corps of Engineers reservoirs. The rooted, submersed plant *Hydrilla verticillata,* for example, produces vegetative propagules in the sediment that enable survival in environments subject to seasonal drawdown. Presence of these resistant and long-lived propagules makes management of *H. verticillata* infestations quite difficult.

Aquatic plant invasions can occur rapidly. Dispersal of plant fragments by water movement can result in rapid expansion of pioneering populations. Early detection of pioneer populations of invasive aquatic plant species is necessary for effective control.

Aquatic plant populations in Oregon lakes and reservoirs have received little study. Falter and Naskali (1974) surveyed aquatic plants in the upper Columbia River system. Geiger and Rathburn surveyed aquatic plants in USACE reservoirs on the Columbia River in 1984. Aquatic plants in Fern Ridge Reservoir have been described (Sytsma 1997). Aquatic plants in Kirk Pond, near Fern Ridge Reservoir, were mapped in detail (Madsen 1994). Several lakes and reservoirs were surveyed in 1996, primarily for *H. verticillata* (Sytsma, unpublished data) The Lake Watch Program at Portland State University has encouraged volunteers to report problematic aquatic plants. There has never been a systematic and thorough survey of aquatic plants in Oregon.

The primary purposes of this study were to:

- survey aquatic plants in selected Corps of Engineer reservoirs in Oregon,
- identify invasive species present in the reservoirs, and
- identify reservoirs where beneficial uses are threatened by invasive aquatic plants.

A one-day plant identification course was also provided for Corps of Engineers personnel.

Methods

Submersed aquatic plant populations were surveyed in 16 Corps of Engineers reservoirs in Oregon between 2 July and 10 August 1999 (Table 1). Fourteen of the reservoirs were surveyed once. Four reservoirs were surveyed twice during the sampling period to observe any seasonal change in abundance and community composition. Dexter reservoir was visited a third time as part of a one-day plant identification course, although, a complete survey was not conducted.

At each reservoir a survey of 25 percent of the total shoreline mileage (no less than 5 miles) was conducted by cruising in a boat. Plants were identified using a bottom viewer constructed of 1.5-m length of 15.25-cm diameter PVC pipe fitted with a leak-proof, clear plexiglass bottom.

Table 1. Corps of Engineers reservoirs included in 1999 survey of aquatic plants.

Reservoir	Survey Date	Reservoir	Survey Date
Applegate	2 July	Dexter	21 July
Lost Creek	3		11 August
			8
Cottage Grove	6 July		
	9 Sept	Lookout Point	27
Foster	13	Fall Creek	28 July
Green Peter	14 July	Hills	28
	15		
		Blue River	3
Big	16	Cougar	3
Fern Ridge	10 August	Willow Creek	2
Detroit	8 Sept	Dorena	5 July
	20 July		9 Sept

Detailed sampling was conducted at sites selected from USACE maps of the reservoirs (Appendix B). Areas that were relatively shallow and protected from prevailing winds were considered most likely to support aquatic plants. Sites with aquatic plants that were observed while in transit between stations were also sampled.

The location of each sampling site was recorded using GPS (Garmin GPS 12). Plants were sampled at 1.0 m, 2.0 m and 3.0 m depths along a transect perpendicular to the shoreline. At each sampling location, the boat was anchored and plants were collected using a rake sampler deployed off the port and starboard bow, amidships, and stern of the boat. Aquatic plant cover was estimated with a 0.5 m x 0.5-m quadrats constructed of half-inch PVC pipe that was weighted down by wire cable inside the pipe. The quadrats were haphazardly deployed off the port and starboard amidships at each sampling depth. Cover was determined by viewing the quadrat with a bottom viewer. Two cover estimates were made at each sampling depth. The bottom viewer and rake sampler were also used to estimate the maximum depth of plant colonization on each transect.

Each sampling site at Cottage Grove, Fern Ridge, Dorena, and Dexter reservoirs was surveyed twice. Species present, bottom cover, and maximum depth of plant colonization were recorded using the same methods as in the first survey.

Collected plants were placed in a large cooler and then prepared for pressing of voucher specimens. Photographs of notable plant beds were taken where appropriate. Plant identification was based on Hitchcock and Cronquist (1973), Guard (1995), and Cooke (1997). Voucher specimens of all collected samples were prepared for deposit in Portland State University and Oregon State University herbariums.

Results and Discussion

Aquatic plant species were observed in a wide variety of habitats during the survey. They were most frequent in shallow, calm-water areas, such as historic floodplains that were submerged at maximum pool levels, reservoir side pools[1], boat ramp harbors and roadside canals.

Fontinalis antipyretica (water moss) was the most frequently encountered species. *F. antipyretica* occurred in 62.5 percent of the reservoirs and 25.8 percent of the transects surveyed (Table 2). Among the vascular plants, *Potamogeton pectinatus* (sago pondweed) and *Potamogeton epihydrus* (ribbon-leafed pondweed)were the most commonly found species. *P. epihydrus* occurred in 12.6 percent of the transects and 25 percent of the reservoirs sampled. *P. pectinatus* occurred in 12.4 percent of the transects and 18.8 percent of the reservoirs. *Myriophyllum aquaticum* (parrotfeather) and *Potamogeton crispus* (curly leaf pondweed) were the most widely distributed introduced species.

Several species were rare. *Myriophyllum hippuroides, Myriophyllum spicatum, Ranunculus aquatilis, Polygonum hydropiperoides, Ceratophyllum demersum, Elodea canadensis, Nymphaea odorata, Najas guadalupensis*, and *Utricularia vulgaris* occurred in only one reservoir or less than five percent of the transects sampled.

The aquatic plant community of several reservoirs was dominated by single species that was not common in other reservoirs. *N. guadalupensis*, a native species, occurred only in Willow Creek Reservoir where it was very widespread; it was found in 80 percent of the transects sampled. *E. canadensis*, native species common in lakes and streams in Oregon, was found only in Dexter Reservoir, where it occurred in 86 percent

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[1] Reservoir side pools are pools once belonging to the reservoir proper which have been separated by the construction of a road that no longer allows direct connection to the reservoir proper other than a high water culvert.

of the transects sampled. *M. spicatum,* a weedy species that typically dominates aquatic plant communities when it is present, occurred only in Fern Ridge and Dexter Reservoirs, but it was not the most widespread species in either reservoir. *M. spicatum* occurred in 44.4 percent of the transects sampled in Fern Ridge Reservoir and 11 percent of the transects in Dexter.

Three types of reservoirs could be identified based on species richness. Species richness in Cottage Grove, Dorena, Fern Ridge, Dexter, and Willow Creek Reservoirs was high (Figure 1). Foster, Green Peter, Big Cliff, Lookout Point, Fall Creek, Hills Creek, Blue River, and Cougar Reservoirs had low species richness. Applegate, Lost Creek, and Detroit had no plants.

Applegate, Lost Creek, Blue River, Cougar, Green Peter, Hills Creek, and Big Cliff Reservoirs

Eleven of the 16 reservoirs surveyed had no aquatic plants or were primarily colonized by nonvascular bryophytes and macroalgae. No aquatic plants were found in Applegate and Lost Creek Reservoirs. Blue River, Cougar, Green Peter, Hills Creek, and Big Cliff Reservoirs contained only *F. antipyretica*. *F. antipyretica* in these reservoirs was located primarily in areas with shallow water with a sandy bottom, often at the mouth of prominent inlets. *F. antipyretica* in Big Cliff Reservoir grew on a rocky substrate.

Detroit, Foster, Lookout Point, and Fall Creek Reservoirs

Foster, Lookout Point, and Fall Creek reservoirs contained *F. antipyretica* and *Chara* spp. All these reservoirs had one or two sites with 75 to 100 percent *F.*

antipyretica cover, and at least one site that was shallow with 75 percent *F. antipyretica* and 25 percent *Chara* spp. cover. Four sites in Detroit Reservoir had 50 to 75 percent cover by *F. antipyretica*. At two of the Detroit sites, small (1 m^2) beds with 50 to 75 percent cover by *R. aquatilis* (water buttercup) were found along the shoreline.

Table 2. Frequency of occurrence (percent) of aquatic plants in survey transects in Corps of Engineers reservoirs.

		Species																
Reservoir	Number of Transects	Fontinalis antipyretica	Polygonum amphibium	Myriophyllum hippuroides	Potamogeton pectinatus	Myriophyllum aquaticum	Potamogeton epihydrus	Potamogeton nodosus	Ranunculus aquatilis	Chara spp.	Polygonum piperoides	Myriophyllum spicatum	Potamogeton crispus	Ceratophyllum demursum	Elodea canadensis	Nymphaea odoratus	Najas guadalupensis	Utricularia vulgaris
Cottage Grove	5	100.0	20.0	40.0	40.0	40.0	80.0	80.0	40.0	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dorena	6	100.0	66.7	0.0	33.3	50.0	33.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fern Ridge	9	0.0	33.3	0.0	44.4	0.0	44.4	66.7	0.0	0.0	0.0	44.4	11.1	11.1	0.0	0.0	0.0	11.1
Dexter	7	0.0	0.0	28.6	0.0	14.3	44.4	0.0	0.0	22.2	11.1	11.1	71.4	42.9	85.7	14.3	0.0	0.0
Willow Creek	5	0.0	0.0	0.0	80.0	0.0	0.0	20.0	0.0	60.0	0.0	0.0	20.0	0.0	0.0	0.0	80.0	0.0
Applegate	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lost Creek	8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Foster	5	40.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Green Peter	12	25.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Big Cliff	5	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Detroit	8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lookout Point	9	33.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fall Creek	8	37.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hills Creek	6	16.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Blue River	5	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Couger	5	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mean Transect Frequency		25.8	7.5	4.3	12.4	6.5	12.6	10.4	2.5	8.4	0.7	3.5	6.4	3.4	5.4	0.9	5.0	0.7
Reservoir Frequency		62.5	18.8	12.5	18.8	18.8	25.0	18.8	6.3	31.3	6.3	12.5	18.8	12.5	6.3	6.3	6.3	6.3

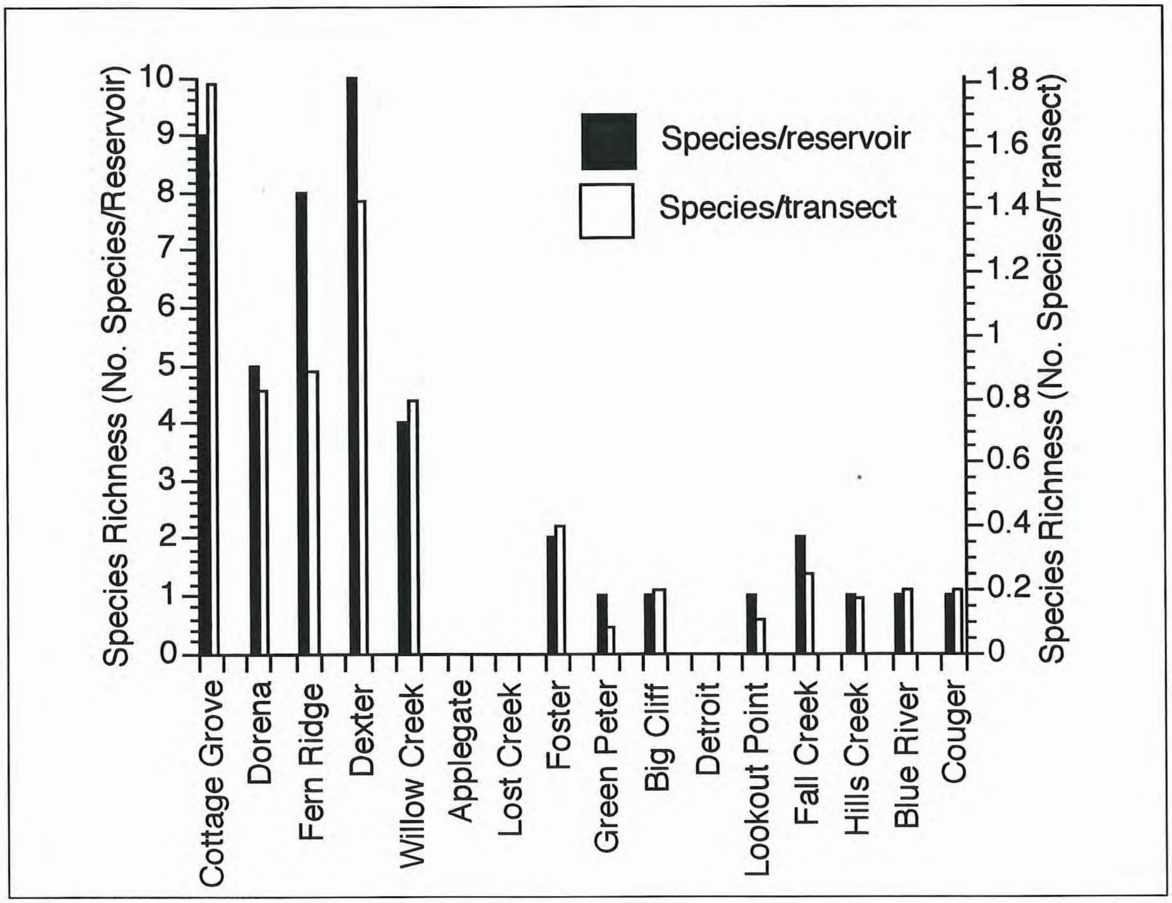


Figure 1. Species richness of aquatic plants in Corps of Engineers reservoirs.

The five other reservoirs surveyed contained more diverse and abundant vascular plant populations. Aquatic plant populations in these reservoirs are described below.

Cottage Grove Reservoir

Aquatic plants occurred on gravely to sandy soils in Cottage Grove Reservoir. Maximum depth of colonization was 6.8 m. Cottage Grove Reservoir was dominated by water moss and native *Potamogeton* and *Myriophyllum* species. *M. aquaticum* was the only invasive, nonnative species observed in the reservoir. Sampling sites one and two had 100 percent cover by *F. antipyretica* with dispersed beds consisting of eight to 10 individual plants of *M. hippuroides* (western watermilfoil), *P. nodosus* (american pondweed), *P. epihydrus* and *M. aquaticum.* These dispersed beds comprised approximately 50 percent of the total plant cover. Sites 3 and 5 showed no signs of either *Myriophyllum* species, but again there was 100 percent cover of *F. antipyretica* with dispersed beds of both *P. nodosus* and *P. epihydrus.* The dispersed beds comprised approximately 50 percent of the total plant cover. The main inlet at the south end of the reservoir flowed into a 25-m2 shallow pool (Site 4) that had 25 percent *F. antipyretica,* 10 percent *P. pectinatus* and 65 percent dense *Chara* spp. growth. Small shoreline beds (1 m^2 , 50 to 75 percent cover) of *R. aquatilis* dotted the shoreline surrounding site 4.

Two single plants of *P. amphibium* were located at site three and were removed for species identification. The second survey did not find any specimens of *P. amphibium* throughout the entire reservoir.

Cottage Grove reservoir contained a diverse population of plants that included some of the less common native plants such as *M. hippuroides* and *Chara* spp. The presence of the exotic invasive *M. aquaticum* is a concern. *M. aquaticum* distribution in the reservoir was limited; it has not yet displaced the native milfoil. *M. aquaticum* has the potential to cause a severe environmental and operational impact on the reservoir. Currently this plant is found only in the northwest shallows of the reservoir. Extensive recreational use may spread this nuisance plant throughout the reservoir.

Dorena Reservoir

Dorena reservoir contained dense beds of aquatic plants that were most notable at the southeast end. A profuse population of *P. amphibium* was the dominant plant.

Another prominent plant was *M. aquaticum*, which was found spreading around the edges of the *P. amphibium* beds.

Sites 1 and 2 had 75 to 100 percent cover by *F. antipyretica* with dispersed beds of *P. amphibium*, *P. epihydrus* and *M. aquaticum* rising to the water's surface. The dispersed beds comprised 25 percent of the total plant cover. Sites 3 and 4 had little or no growth of these species. Site 3 had 25 to 50 percent cover by a uniform mixture of *F. antipyretica* and *P. pectinatus.*

The most prominent inlet at the southeast end of the reservoir was densely covered with 10 – 20 m^2 monoculture beds of *P. amphibium, P. epihydrus* and *M. aquaticum.* These beds were located in water 6-8 m in depth with stems up to 9.5 m long. Water turbidity did not allow for bottom viewing and therefore no percentage cover of the basin floor was available. These areas of dense vegetation covered approximately 50 percent of the maximum pool area of the reservoir.

The excessive growth of aquatic plants in Dorena reservoir was indicative of unchecked invasion by invasive plants. Dorena is similar to Cottage Grove reservoir. Both reservoirs are similar in age, structure, and size. They are located within the same geographic area and experienced similar climatic influences. F. antipyretica, P. nodosus, P. epihydrus and M. aquaticum occurred in both reservoirs. A major difference between the two reservoirs was the absence of the native plants, *M. hippuroides* and *Chara* spp., and the well-established presence of a non-native plants, *M. aquaticum,* in Dorena.

Dorena has many aspects that support the current plant population and possibly promote a population increase. The shallow shorelines, warm water temperature and a moderate turbidity of this reservoir (in relation to the other reservoirs of this study) allowed these aquatic plants to colonize a large percentage of the reservoir. The basin of the reservoir is a broad flood plain, with nutrient-rich soils. Nutrient loading of the water column and soil from the yearly decomposition of acres of plant biomass as well as inputs from flooding and agricultural runoff provide ample nutrients for plant growth. The extensive recreational use aids in dispersal of plants throughout the reservoir.

P. amphibium is very productive in Dorena while only two plants were found in Cottage Grove. This could be due to the large amount of plant biomass contributing organic nutrients to the soil each year. The growth characteristics of *P. amphibium* have exploited the water regime of Dorena. *P. amphibium* is a hardy, thick-stemmed, amphibious plant. It can grow as an emergent on saturated shoreline muds and as a submersed plant in deeper water. The water level fluctuations do not change at rate more rapid than the plant's growth. As the water level rises, the plant extends its apical meristem to keep a sufficient portion of the plant's aerial architecture at the water's surface to meet photosynthetic needs for the entire plant. As the plant continues to grow, the biomass of aerial architecture increases proportional to the overall plant size, which is parallel to the increase in water level. This produces a plant that can grow in 0.0 m to 30.0 m of water, create a dense mat on the water's surface, and survive flooding and drawdown stress.

As mentioned above, Dorena supports a large plant biomass, which is indicative of high-nutrient, eutrophic conditions. The shallow, former flood plain has 100 percent vegetative cover all year. When the soils are exposed, a dense invasive monoculture of *Phalaris arundinacea* (reed canary grass) is present. As the water level rises the *P.*

arundinacea is submersed and the seed bank of *P. amphibium* begins to germinate amongst the senescing grasses. As the water level returns to minimum pool the *P. amphibium* begins to sprawl across the exposed flood plain, where it senesces and adds nutrients to the soil. Each year the recycling of nutrients and the influx of more nutrients brings Dorena closer to a eutrophic state, which makes this reservoir especially susceptible to more serious plant invasions.

Dorena is in a more advanced state of plant colonization than Cottage Grove. Both reservoirs are similar in many ways but have different aquatic plant communities. The reservoirs are similar in age, basin morphology, and size. The are located within the same geographic and climatic zone. Dorena could conceivable have been more similar to Cottage Grove in its aquatic plant species richness and production.

One hypothesis concerning Dorena and Cottage Grove reservoirs is that plant communities in Dorena experience more disturbance and environmental stress. Dorena has a larger number of boat launches and shoreside parks which allow for more recreational usage. Dorena lacks the more protective surrounding mountains of Cottage Grove (which was noticeable when afternoon winds caused a 2-4 ft chop on the northwest end of Dorena). It is also conceivable that the plant species in Dorena have undergone competitive stresses for a longer period of time than Cottage Grove. Over time species become displaced by the more dominant species present. Native *M. hippuroides* may have been present for a time in Dorena, but displaced by *M. aquaticum*. Native *Chara* spp. may have been present in Dorena, but then displaced by the native weedy *P. pectinatus*. It is not currently apparent, but the overwhelming population of *P. amphibium* could be in the process of displacing the native *P. nodosus* and *P. epihydrus*.

As mentioned before, a more thorough survey is needed to better understand these reservoirs. Including a inspection of the nutrient content of the littoral zone of both reservoirs could show possible differences in available nutrients which could determine the species present. The physiological response of species is often defined in terms of increasing performance as the resource level increases. Plants with all other environmental factors at suitable levels will, under conditions of resource sufficiency, form a closed canopy. Light will be the limiting factor under high levels of resource. The tradeoff between resource and light is well documented by Tilman (1988), but there are frequently conditions in nature where resources become toxic. Grime gives a second approach. Grime's theory predicts that the species with the greatest capacity for resource capture will be the superior competitor, while Tilman defines it as a net negative relationship between the abundance of competing species that involves both resource capture and tolerance to low resource levels. The primary differences between the two theory lies in the role of various forces that lead to dominance.

An alternative conclusion regarding the difference in plant communities present in these two reservoirs could be due to the absence of introduction. The native species found in Cottage Grove may not have had an opportunity to be introduced into Dorena. These conclusions can not be proven accurate due to the lack of historical aquatic plant presence data.

Fern Ridge Reservoir

Fern Ridge reservoir had a diverse and well-established aquatic plant community. The most prevalent plant species were *P. epihydrus*, and *P. nodosus*, which covered most of the southeast area of the reservoir.

Sites 1 and 2 had no rooted vegetation but did have floating plant debris of all species found in the reservoir. The portion of the reservoir which is covered at maximum pool level had approximately 75 percent cover by 5-10 m^2 monoculture beds of *P. epihydrus, P. nodosus* and *M. spicatum* (eurasian watermilfoil). Navigation was extremely difficult due to the high turbidity and extensive vegetative cover (mostly bulrush hummocks) of the reservoir. The carnivorous native aquatic plant *U. vulgaris* (bladderwort) was present in a relatively large bed in one site only (Site 7). *P. crispus* was present (four 1-m long plants) only at site 8. The second visit to the reservoir did not find any *P. crispus* at any of the sampling sites.

Shallow plains within the reservoir, with an average depth of 1.0 m, had 75 to 100 percent cover of a uniform mixture of *F. antipyretica*, *P. pectinatus* and *Chara* spp. with intermittent small *M. spicatum* beds (1.0 m in length, 4-5 plants per bed). These areas were located on the shoreline of the southwest finger of the reservoir. The canals of the Long Tom River and Coyote Creek inlets had 100 percent cover by *C. demersum* (coontail) and *M. spicatum*. *P. amphibium* was restricted to the shoreline and has not spread to the open water of the reservoir.

Light may limit production of aquatic plants in Fern Ridge. The shallow, nutrient-rich sediment in the reservoir provides an opportune habitat for aquatic plants but the high turbidity may deter plant production. Though the high turbidity is a sign of poor water quality and is not particularly aesthetically pleasing, it is an effective control for an aquatic plants.

Even with the limiting high turbidity the reservoir displayed a high species richness in relation to other reservoirs of this survey. The entire east shore of the reservoir was not navigable by boat due to the complete cover by *P. nodosus* and *P. epihydrus*. Plants were most abundant in protected harbors and boat docks and roadside canals. Most notable was the presence of the exotic and highly invasive *M. spicatum* which was most prevalent on the west shore.

The sparseness of previously noted, mature and well-established plant beds (personal conversation, Sytsma) could be related to the late and unseasonably cool summer of 1999 (National Climatic Data Center, 1999).

Dexter Reservoir

Dexter reservoir had one very dense and continuos shoreline aquatic plant bed along the west end of the reservoir that consisted of a mixed population of *E. canadensis*, *M. hippuroides*, *C. demersum*, *Chara* spp., *P. epihydrus* and *P. crispus*. The detached side pools of the reservoir also had dense, well-established beds of *E. canadensis, C. demersum*, and *M. aquaticum.*

No plants were found at site 1 during the initial survey, but six weeks later the site had 85 percent cover. The site contained approximately 25 percent *E. canadensis*, 10 percent *M. hippuroides*, 20 percent *C. demersum*, 20 percent *Chara* spp., five percent *P. epihydrus* and 20 percent *P. crispus.*

Site 2 had a well-established and diverse plant bed when first surveyed and maintained this diversity during the second survey. The distribution of species was similar to that described for the second survey of site 1 Site 3 resembled site 4, which was a large flood plain with an average depth of 1.5 m containing mostly of *P. crispus.* . Site 5 contained a planted *N. odorata* (white water lily) bed, which appeared to be contained and maintained by the waterfront landowners adjacent to the plant bed.

The southeast end of the reservoir directly below Lookout Point Dam did not have any major plant beds, but the reservoir basin west of river mile 19 had more than 50 percent cover by rooted aquatic plants such as, *E. canadensis*, *M. hippuroides*, *C. demersum*, *P. epihydrus* and *P. crispus*..

The second survey revealed an obvious increase in plant biomass in the reservoir. Species not previously documented were located in the detached side pools of the reservoir proper. Side pool 2 had dense *E. canadensis* beds, which were lined with dense *M. aquaticum* beds. Side pool 1 contained 50 percent *M. spicatum* and 50 percent *C. demersum* that were lined along the shoreline with *P. hydropiperoides* (waterpepper) which was not documented at any other reservoirs within this preliminary survey.

The effect of *E. canadensis* in Dexter Reservoir on the fishery downstream from the reservoir has been twenty-year concern (Lane County Sherriff, Marine Patrol Officer, personal conversation). *E. canadensis* is native but can be quite productive. The shoreline of Dexter is covered with an aquatic plant bed filled with a diverse species mix not seen in any of the other reservoirs in this survey. The plants within the reservoir proper were all native species except for *P. crispus*. The nonnative *P. crispus* may displace the native plants, *E. canadensis, M. hippuroides, C. demersum, Chara* spp. and *P. epihydrus*. Shallow areas on the northwest shore were dominated by a *P. crispus*. All of the boat launches had small, pioneering populations of *P. crispus* within the mixed native plant community, which suggests that cover of *P. crispus* cover in the reservoir may expand with the concomitant loss of native species diversity.

The side pools of Dexter illustrated the rapid progression of plant invasion. Exotic and invasive *M. aquaticum* and *M. spicatum* were found in dense monocultures in the side pools. The introduction of these invasive plants is only a precursor to the possibilities of the invasion of the reservoir proper. *M. spicatum* and *M. aquaticum* are common and abundant in nearby Fern Ridge Reservoir. These plants could easily be transported to Dexter by uneducated boaters.

Willow Creek Reservoir

Willow Creek reservoir has an entirely different climate than the 15 other reservoirs in this survey, and had a distinctive plant community. Willow Creek reservoir contained a continuous bed of *N. guadalupensis* (southern naiad) and *Chara* spp. on the south shoreline. Small beds of *P. crispus* dotted the southern shoreline as well. *P crispus* grew in deeper water on the southern side off the reservoir also. The morphology of the reservoir basin did not allow for any plant growth on the north shore; the extreme slope (greater than 45°) did not allow formation of a littoral zone.

Sites 1, 2 and 4 closely resembled each other both physically and vegetatively. There was 50 to 100 percent plant cover to a depth of 3.5 m. *N. guadalupensis* comprised 50 percent of the plant cover at 1.0-m depth and 25 to 50 percent of the plant cover at 2.0 m and 3.0 m. *Chara* spp. comprised 25 percent of the plant cover a 1.0m only. *P. pectinatus* comprised 25 percent of the plant cover at 1.0 m, 2.0 m and 3.0 m depths. *P. crispus* beds covered 50 percent of the basin at 2.0 m and 3.0 m depths. These beds were in dense 1 –2 m^2 patches with approximately 10 m between beds all along the south shore of the reservoir. Soils were sandy and the slope was gradual.

A mixed population of *N. guadalupensis* and *P. pectinatus* provided 10 percent cover on the steep-sloped, north side of the reservoir (site 3). The West end of the reservoir (site 4) contained a 5-m^2 bed of *P. epihydrus* that extended from1.0 m to 3.5 m. It was apparent that all of the plant beds were beginning to senesce and were probably larger earlier in the season.

The presence of *P. crispus* in the reservoir is a concern. If the isolated and patchy *P. crispus* stands on the southern shore expand, the native *N. guadalupensis* could be displaced.

Conclusions and Recommendations

Although there are some plants of concern, the overall condition of the aquatic plant communities in the reservoirs surveyed was good. *M. spicatum, M. aquaticum,* and *P. crispus* were the most common invasive species found. No *Salvinia molesta, Egeria densa* or *Hydrilla* was found.

M. spicatum was found in only one reservoir (Fern Ridge) and one side pool (Dexter). *P. crispus* was found in Fern Ridge, Dexter, and Willow Creek reservoirs. The native species *P. amphibium* and *E. canadensis* formed abundant populations that could be considered a nuisance. *P. amphibium* was quite abundant in Dorena, but could also pose a problem in Cottage Grove or Fern Ridge where the plant is currently restricted to the shoreline. According to a Lane County Sheriff, Marine Patrol Officer's personal account, *E. canadensis* interferes with fisheries downstream of Dexter Reservoir.

Basin and sediment characteristics appeared to determine aquatic plant abundance in the reservoirs surveyed. Deep reservoirs with steep banks (Applegate, Lost Creek, Blue River, Cougar, Green Peter, Hills Creek and Big Cliff) did not support aquatic macrophytes. The eutrophic reservoirs surveyed (Cottage Grove, Dorena, Fern Ridge, Dexter and Willow Creek) that had shallow littoral zones with nutrient-rich sediments supported abundant macrophytes. The eutrophic reservoirs are most at risk for invasion by more problem-causing invasive plants. They also serve as source populations for dispersal of invasive species to other waterbodies, such as the mesotrophic reservoirs (Detroit, Foster, Lookout Point and Fall Creek). Environmental conditions in these reservoirs would support aquatic weeds if they were introduced (Mitchell and Thomas, 1972). The mesotrophic reservoirs should also be considered at risk to invasion, however, the lower nutrient availability may limit productivity and slow the spread of invasive plants within the reservoirs.

Prevention of the spread of invasive aquatic plants is critical to maintaining the reservoirs. The reservoirs are hydrologically connected with the waters of the State, and prevention efforts for the Corps of Engineers reservoirs can only be effective if they are part of a statewide program. The Corps should support development of a statewide management program for aquatic nuisance species to protect the reservoirs, and should cooperate with ongoing management efforts in the State. Such a statewide program would be the efficacious way to prevent introduction of extremely invasive species that are not yet present in Oregon.

Prevention activities can be implemented at Corps facilities that are independent of the statewide effort. The Corps has deployed zebra mussel placards at boat ramps throughout the state. A similar effort should be made to educate boaters about the risk and remedies to transporting invasive aquatic plants between waterbodies. Boat washing stations could be established at boat ramps to allow boaters to remove plant fragments prior to leaving the reservoir.

Aquatic plant populations change seasonally, and year-to-year changes in abundance can occur as a result of climate variation. Annual surveys would facilitate understanding of the factors that control plant abundance in the reservoirs and permit early detection of infestations of invasive species. Surveys could be most economically conducted by focusing on those reservoirs that currently support aquatic plant populations, particularly around boat ramps, where introduced species are most likely to occur.

Management of existing invasive species populations is difficult. Where an invasive plant population is limited in coverage and abundance a variety of methods may be used to limit further spread, and perhaps eradicate the population. Handpulling may be used if plants are limited in number and restricted to a small area. Bottom barriers may be deployed when relatively dense stands are present in a small area. Spot herbicide treatments may also be appropriate to control small populations of invasive species.

As with all pest management programs, and integrated approach is recommended. All management options should be evaluated as part of an integrated pest management plan. Aquatic plant management plans should be developed for all Corps reservoirs. Plan development should initially focus on those reservoirs that support abundant plant populations, however, even those reservoirs that do not currently support aquatic plants are vulnerable to invasion and need prevention plans.

References

Bennett, F.D., Investigation on insects as controlling agents for *Salvinia auriculata* Aublet and *Eichhornia crassipes* (Mart.) Solms, two aquatic weeds of Neotrophical origin, report, Commonwealth Inst. Of Biol. Contr., Curepe, Trinidad, 1968.

Carpenter, S.R., and D.M. Lodge. 1986. Effects of submersed macrophytes on Ecosystem processes. Aquatic Botany 26: 341-370.

Cooke, S.S. *A Field Guide to Common Wetland Plants of Western Washington and Northwestern Oregon.* Seattle Audubon Society, Seattle, WA, 1997.

Falter, C.M. and R. Naskali. 1974. Aquatic Macrophytes of the Columbia and Snake River Drainages (United States). USACE, Walla Walla District. DACW68-72-C-0269.

Guard, B. J., *Wetland Plants of Oregon and Washington.* Lone Pine Publishing, Renton, WA, 1985.

Geiger, N.S. and R.L. Rathburn. *1984 Portland District Aquatic Plant Surveys*, 1984.

Hitchcock, C. Lea and Arthur Cronquist. *Flora of the Pacific Northwest: An illustrated manual.* U. of Washington Press, Seattle, 1973.

Little, E.C.S., The invasion of man-made lakes by plants, in *Man-Made Lakes*, edited by R.H. Lowe-McConnell, pp. 75-86, Academic, London, 1966.

Madsen, J. D., Dick, G. O., and Honnell, D. 1994. Ecological assessment of Kirk Pond. Miscellaneous Paper A-94-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. NTIS No. AD A279 090.

Mitchell, D.S., and P.A. Thomas, Ecological survey of the aquatic weeds *Salvinia* spp. and *Eichhornia crassipes* and their natural enemies in the neotropics, *Tech. Pap, Hydrol. 12,* U. N. Educ., Sci. and Cult. Organ., Paris, 1972.

Mitchell, D.S., Aquatic Weeds in Man-Made Lakes. *Man-Made Lakes: Their Problems and Environmental Effects.* Am. Geophysical Union, Washington, D.C., 1973.

ODEQ 1996. Water Quality Limited Waterbodies in Oregon (303-d listing). Oregon Department of Environmental Quality, 811 SW 6th Ave. Portland OR 97204.

Sculthorpe, C.D., *The Biology of Aquatic Vascular Plants*, Edward Arnold, London, 1967.

Sytsma, M.D., *Fern Ridge Lake Volunteer Water Quality Monitoring Report,* 1997.

Sytsma, M.D., Hydrilla, unpublished work.

Tilman, D. *Plant strategies and the Structure and Dynamics of Plant communities.* Princeton Univ. Press, Princeton, New Jersey, 1988.

Westlake, D.F., Some basic data for investigations of the productivity of aquatic macrophytes, in *Primary Productivity in Aquatic Environments, Mem, Ist. Ital. Idrobiol.,* suppl. 18, edited by C.R. Goldman, pp. 229-248, University of California Press, Berkley, 1966.

Appendix A: List of Plant Species

Applegate Reservoir

No aquatic plants present

Lost Creek Reservoir

No aquatic plants present

Cottage Grove Reservoir

Water moss
Fontinalis antipyretica
Water smartweed
Polygonum amphibium
Western watermilfoil
Myriophyllum hippuroides
Sago pondweed
Potamogeton pectinatus
Parrot feather
Myriophyllum aquaticum
Ribbonleaf pondweed
Potamogeton epihydrus
American pondweed
Potamogeton nodosus
Aquatic buttercup
Ranunculus aquatilis
Chara
Chara spp.

Foster Reservoir

Water moss
Fontinalis antipyretica
Chara
Chara spp.

Green Peter Reservoir

Water moss
Fontinalis antipyretica

Big Cliff Reservoir

Water moss
Fontinalis antipyretica

Detroit Reservoir

Water moss
Fontinalis antipyretica
Aquatic buttercup
Ranunculus aquatilis

Dexter Reservoir

Water moss
Fontinalis antipyretica
Waterpepper (side pool 1)
Polygonum hydropiperoides
Sago pondweed
Potamogeton pectinatus
Parrot feather (side pool 2)
Myriophyllum aquaticum
Eurasian watermilfoil (side pool 1)
Myriophyllum spicatum
Ribbonleaf pondweed
Potamogeton epihydrus
Curlyleaf pondweed
Potamogeton crispus
Coontail
Ceratophyllum demersum
American elodea
Elodea canadensis
Native watermilfoil
Myriophyllum spp.
Chara
Chara spp.
White water lily
Nymphaea odoratus

Lookout Point Reservoir

Water moss
Fontinalis antipyretica
Chara
Chara spp.

Fall Creek Reservoir

Water moss
Fontinalis antipyretica
Chara
Chara spp.

Hills Creek Reservoir

Water moss
Fontinalis antipyretica
Chara
Chara spp.

Blue River Reservoir

Water moss
Fontinalis antipyretica

Cougar Reservoir

Water moss
Fontinalis antipyretica

Dorena Reservoir

Water moss
Fontinalis antipyretica
Water smartweed
Polygonum amphibium
Sago pondweed
Potamogeton pectinatus
Parrot feather
Myriophyllum aquaticum
Ribbonleaf pondweed
Potamogeton epihydrus
Chara
Chara spp.

Fern Ridge Reservoir

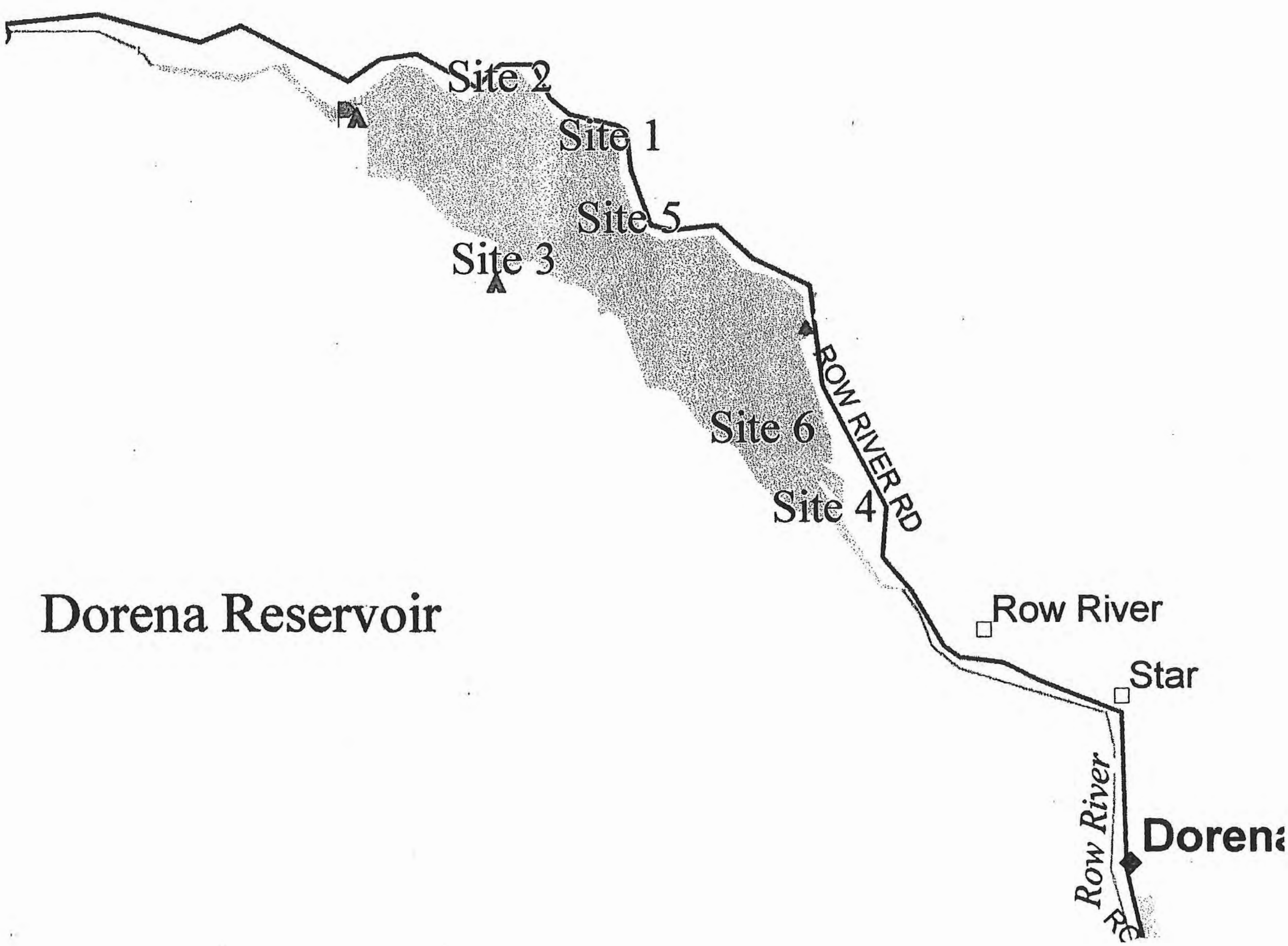
Water moss
Fontinalis antipyretica
Water smartweed
Polygonum amphibium
Sago pondweed
Potamogeton pectinatus
Ribbonleaf pondweed
Potamogeton epihydrus
American pondweed
Potamogeton nodosus
Chara
Chara spp.
Coontail
Ceratophyllum demersum
Eurasian watermilfoil
Myriophyllum spicatum
Bladderwort
Utricularia vulgaris
Curlyleaf pondweed
Potamogeton crispus

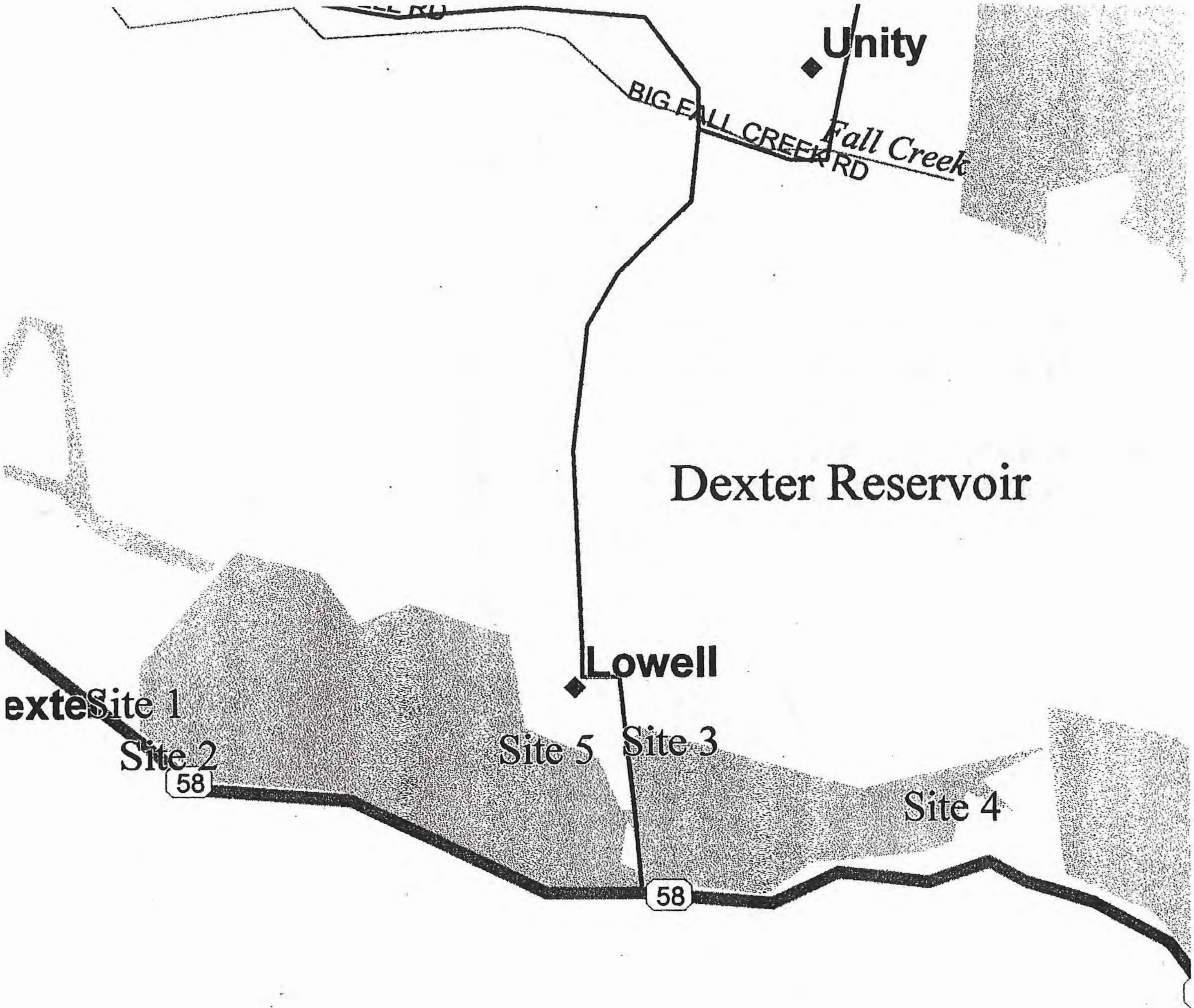
Willow Creek Reservoir

Southern naiad
Najas guadalupensis
Sago pondweed
Potamogeton pectinatus
Ribbonleaf pondweed
Potamogeton epihydrus
Chara
Chara spp.

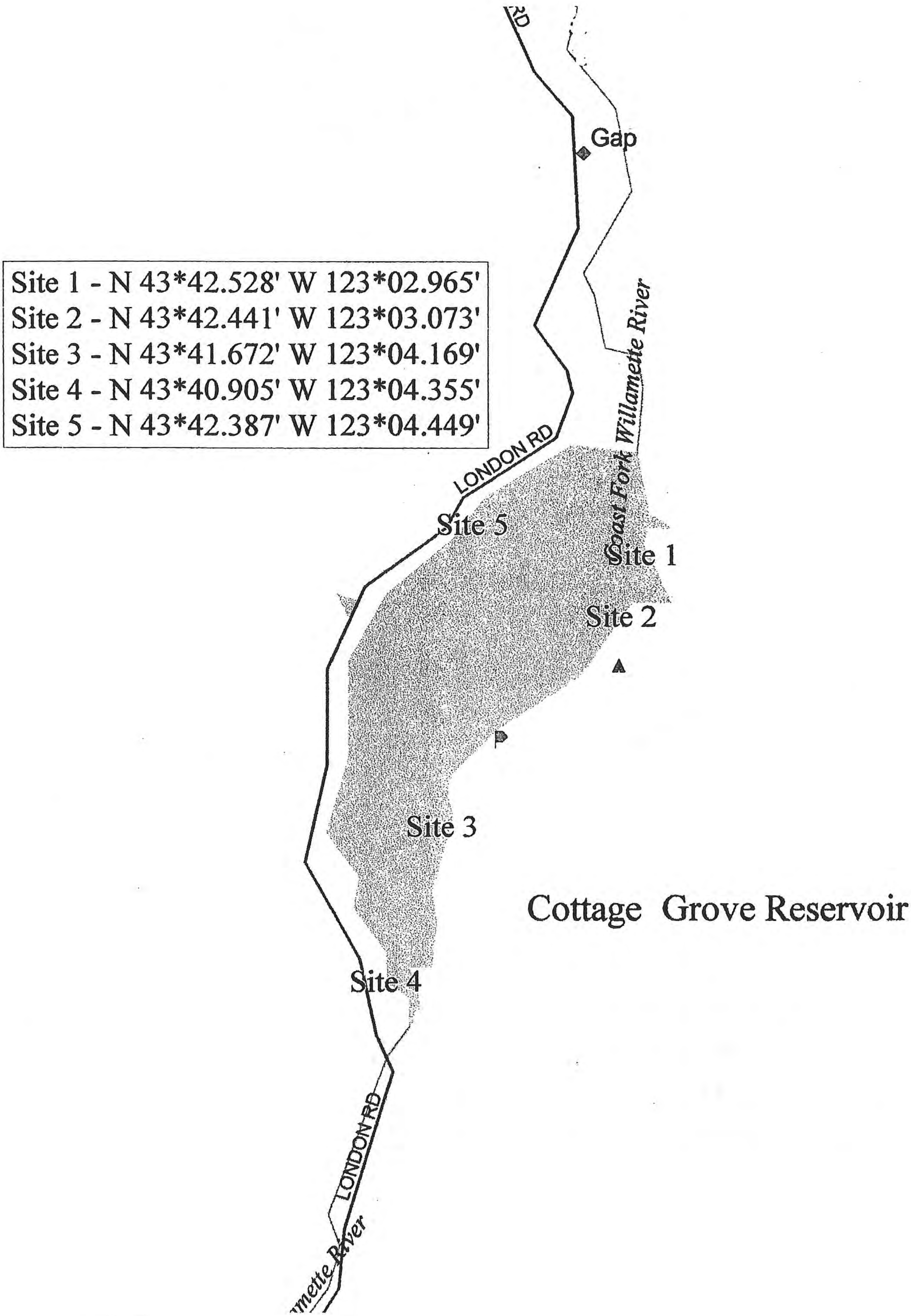
Appendix B: Sampling Site Maps

Site 1 - N 43*47.089' W 122*55.607'
Site 2 - N 43*47.430' W 122*56.265'
Site 3 - N 43*46.387' W 122*56.230'
Site 4 - N 43*45.000' W 122*53.893'
Site 5 - N 43*46.735' W 122*55.529'
Site 6 - N 43*45.506' W 122*53.897'

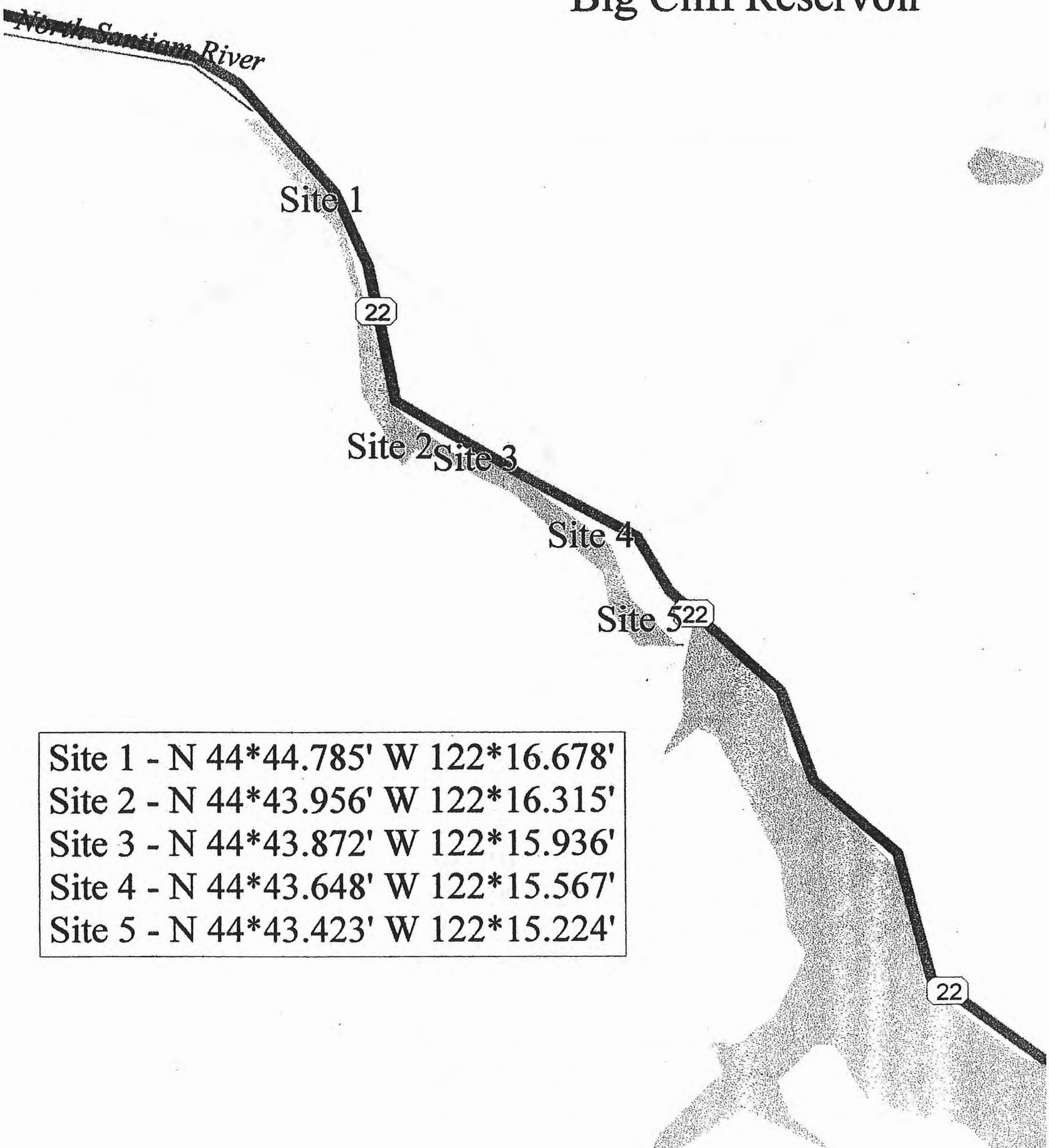




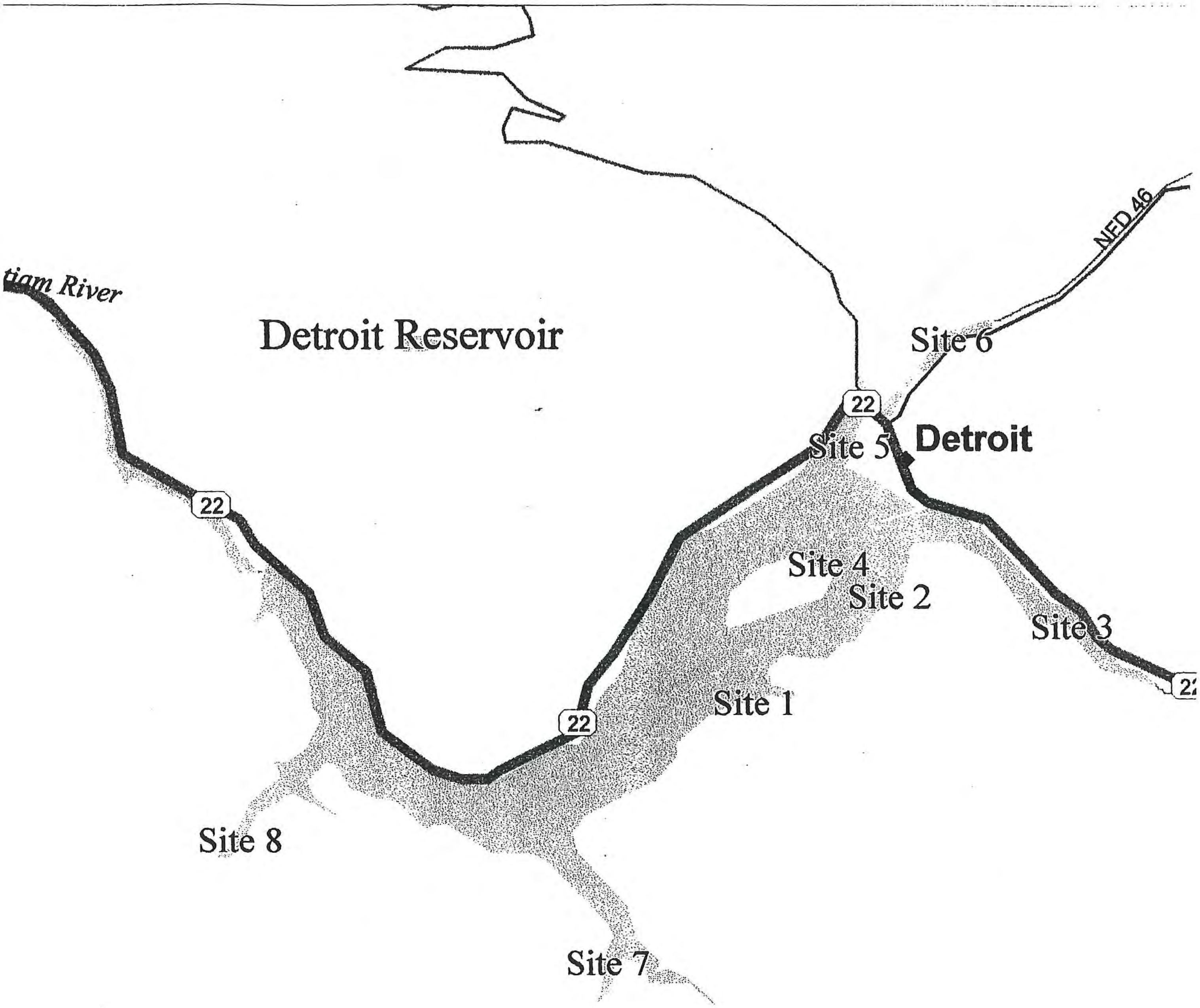
Site 1 - N 43*55.006' W 122*48.672'	
Site 2 - N 43*54.953' W 122*48.661'	
Site 3 - N 43*54.919' W 122*46.588'	
Site 4 - N 43*54.739' W 122*45.531'	
Site 5 - N 43*54.861' W 122*46.925'	


Site 1 - N 43*42.528' W 123*02.965'
Site 2 - N 43*42.441' W 123*03.073'
Site 3 - N 43*41.672' W 123*04.169'
Site 4 - N 43*40.905' W 123*04.355'
Site 5 - N 43*42.387' W 123*04.449'
Gap
LONDON RD
Coast Fork Willamette River
Site 5
Site 1
Site 2
Site 3
Site 4
Cottage Grove Reservoir
LONDON RD

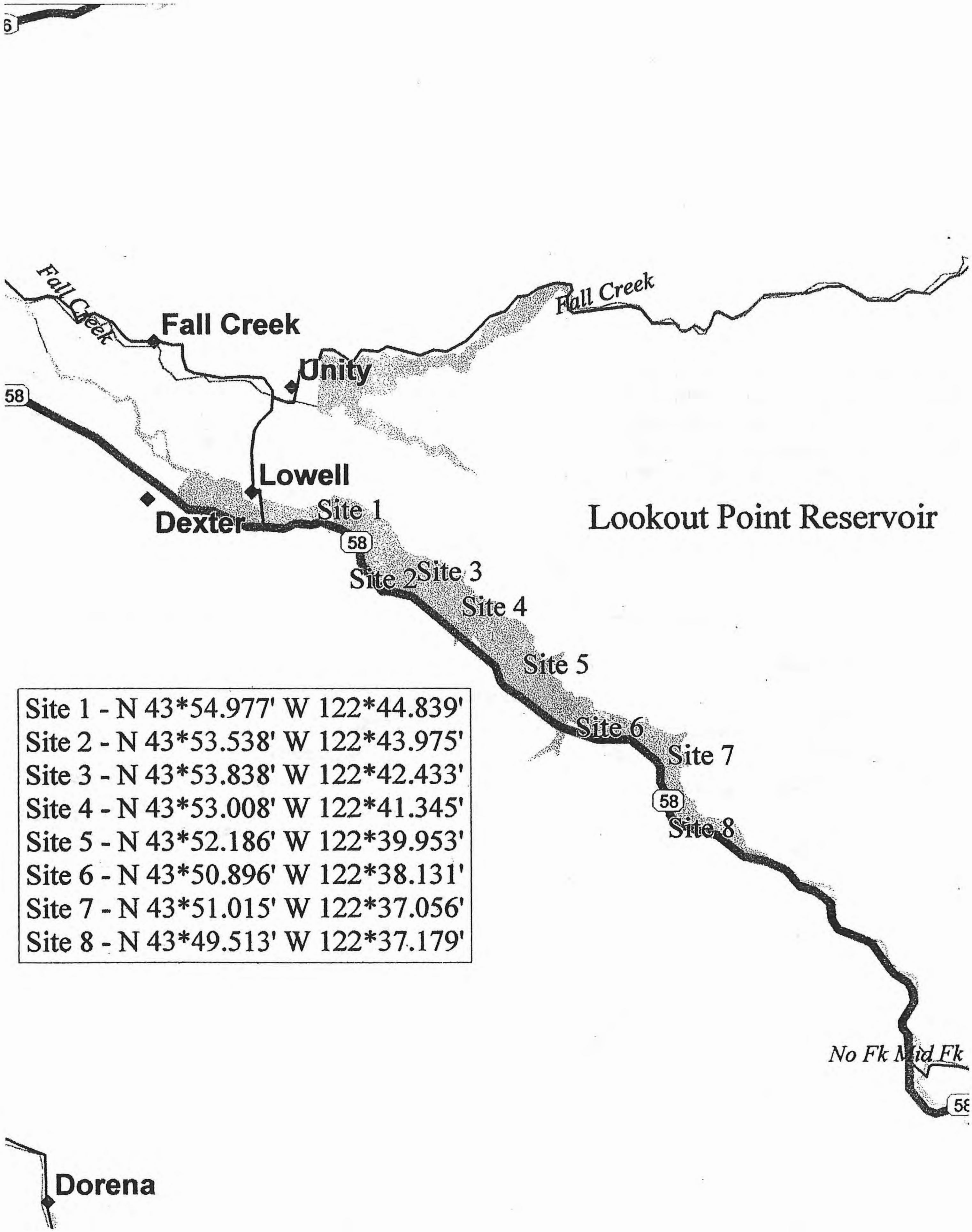
Big Cliff Reservoir

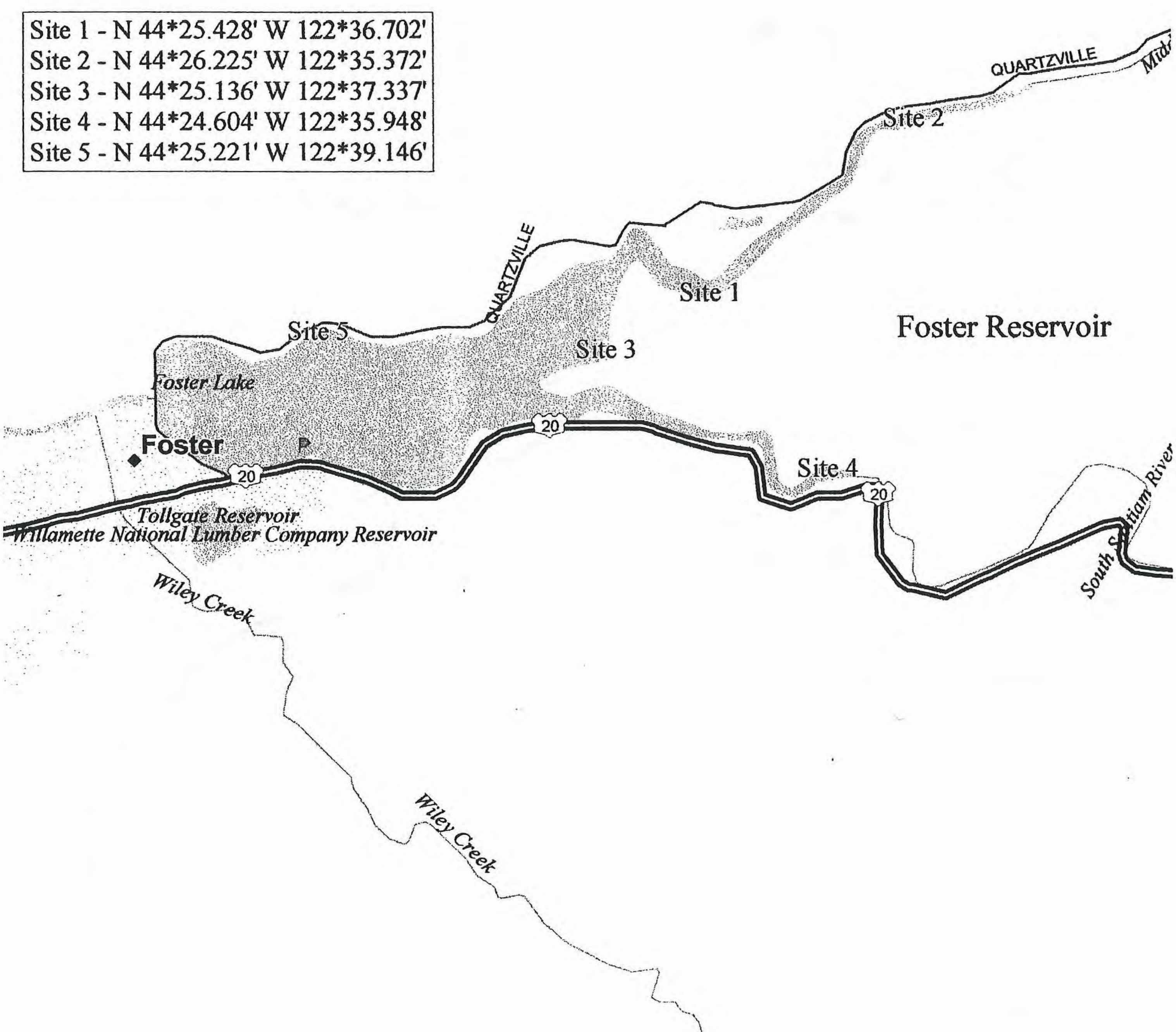


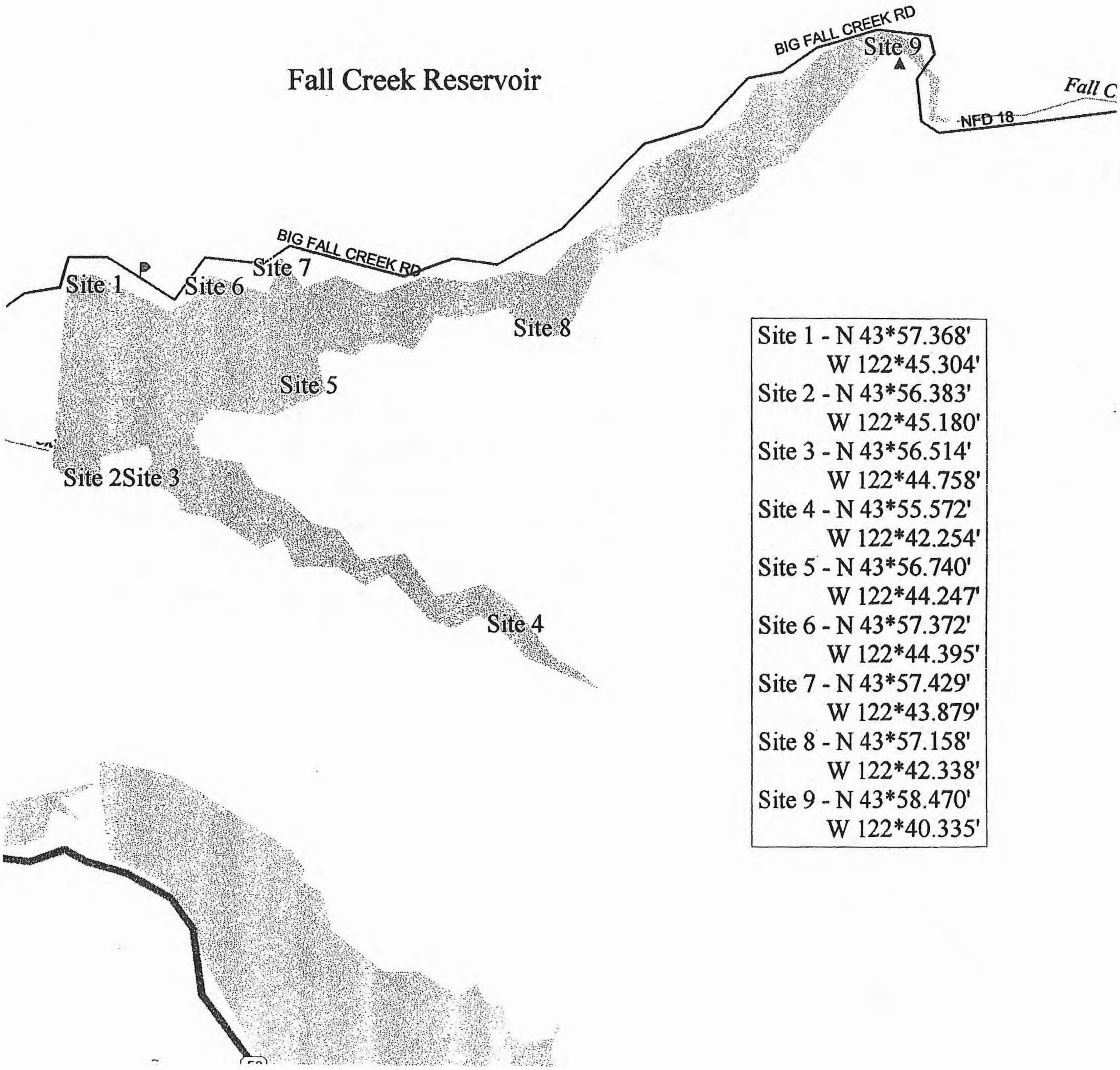
Site 1 - N 44*44.785' W 122*16.678'
Site 2 - N 44*43.956' W 122*16.315'
Site 3 - N 44*43.872' W 122*15.936'
Site 4 - N 44*43.648' W 122*15.567'
Site 5 - N 44*43.423' W 122*15.224'



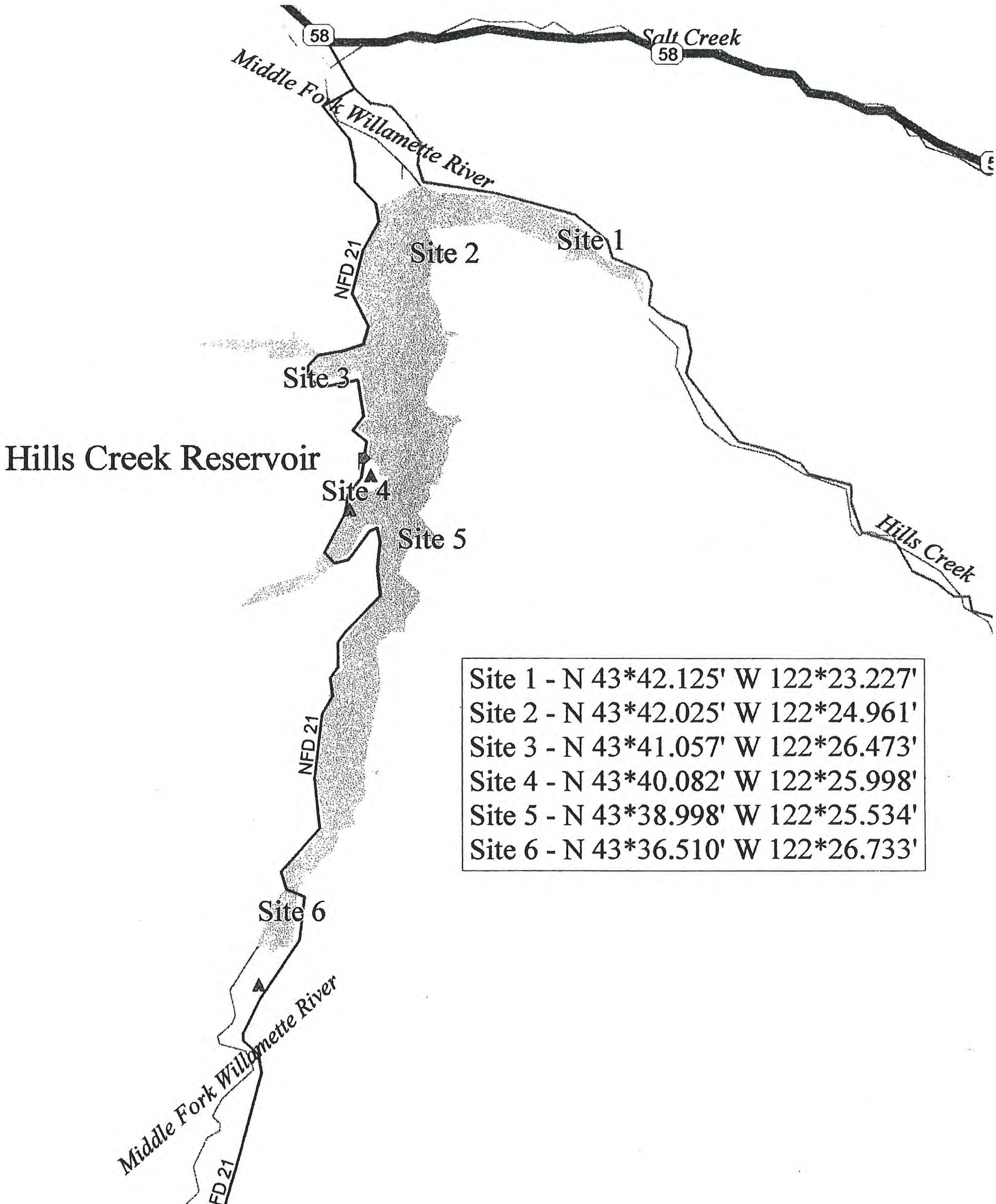
Site 1 - N 44*42.606' W 122*10.330'	
Site 2 - N 44*43.129' W 122*09.143'	
Site 3 - N 44*42.938' W 122*07.398'	
Site 4 - N 44*43.373' W 122*09.535'	
Site 5 - N 44*44.117' W 122*09.459'	
Site 6 - N 44*44.816' W 122*08.660'	
Site 7 - N 44*40.710' W 122*11.723'	
Site 8 - N 44*41.513' W 122*15.176'	


Fall Creek
Fall Creek
Fall Creek
Unity
58
Lowell
Dexter
Site 1
58
Site 2
Site 3
Site 4
Site 5
Site 6
Site 7
58
Site 8
Lookout Point Reservoir
Site 1 - N 43*54.977' W 122*44.839'
Site 2 - N 43*53.538' W 122*43.975'
Site 3 - N 43*53.838' W 122*42.433'
Site 4 - N 43*53.008' W 122*41.345'
Site 5 - N 43*52.186' W 122*39.953'
Site 6 - N 43*50.896' W 122*38.131'
Site 7 - N 43*51.015' W 122*37.056'
Site 8 - N 43*49.513' W 122*37.179'
No Fk Mid Fk
Dorena

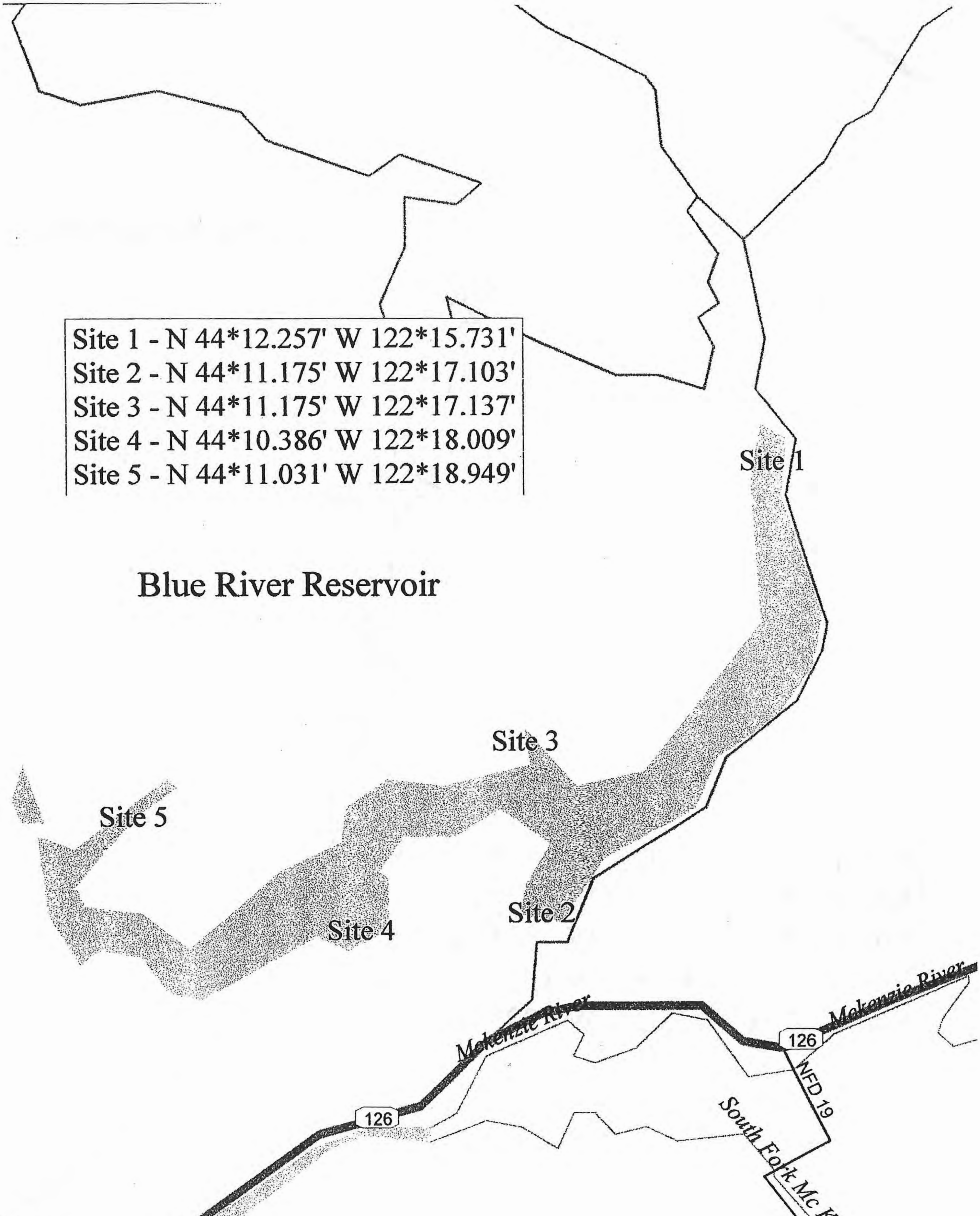

Site 1 - N 44*25.428' W 122*36.702'
Site 2 - N 44*26.225' W 122*35.372'
Site 3 - N 44*25.136' W 122*37.337'
Site 4 - N 44*24.604' W 122*35.948'
Site 5 - N 44*25.221' W 122*39.146'
QUARTZVILLE
QUARTZVILLE
Site 2
Site 1
Site 5
Site 3
Site 4
Foster Reservoir
Foster Lake
Foster
20
20
20
20
Tollgate Reservoir
Willamette National Lumber Company Reservoir
Wiley Creek
Wiley Creek
South Santiam River

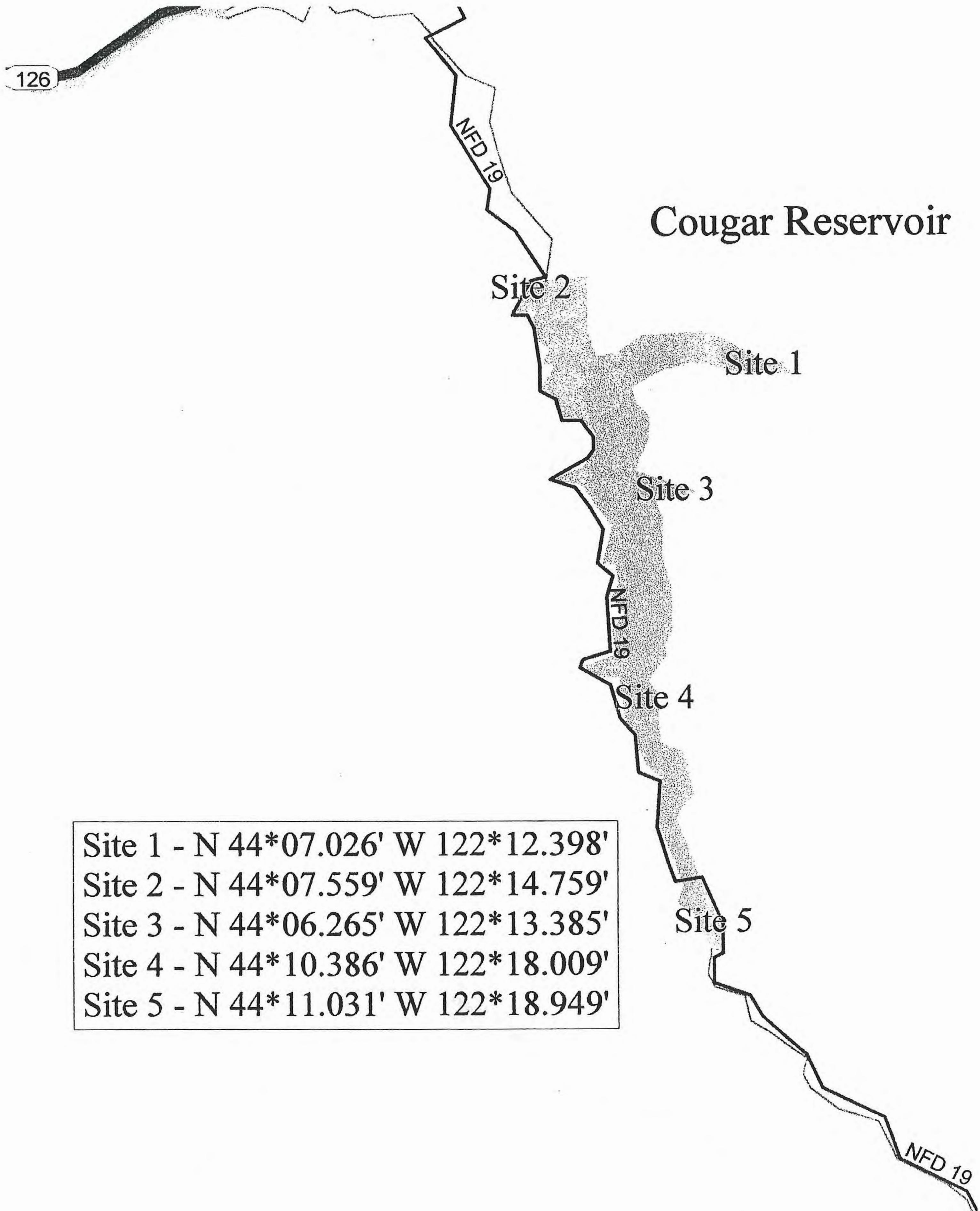


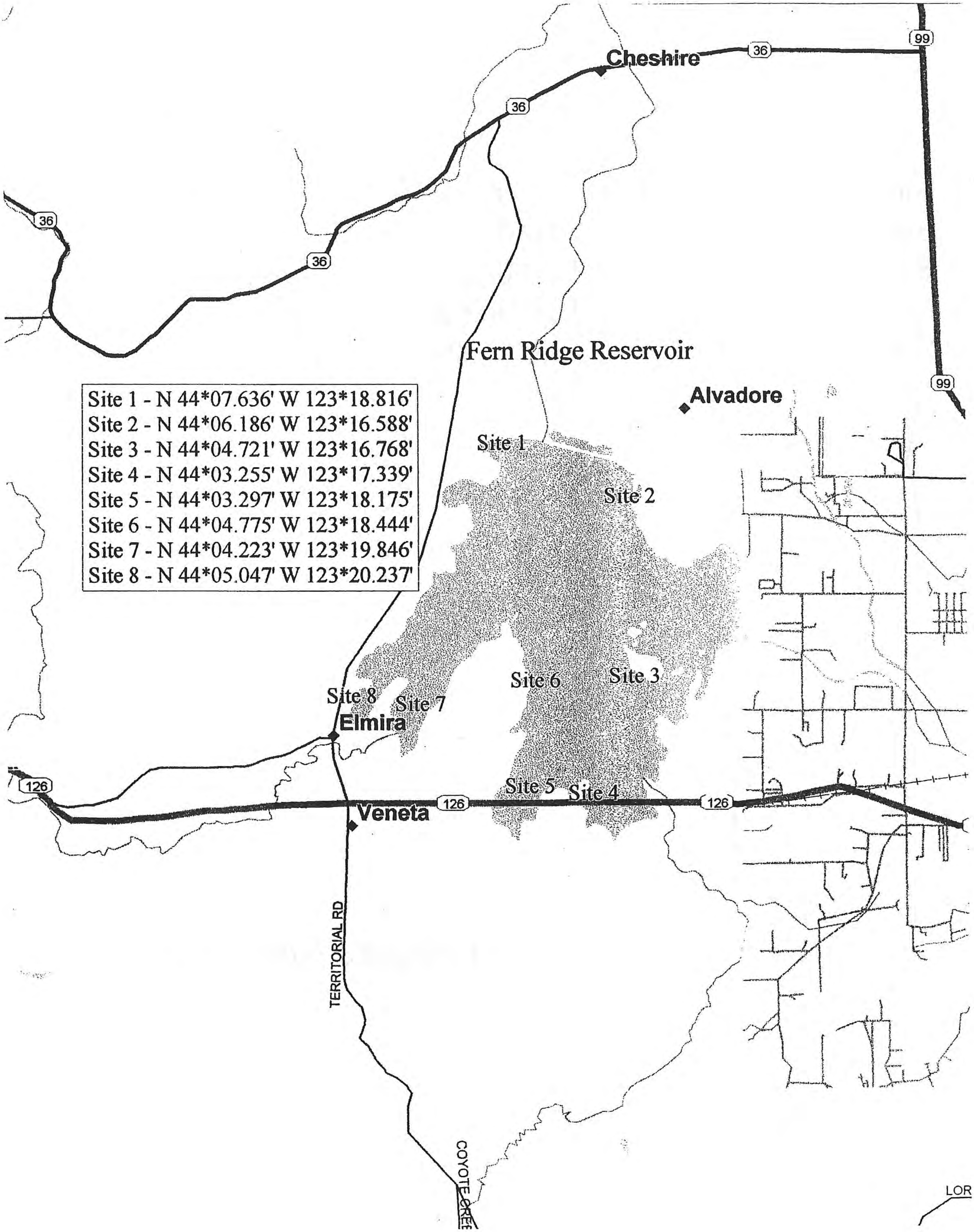
Fall Creek Reservoir
BIG FALL CREEK RD
BIG FALL CREEK RD
NFD 18
Fall C
Site 1
Site 2
Site 3
Site 4
Site 5
Site 6
Site 7
Site 8
Site 9
Site 1 - N 43*57.368' W 122*45.304'
Site 2 - N 43*56.383' W 122*45.180'
Site 3 - N 43*56.514' W 122*44.758'
Site 4 - N 43*55.572' W 122*42.254'
Site 5 - N 43*56.740' W 122*44.247'
Site 6 - N 43*57.372' W 122*44.395'
Site 7 - N 43*57.429' W 122*43.879'
Site 8 - N 43*57.158' W 122*42.338'
Site 9 - N 43*58.470' W 122*40.335'



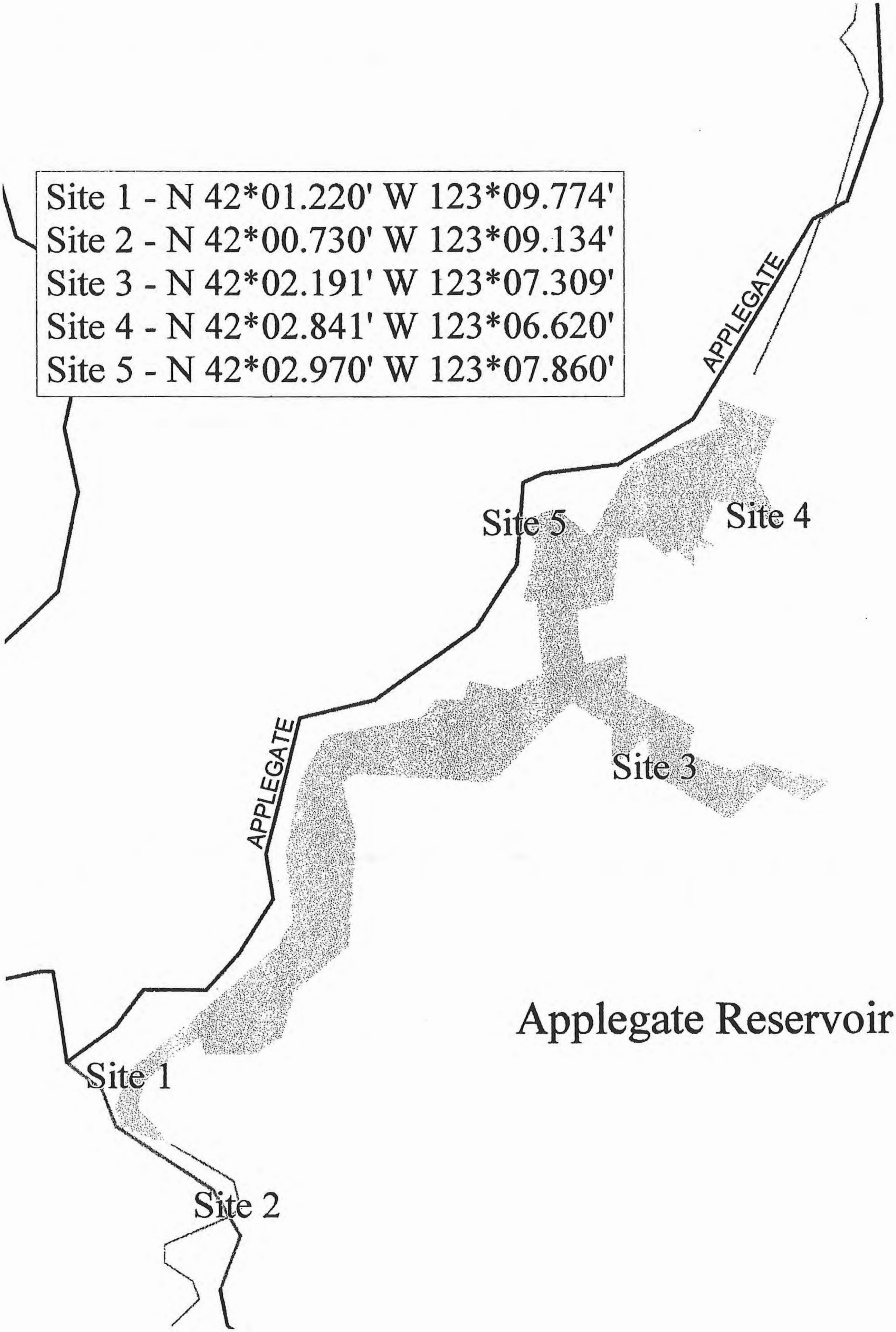
58
Salt Creek
58
Middle Fork Willamette River
Site 1
Site 2
NFD 21
Site 3
Hills Creek Reservoir
Site 4
Site 5
Hills Creek
Site 1 - N 43*42.125' W 122*23.227'
Site 2 - N 43*42.025' W 122*24.961'
Site 3 - N 43*41.057' W 122*26.473'
Site 4 - N 43*40.082' W 122*25.998'
Site 5 - N 43*38.998' W 122*25.534'
Site 6 - N 43*36.510' W 122*26.733'
NFD 21
Site 6
Middle Fork Willamette River
NFD 21

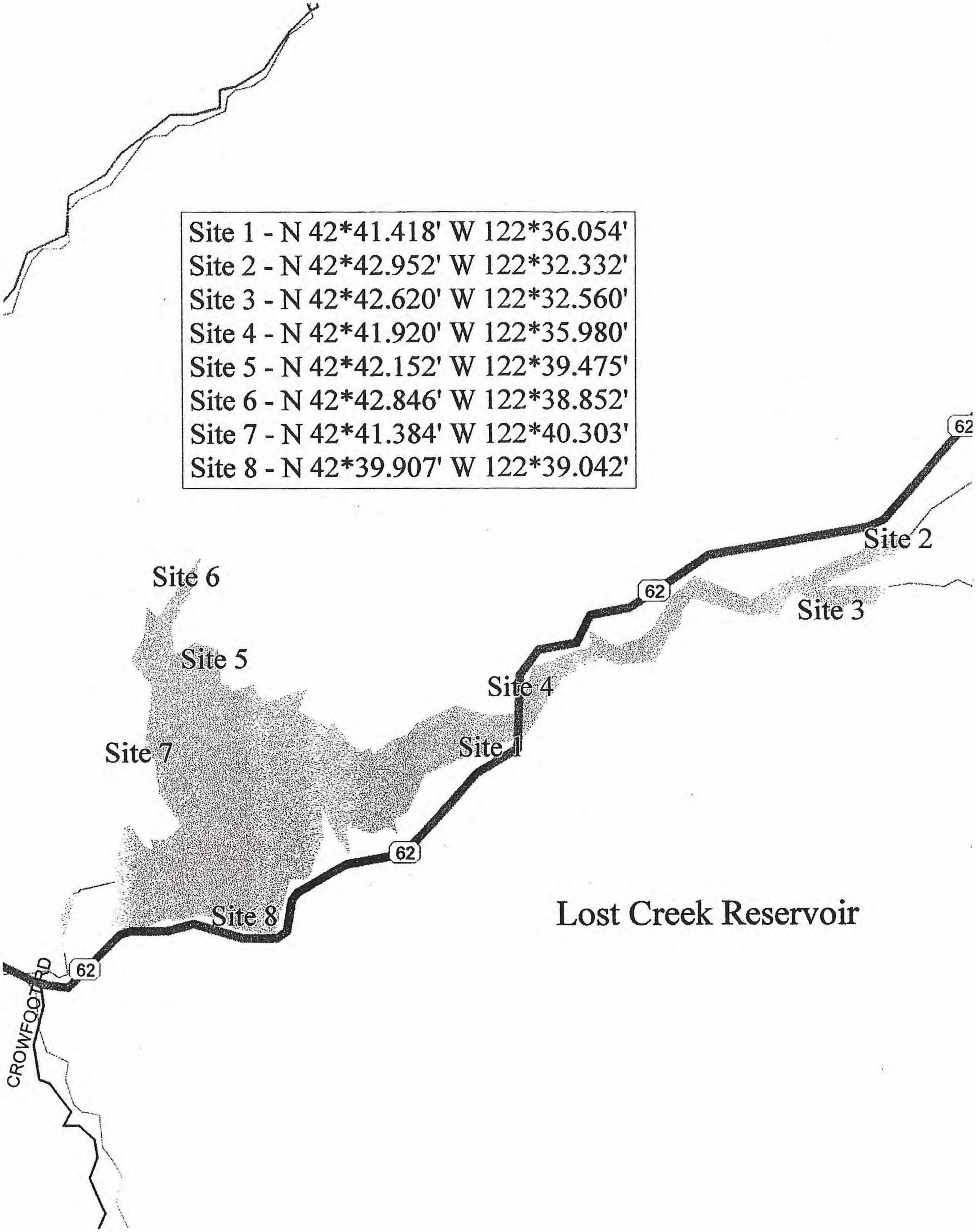

Site 1 - N 44*12.257' W 122*15.731'
Site 2 - N 44*11.175' W 122*17.103'
Site 3 - N 44*11.175' W 122*17.137'
Site 4 - N 44*10.386' W 122*18.009'
Site 5 - N 44*11.031' W 122*18.949'
Blue River Reservoir
Site 1
Site 3
Site 5
Site 2
Site 4
Mckenzie River
Mckenzie River
126
126
NFD 19
South Fork Mc Kenzi


126
NFD 19
Cougar Reservoir
Site 2
Site 1
Site 3
NFD 19
Site 4
Site 5
NFD 19
Site 1 - N 44*07.026' W 122*12.398'
Site 2 - N 44*07.559' W 122*14.759'
Site 3 - N 44*06.265' W 122*13.385'
Site 4 - N 44*10.386' W 122*18.009'
Site 5 - N 44*11.031' W 122*18.949'



Cheshire
36
99
Fern Ridge Reservoir
Alvadore
Site 1 - N 44*07.636' W 123*18.816'
Site 2 - N 44*06.186' W 123*16.588'
Site 3 - N 44*04.721' W 123*16.768'
Site 4 - N 44*03.255' W 123*17.339'
Site 5 - N 44*03.297' W 123*18.175'
Site 6 - N 44*04.775' W 123*18.444'
Site 7 - N 44*04.223' W 123*19.846'
Site 8 - N 44*05.047' W 123*20.237'
Site 1
Site 2
Site 3
Site 4
Site 5
Site 6
Site 7
Site 8
Elmira
Veneta
126
TERRITORIAL RD
COYOTE CREE
LOR


Site 1 - N 42*01.220' W 123*09.774'
Site 2 - N 42*00.730' W 123*09.134'
Site 3 - N 42*02.191' W 123*07.309'
Site 4 - N 42*02.841' W 123*06.620'
Site 5 - N 42*02.970' W 123*07.860'
APPLEGATE
Site 5
Site 4
APPLEGATE
Site 3
Applegate Reservoir
Site 1
Site 2


Site 1 - N 42*41.418' W 122*36.054'
Site 2 - N 42*42.952' W 122*32.332'
Site 3 - N 42*42.620' W 122*32.560'
Site 4 - N 42*41.920' W 122*35.980'
Site 5 - N 42*42.152' W 122*39.475'
Site 6 - N 42*42.846' W 122*38.852'
Site 7 - N 42*41.384' W 122*40.303'
Site 8 - N 42*39.907' W 122*39.042'
62
Site 2
Site 6
62
Site 3
Site 5
Site 4
Site 7
Site 1
62
Site 8
Lost Creek Reservoir
62
CROWFOOT RD

Reservoir	Site No.	Depth (m)	Fontinalis antipyretica	Polygonum amphibium	Myriophyllum hippuroides	Potamogeton pectinatus	Myriophyllum aquaticum	Potamogeton epihydrus	Potamogeton nodosus	Ranunculus aquatilis	Chara spp.	Polygonum piperoides	Myriophyllum spicatum	Potamogeton crispus	Ceratophyllum demursum	Elodea canadensis	Nymphaea odoratus	Najas guadalupensis	Utricularia vulgaris
			Plant species																
Cottage Grove	1	1.0	50		20		10	20											
		2.0	30		20		10	30	10										
		3.0	30		10		10	10	40										
	2	1.0	40		10		20		30										
		2.0	20		10		10	30	30										
		3.0	30				20	40	10										
	3	0.0								50									
		1.0	50			30		10	10										
		2.0	50			30		10	10										
		3.0	40			10		20	20										
		3.5		HT															
	4	0.0								50									
		1.0	50			10					20								
		2.0	25			10					65								
		3.0	25			10					65								
	5	1.0	50					20	30										
		2.0	50					20	30										
		3.0	40					20	40										
Dorena	1	1.0	50	20			10	20											
		2.0	50	20			20	10											
		3.0	40	40			10	10											
	2	1.0	40	20			15												
		2.0	40	25			10												
		3.0	HT	HT			HT												
	3	1.0	25																
		2.0	HT																
		3.0	HT																
	4	1.0	50			25													
		2.0	HT			HT													
		3.0																	
	5	1.0	25																
		2.0	HT	HT															
		3.0	HT	HT															
	6	1.0	30	20		30	20	20											
		2.0	10	40			40	20											
		3.0					30	30											

Reservoir	Site No.	Depth (m)	Fontinalis antipyretica	Polygonum amphibium	Myriophyllum hippuroides	Potamogeton pectinatus	Myriophyllum aquaticum	Potamogeton epihydrus	Potamogeton nodosus	Ranunculus aquatilis	Chara spp.	Polygonum piperoides	Myriophyllum spicatum	Potamogeton crispus	Ceratophyllum demursum	Elodea canadensis	Nymphaea odoratus	Najas guadalupensis	Utricularia vulgaris
Fern Ridge	1	1.0																	
		2.0																	
		3.0																	
	2	1.0																	
		2.0																	
		3.0																	
	3	1.0		HT		HT		HT	HT										
		2.0				HT		HT	HT										
		3.0				HT		HT	HT										
	4	1.0		HT		HT			HT										
		2.0				HT			HT										
		3.0							HT										
	5	1.0						HT	HT				HT						
		2.0						HT	HT				HT						
		3.0						HT	HT										
	6	1.0						HT	HT				HT	HT					
		2.0						HT	HT				HT						
		3.0						HT	HT				HT						
	7	1.0		HT		HT													
		2.0				HT			HT				HT						HT
		3.0							HT				HT						HT
	8	1.0				HT			HT										
		2.0				HT		HT	HT				HT						
		3.0						HT	HT				HT						
	9	1.0													HT				
Dexter	1	1.0			10			5			20			20	20	25			
		2.0			20			15			15			20	10	20			
		3.0			HT			HT						HT	HT	HT			
	2	1.0			10			5			20			20	20	25			
		2.0			20			15			15			20	10	20			
		3.0			HT			HT						HT	HT	HT			
	3	1.0						20						40		40			
		2.0						10						40		50			
		3.0						40						30		30			
	4	1.0				40		10						20		30			
		2.0				30		20						10		40			
		3.0						25						10		40			
	5	1.0				50								20		30	IA		
		2.0				40								30		30	IA		
		3.0												HT		HT			
	6											IA	IA		IA				
	7						IA									IA			

Reservoir	Site No.	Depth (m)	Fontinalis antipyretica	Polygonum amphibium	Myriophyllum hippuroides	Potamogeton pectinatus	Myriophyllum aquaticum	Potamogeton epihydrus	Potamogeton nodosus	Ranunculus aquatilis	Chara spp.	Polygonum piperoides	Myriophyllum spicatum	Potamogeton crispus	Ceratophyllum demursum	Elodea canadensis	Nymphaea odoratus	Najas guadalupensis	Utricularia vulgaris
Willow Creek	1	1.0				25					25							50	
		2.0				25												25	
		3.0				HT												HT	
	2	1.0				25					25							50	
		2.0				25								25				50	
		3.0				HT								HT				HT	
	3	1.0				5												5	
		2.0																	
		3.0																	
	4	1.0				25					25							50	
		2.0				20			40									15	
		3.0							HT									HT	
	5	1.0																	
		2.0																	
		3.0																	
Applegate	1	1.0																	
		2.0																	
		3.0																	
	2	1.0																	
		2.0																	
		3.0																	
	3	1.0																	
		2.0																	
		3.0																	
	4	1.0																	
		2.0																	
		3.0																	
	5	1.0																	
		2.0																	
		3.0																	

Reservoir	Site No.	Depth (m)	Fontinalis antipyretica	Polygonum amphibium	Myriophyllum hippuroides	Potamogeton pectinatus	Myriophyllum aquaticum	Potamogeton epihydrus	Potamogeton nodosus	Ranunculus aquatilis	Chara spp.	Polygonum piperoides	Myriophyllum spicatum	Potamogeton crispus	Ceratophyllum demursum	Elodea canadensis	Nymphaea odoratus	Najas guadalupensis	Utricularia vulgaris
Lost Creek	1	1.0																	
		2.0																	
		3.0																	
	2	1.0																	
		2.0																	
		3.0																	
	3	1.0																	
		2.0																	
		3.0																	
	4	1.0																	
		2.0																	
		3.0																	
	5	1.0																	
		2.0																	
		3.0																	
	6	1.0																	
		2.0																	
		3.0																	
	7	1.0																	
		2.0																	
		3.0																	
	8	1.0																	
		2.0																	
		3.0																	
Foster	1	1.0																	
		2.0																	
		3.0																	
	2	1.0	50																
		2.0	75																
		3.0	25																
	3	1.0	75																
		2.0	50								25								
		3.0	50																
	4	1.0																	
		2.0																	
		3.0																	
	5	1.0																	
		2.0																	
		3.0																	

Reservoir	Site No.	Depth (m)	Fontinalis antipyretica	Polygonum amphibium	Myriophyllum hippuroides	Potamogeton pectinatus	Myriophyllum aquaticum	Potamogeton epihydrus	Potamogeton nodosus	Ranunculus aquatilis	Chara spp.	Polygonum piperoides	Myriophyllum spicatum	Potamogeton crispus	Ceratophyllum demursum	Elodea canadensis	Nymphaea odoratus	Najas guadalupensis	Utricularia vulgaris
Green Peter	1	1.0																	
		2.0																	
		3.0																	
	2	1.0																	
		2.0																	
		3.0																	
	3	1.0																	
		2.0																	
		3.0																	
	4	1.0																	
		2.0																	
		3.0																	
	5	1.0	25																
		2.0	50																
		3.0																	
	6	1.0																	
		2.0																	
		3.0																	
	7	1.0																	
		2.0																	
		3.0																	
	8	1.0																	
		2.0																	
		3.0																	
	9	1.0																	
		2.0																	
		3.0																	
	10	1.0	75																
		2.0	75																
		3.0																	
	11	1.0																	
		2.0																	
		3.0																	
	12	1.0	50																
		2.0	75																
		3.0																	

Reservoir	Site No.	Depth (m)	Fontinalis antipyretica	Polygonum amphibium	Myriophyllum hippuroides	Potamogeton pectinatus	Myriophyllum aquaticum	Potamogeton epihydrus	Potamogeton nodosus	Ranunculus aquatilis	Chara spp.	Polygonum piperoides	Myriophyllum spicatum	Potamogeton crispus	Ceratophyllum demursum	Elodea canadensis	Nymphaea odoratus	Najas guadalupensis	Utricularia vulgaris
Big Cliff	1	1.0																	
		2.0																	
		3.0																	
	2	1.0																	
		2.0																	
		3.0																	
	3	1.0																	
		2.0																	
		3.0																	
	4	1.0																	
		2.0																	
		3.0																	
	5	1.0	75																
		2.0	75																
		3.0																	
Detroit	1	1.0																	
		2.0																	
		3.0																	
	2	1.0																	
		2.0																	
		3.0																	
	3	1.0																	
		2.0																	
		3.0																	
	4	1.0																	
		2.0																	
		3.0																	
	5	1.0																	
		2.0																	
		3.0																	
	6	1.0																	
		2.0																	
		3.0																	
	7	1.0																	
		2.0																	
		3.0																	
	8	1.0																	
		2.0																	
		3.0																	

Reservoir	Site No.	Depth (m)	Fontinalis antipyretica	Polygonum amphibium	Myriophyllum hippuroides	Potamogeton pectinatus	Myriophyllum aquaticum	Potamogeton epihydrus	Potamogeton nodosus	Ranunculus aquatilis	Chara spp.	Polygonum piperoides	Myriophyllum spicatum	Potamogeton crispus	Ceratophyllum demursum	Elodea canadensis	Nymphaea odoratus	Najas guadalupensis	Utricularia vulgaris
Lookout Point	1	1.0																	
		2.0																	
		3.0																	
	2	1.0																	
		2.0																	
		3.0																	
	3	1.0																	
		2.0																	
		3.0																	
	4	1.0	25																
		2.0	50																
		3.0	25																
	5	1.0																	
		2.0																	
		3.0																	
	6	1.0																	
		2.0																	
		3.0																	
	7	1.0																	
		2.0																	
		3.0																	
	8	1.0	50																
		2.0	50								25								
		3.0	50																
	9	1.0	50																
		2.0	50																
		3.0	25																

Reservoir	Site No.	Depth (m)	Fontinalis antipyretica	Polygonum amphibium	Myriophyllum hippuroides	Potamogeton pectinatus	Myriophyllum aquaticum	Potamogeton epihydrus	Potamogeton nodosus	Ranunculus aquatilis	Chara spp.	Polygonum piperoides	Myriophyllum spicatum	Potamogeton crispus	Ceratophyllum demursum	Elodea canadensis	Nymphaea odoratus	Najas guadalupensis	Utricularia vulgaris
Fall Creek	1	1.0	50																
		2.0	75																
		3.0	50																
	2	1.0	75																
		2.0	75																
		3.0	75																
	3	1.0																	
		2.0																	
		3.0																	
	4	1.0	50																
		2.0	50								25								
		3.0	75																
	5	1.0																	
		2.0																	
		3.0																	
	6	1.0																	
		2.0																	
		3.0																	
	7	1.0																	
		2.0																	
		3.0																	
	8	1.0																	
		2.0																	
		3.0																	
Hills Creek	1	1.0																	
		2.0																	
		3.0																	
	2	1.0																	
		2.0																	
		3.0																	
	3	1.0																	
		2.0																	
		3.0																	
	4	1.0																	
		2.0																	
		3.0																	
	5	1.0																	
		2.0																	
		3.0																	
	6	1.0	25																
		2.0	50																
		3.0	50																

Reservoir	Site No.	Depth (m)	Fontinalis antipyretica	Polygonum amphibium	Myriophyllum hippuroides	Potamogeton pectinatus	Myriophyllum aquaticum	Potamogeton epihydrus	Potamogeton nodosus	Ranunculus aquatilis	Chara spp.	Polygonum piperoides	Myriophyllum spicatum	Potamogeton crispus	Ceratophyllum demursum	Elodea canadensis	Nymphaea odoratus	Najas guadalupensis	Utricularia vulgaris
Blue River	1	1.0																	
		2.0																	
		3.0																	
	2	1.0																	
		2.0																	
		3.0																	
	3	1.0																	
		2.0																	
		3.0																	
	4	1.0	75																
		2.0	75																
		3.0																	
	5	1.0																	
		2.0																	
		3.0																	
Cougar	1	1.0																	
		2.0																	
		3.0																	
	2	1.0																	
		2.0																	
		3.0																	
	3	1.0																	
		2.0																	
		3.0																	
	4	1.0	75																
		2.0	75																
		3.0																	
	5	1.0																	
		2.0																	
		3.0																	