Ground Water Quality

The pump-and-treat facilities have been operating for 10 years, and the plume, with one exception, appears to be stable (i.e., its extent not appreciably changing in time and space). A bulge in the contaminant plume in the Lower Murray subbasin has developed to the southwest crossing below Murray Creek and toward MAMC. This bulge is caused by local variations in the surface aquifer potentiometric surface, and suggests that the ground water extraction and treatment system is not entirely containing the TCE plume. An objective of the remediation system is to restore the water quality in the surface aquifer to drinking water standards by reducing the concentration of TCE to less than the maximum contaminant level of 5 μg/L within 30 years. Because contaminant source removal activities have not been completed, TCE concentrations in the plume do not appear to be decreasing. For this reason, it is not anticipated that drinking water standards will be achieved in the surface aquifer within the next 30 years (USACE 2002).

3.5.3 Primary Ground Water Data Sources and Data Gaps

Information on ground water in the study area was obtained primarily from the following sources:

- WDSHS (1987) – *Survey of Groundwater and Surface Water Quality for the Chambers-Clover Creek Drainage Basin, Pierce County*
- Woodward-Clyde (1990) – *Fort Lewis Landfill No. 5, Remedial Investigation/Feasibility Study: Hydrogeology and Water Quality-Technical Memorandum*
- AGI (1993) – *Landfill 4/SRCPP Remedial Investigation Report, Fort Lewis, Washington*
- CH2M Hill (1994) – *Stationing of Mechanized Forces or Armored Combat Forces at Fort Lewis, Washington*
- AGI (1996) – *Sequalitchew Lake Ground Water Seepage Estimates*
- Shapiro (1996) – *An Assessment of Murray Creek in Pierce County, Washington*
- Pierce County (1997) – *Chambers-Clover Creek Watershed Action Plan-A Water Quality Plan for Reducing Non-Point Pollution*
- Shapiro (1997a) – Lake-*Level Management Plan for Sequalitchew Lake*
- Shapiro (1997b) – *Murray Creek Planning Guide*

- Woodward-Clyde (1997a) – *American Lake Watershed Management Plan*
- Woodward-Clyde (1997b) – *American Lake Watershed Phosphorus Source Evaluation*
- ENSR (1998a) – *Final Sequalitchew Lake Level Management Plan Environmental Assessment*
- ENSR (1998b) – *Feasibility of Alternatives for Restoring Baseflow to Murray Creek, Fort Lewis, Washington*
- ENSR (2000) – *Final Integrated Natural Resources Management Plan*
- USACE (2002) – *Five-Year Review Report: Second Five-Year Review for Logistics Center, Fort Lewis, Pierce County, Washington*
- Anteon (2004) – *Fort Lewis Construction Storm Water Pollution Prevention Plan*
- Engineering and Environment et al. (2004) – *Fort Lewis Installation Action Plan*
- Bussey (2005) – Personal communication (telephone conversation with Matthew Brennan, Herrera Environmental Consultants, concerning ground water contamination in the Murray/Sequalitchew watershed)
- Crown (2005b) – Personal communication (electronic mail to Mary Larkin, Herrera Environmental Consultants, providing information about water management at Fort Lewis)
- U.S. Army (2005a) – *Fort Lewis Installation Sustainability Implementation Plan for FY05–10*
- Site visit of July 11, 2005

No substantial data gaps have been identified with respect to ground water.

3.5.4 Ongoing Ground Water Studies and Research

MAMC personnel are conducting a study related to water supply for the hospital cooling system, which began in October 2004 and is anticipated to be completed in 2006. The study is investigating the decreased capacity from the hospital pumping wells and the possibility of using treated water for cooling, if temperature concerns can be addressed. In addition to the base flow loss observed in Murray Creek, MAMC personnel have observed decreased pumping capacity from their wells and are concerned about water quality impacts associated with the TCE plume.

3.5.5 Key Ground Water Issues

The extraction of cooling water at MAMC causes local drawdown of the surface aquifer, which likely affects base flow in Murray Creek. In addition, ground water extraction at the EGDY and Interstate 5 pump-and-treat systems likely contribute to the loss of base flow in Murray Creek during low-flow portions of the year (Bussey 2005).

Historical waste disposal at the EGDY is the cause of the contaminant plume located beneath the Logistics Center. Some source material is still present in the subsurface (as indicated by very high TCE concentrations), and will continue to supply the plume until it has been remediated. This site is listed on the Superfund National Priorities List (NPL; USACE 2002).

The surface aquifer TCE plume has migrated across Murray Creek in two locations: near the Madigan housing area in the Middle Murray subbasin, and in the vicinity of MAMC in the Lower Murray subbasin. It has been suggested that local effects of the creek on the water table elevation has caused this migration (Bussey 2005). However, Murray Creek in the vicinity of MAMC was identified by Shapiro (1996) as a losing reach, suggesting that Murray Creek would not have this effect. It is possible that pumping at the MAMC wells has caused local drawdown that has led to plume migration at this location. MAMC well pumping may also be partially responsible for migration of the sea level aquifer in a southwesterly direction.

One offsite location is also on the NPL: ground water beneath American Lake Gardens (in the American Lake subbasin) is contaminated with VOCs. A pump-and-treat remediation system has been in operation at this location since 1993. The source of this contamination is believed to be a former landfill on McChord Air Force Base (USEPA 2005).

Underground heating oil tanks located throughout Fort Lewis are a potential source of ground water contamination. In addition, potential impacts on ground water quality have been identified at the following locations (Engineering and Environment et al. 2004):

- The Defense Reutilization and Marketing Office (DRMO) yard (Upper Murray subbasin) – Polychlorinated biphenyl (PCB) soil contamination adjacent to EGDY in the Logistics Center
- Outfall #7/settling basin (Lower Murray subbasin) – Surficial sediments contaminated with petroleum products, solvents, and metals (located within the Logistics Center NPL site)
- Landfill #1 (Sequalitchew subbasin) – VOCs detected in shallow ground water
- Landfill #4 (Sequalitchew subbasin) – TCE and vinyl chloride detected in ground water; remediation conducted 1997 to 1999
- Landfill #6 (Lower Murray subbasin) – Soil contamination detected at this site (located within the Logistics Center NPL site)

The wellhead protection areas associated with many of the potable ground water supply wells and Sequalitchew Springs do not appear to be appropriately delineated. The wellhead protection areas associated with many of these sources are oriented directly east from the well of concern and cover a very narrow area (see Figure 3.5-1). In some cases, the well is not located within the wellhead protection areas. Ground water in the surface and sea level aquifers flows generally in a northwesterly direction, and is subject to local variation. Narrow wellhead protection areas will not adequately protect a well from a contamination plume that spreads laterally from an outside source.

3.5.6 Previous Study Recommendations

Shapiro recommended that Fort Lewis develop a water conservation plan for the watershed. Shapiro also recommended that the pumped ground water from the MAMC infiltration ponds be returned to Murray Creek during periods of low base flow. As noted previously, MAMC is currently undertaking a study related to water supply issues.

The *Fort Lewis Installation Sustainability Implementation Plan* (U.S. Army 2005a) includes the strategic goal of reducing Fort Lewis potable water consumption by 75 percent by 2025. Proposed supporting actions include the following:

- Develop and deploy a Fort Lewis water outreach program to promote public awareness of the need for water conservation measures.

- Reduce per capita potable water consumption by implementing conservation and best management practices. In support of this objective, Fort Lewis is developing and implementing a water outreach program as part of an installation water conservation plan. In 2008, Fort Lewis plans to implement a water conservation plan.

- Reduce per capita potable water consumption by eliminating irrigation from potable sources.

The *Fort Lewis Installation Sustainability Implementation Plan for FY05–10* (U.S. Army 2005a) has outlined a number of strategic goals and specific objectives for ground water improvement. One goal (Strategic Goal #11 – Fort Lewis contributes no pollutants to ground water and has remediated all contaminated ground water by 2025) specifically addresses ground water. Below are 5-year objectives and associated actions described in the plan:

- Objective: Replace/upgrade all heating oil tanks on Fort Lewis by 2007.
    - Action: Conduct inventory and gap analysis
    - Action: Heating oil tank repair/upgrade/demolition

- Objective: Begin implementation of nonpolluting range management practices by 2010.

- Action: Draft munitions management strategy
- Action: Coordinate and staff munitions management strategy
- Action: Implement munitions management strategy

- Objective: Obtain remedy-in-place for Logistics Center NPL site.
  - Action: Complete aggressive source treatment at NAPL areas 2–3
  - Action: Install reconfigured EGDY pump-and-treat system
  - Action: Install new monitoring wells to complete aquifer characterization
  - Action: Confirm no indoor air risk to Madigan housing
  - Action: Complete focused feasibility study for sea level aquifer remedy
  - Action: Document and implement remedy for EGDY soil risk
  - Action: Complete Record of Decision (ROD) amendment
  - Action: Implement sea level aquifer remedy
  - Action: ROD required tasks: Logistics Center Remedial Action Monitoring (LogRAM), pump-and-treat operations and maintenance, maintain institutional controls

- Objective: Obtain no further action (NFA) status; maintain remedies for all Federal Facility Agreement (FFA) Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites outside Logistics Center.
  - Action: Suitable remedy for DRMO yard in place
  - Action: Complete ROD amendment
  - Action: Maintain remedies associated with Landfill 1, Landfill 4, solvent refined coal pilot plant, etc.

- Objective: Determine potential risk posed by FFA CERCLA sites within the Logistics Center.
  - Action: Assess risk posed by Landfill 6, industrial wastewater treatment plant, and DRMO yard

- Objective: Obtain NFA status for as many Fort Lewis Agreed Order (FLAO) sites as possible, and move toward remedy selection on remaining FLAO sites.
    - Action: Complete remedial investigation
    - Action: Complete risk assessment and feasibility study work plan
    - Action: Complete feasibility study
- Objective: Obtain NFA status on leaking tank sites not part of FLAO.
    - Action: Conduct site investigation after FLAO feasibility study is complete

To restore and protect base flow quantity in Murray Creek, Shapiro (1997b) provided recommended planning guidelines for increasing infiltration of stormwater in developed portions of the watershed. These recommendations are discussed in the surface water section of this document.

Several recommendations were evaluated by ENSR (1998b) to address surface water/ground water interaction in Middle Murray Creek. These recommendations primarily address surface water quantity issues, but also pertain to ground water quantity. ENSR recommended additional data collection (flow measurements in Murray Creek and temperature monitoring in the MAMC cooling pond, EGDY pump-and-treat system discharge, and in Murray Creek) and suggested that two of the alternatives be considered further:

- Discharge MAMC cooling water directly into Murray Creek
- Construct new well(s) to supplement Murray Creek flow

A third alternative, to divert pump-and-treat discharge water from the EGDY system to Murray Creek, was determined to be questionable because it may not provide the water flow rates needed. However, ENSR (1998b) recommended that this alternative be considered if the other two alternatives cannot be implemented.

Woodward-Clyde (1997a) recommended a number of source control measures to reduce phosphorus concentrations in ground water up gradient of American Lake. These recommendations focused primarily on the use and maintenance of on-site septic systems in the American Lake and Tillicum areas. Because wastewater generated within the Fort Lewis boundaries is collected and treated at the Fort Lewis wastewater treatment plant, the recommendations are not applicable to the Army.

3.5.7 Potential Solutions for Ground Water

In addition to the actions proposed in previous studies, it is recommended that the designated wellhead protection areas on Fort Lewis be reviewed to determine the assumptions and data sources used to develop them. Where appropriate, the wellhead protection areas should be

redelineated to accurately reflect ground water flow direction and the lateral migration potential of contamination sources, for reasons noted in Section 3.5.5.

3.6 Upland Habitat within the Watershed

Upland forests, woodlands, and prairies perform valuable functions for the watershed, including infiltrating precipitation into soils, recharging ground water, reducing storm event impacts on streams (erosion and resulting downstream sedimentation), and providing habitat for diverse plant and animal species. Plant communities in the vicinity of Fort Lewis can be divided into four broad types: coniferous forest, oak woodlands, prairie, and wetland and riparian areas. This section discusses upland forest, woodland, and prairie habitats, collectively referred to as upland habitats, as well as the wildlife associated with these habitats. Wetland and riparian habitats and their plant and wildlife communities are discussed in subsequent sections of this plan.

3.6.1 Historical Upland Habitat Conditions

When glaciation ended, lodgepole pine (*Pinus contorta* var. *contorta*) initially colonized the infertile glacial deposits covering the area. Lowland conifers, including Sitka spruce (*Picea sitchensis*), western hemlock (*Tsuga heterophylla*), subalpine fir (*Abies lasiocarpa*), and slide (Sitka) alder (*Alnus viridis* subsp. *sinuata*) grew in association with lodgepole pine about 12,000 to 10,000 years ago, followed by the arrival of Douglas-fir.

Douglas-fir, Oregon white oak (*Quercus garryana*), western bracken fern (*Pteridium aquilinum*), sagebrush (*Artemisia tridentata*) and native grasses emerged as dominant species for several thousand years. During this period, the south Puget Sound prairies became established on well-drained glacial outwash, and oak woodlands occupied the transitional areas between open prairie and surrounding forest. These oak woodlands were distinguished by open canopies that allowed understory grasses to persist to varying degrees, ranging from open savannahs with few trees to woodlands with denser canopies and abundant understory shrubs.

It is estimated that as many as 160,000 acres of prairie once existed in the south Puget Sound region (Fort Lewis 2005). The prairies were maintained in part by Native Americans, who burned the grasslands in the summer and fall to encourage the growth of camas (*Camassia* sp.), a prairie-dependent herbaceous perennial with a nutritious bulb that was harvested for food by the local tribes (Fort Lewis 2005). These periodic fires suppressed Douglas-fir, as well as other conifer and Oregon white oak trees, and helped to maintain open grassland conditions.

3.6.2 Existing Upland Habitat Conditions

The Puget Sound lowlands currently support a number of land uses, including urban development, agriculture, and resource extraction (e.g., gravel mining, timber, and water). These and other anthropomorphic activities have affected the lowland forest and prairie habitats in the region, including habitats within the confines of Fort Lewis.

Plant Communities within the Upland Habitats of Fort Lewis

Fort Lewis contains some of the largest expanses of undeveloped low-elevation habitat remaining in the Puget Sound area. Conifer forests dominate nearly three-fifths of Fort Lewis, including 36,600 acres of dry-site Douglas-fir forest; 9,600 acres of moist Douglas-fir, western red cedar (*Thuja plicata*), and western hemlock forest; and scattered or small pure stands of ponderosa pine (*Pinus ponderosa*) and lodgepole pine, comprising 1,700 acres. The majority of forest stands on Fort Lewis are of a similar age (45 to 85 year-old trees). Fort Lewis contains approximately 3,500 acres of oak woodland and 20,700 aces of prairie/grassland habitat (U.S. Army 2005a). To put this number in perspective, the total remaining native prairie in the Puget Sound area is estimated to total approximately 23,000 acres (Fort Lewis 2005).

Much of the Murray/Sequalitchew watershed lies within the Fort Lewis cantonment area. As a result of this concentration of human activity and development in the cantonment area, only limited amounts of coniferous forest, oak woodland, and prairie habitat remain in the Murray/Sequalitchew watershed (see Figure 3.3-2). The Upper Murray subbasin contains a patch of prairie land surrounded primarily by forest. The Middle and Lower Murray subbasins contain forest stands abutting areas of development to the west and larger expanses of forest or prairie lands extending south and east beyond the Murray/Sequalitchew watershed boundaries. Forest surrounds Sequalitchew Lake and extends outward from the Sequalitchew subbasin eastern, southern, and western limits. Small forest stands are interspersed with development along the south and west sides of American Lake within the American Lake subbasin.

Protected Plant Species within Upland Habitats

Two special status upland plant species are known to occur on Fort Lewis: white-top aster (*Aster curtus*), a species of special concern under the Endangered Species Act and a Washington state sensitive species, and pine-foot (*Pityopus californica*), a Washington state sensitive species (Fort Lewis 2001).

White-top aster is a regional endemic perennial forb with tightly clustered flowers on the ends of shoots that spreads via rhizomes. White-top aster occurs only on low-elevation, open to partially wooded, prairies with greater than 50 percent cover of native species (Thomas and Carey 1996). Without the controlling influence of fire, native species such as Douglas-fir and invasive species such as Scotch broom (*Cytisus scoparius*) are encroaching on the white-top aster's prairie habitat. Within the Murray/Sequalitchew watershed, white-top aster has been located throughout the northern portion of the Lower Murray subbasin and the northern and eastern portions of the Upper Murray subbasin (Thomas and Carey 1996).

Pine-foot is a saprophytic plant that grows in second-growth mixed coniferous forests at low elevations, in association with eurhynchium moss (*Eurhynchium oreganum*). It is known from one recent occurrence on the southern extent of Fort Lewis (WDNR 2003). It is not known to occur in the Murray/Sequalitchew watershed.

Noxious Weed Species within Upland Habitats

In the cantonment area, noxious weeds predominantly occur along fence lines, buildings, roads, and open spaces. Unwanted species include Scotch broom, tansy ragwort (*Senecio jacobaea*), several knapweeds (*Centaurea* spp.), and Himalayan blackberry (*Rubus armeniacus,* formerly *R. discolor*). The Fort Lewis Fish and Wildlife Program and Integrated Training Area Management (ITAM) Program are responsible for controlling Scotch broom and unwanted plants in the training areas. Most of the control effort has focused on Scotch broom. Control efforts include mechanical control, hand and machine removal, tree girdling, controlled burns, establishment of desirable cover, and use of residual and nonresidual herbicides.

Wildlife Species that use Upland Habitats in the Vicinity of Fort Lewis

A variety of terrestrial wildlife species use the coniferous forests, oak woodlands, and prairie habitats on Fort Lewis. A total of 17 species of reptiles and amphibians, 174 species of birds, and 57 species of mammals have been recorded on or within the vicinity of Fort Lewis (U.S. Army 1998a).

In contrast to surrounding areas that have undergone urbanization, Fort Lewis contains large expanses of undeveloped upland habitat. This habitat contains many wildlife species whose presence affects management decisions for the upland areas. Mammals found here include black-tailed deer (*Odeocoileus hemionus*), raccoon (*Procyon lotor*), coyote (*Canis latrans*), black bear (*Ursus americanus*), and a number of types of bats. All of these mammals heavily utilize upland areas. Forested areas within Fort Lewis provide trees and snags, important habitat for several bird species. Oak woodlands provide important forage and nesting habitat. Prairies on the installation provide habitat for a number of species, including the Mazama pocket gopher (*Thomomys mazama*) and several bird and butterfly species specifically adapted to the Fort Lewis prairie environment (U.S Army 2005c).

Critical Habitat for Protected Wildlife Species

Due to habitat alteration throughout the Puget Sound region, many wildlife species have been listed as threatened or endangered by state and federal agencies. Within the vicinity of Fort Lewis, a large percentage of oak woodlands and prairie habitats on Fort Lewis have been altered by the suppression of fire and the subsequent invasion of trees and Scotch broom. Yet the oak woodlands provide habitat for a number of rare animals, including the western gray squirrel (*Sciurus griseus*), and several bird species.

Currently northern spotted owl (*Strix occidentalis caurina*), a federal threatened species and state endangered species, is the only species for which critical habitat has been designated on Fort Lewis. A candidate species conservation agreement is currently under development for several federal candidate species. This agreement would identify areas on Fort Lewis that provide habitat for species under consideration for listing under the Endangered Species Act.

To support recovery of endangered, threatened and candidate species, efforts are made to protect the existing habitats that these species use. Table 3.6-1 (U.S. Fish and Wildlife Service [USFWS]

2005; WDFW 2005) provides a list of special status wildlife species that may be found on or within the vicinity of Fort Lewis. Although some of these species have not been documented on the installation in recent years, potential habitat for these animals is present on Fort Lewis. For this reason, the WDFW has listed some of these habitat areas as Washington state priority habitat (WDFW 1998).

Table 3.6-1 Special Status Wildlife Species That May Be Found On or Near Fort Lewis.

Common Name	Scientific Name	Federal Status	State Status
	Invertebrate		
Fender's soliperlan stonefly	*Soliperla fenderi*	SC	–
Mardon skipper	*Polites mardon*	C	E
Taylor's (Whulge) checkerspot	*Euphydryas editha taylori*	C	C
Valley silverspot	*Speyeria zerene bremeri*	SC	C
	Reptile and Amphibian		
Cascade frog	*Rana cascadae*	SC	–
Northwestern pond turtle	*Clemmys marmorata marmorata*	SC	E
Oregon spotted frog*	*Rana pretiosa*	C	E
Tailed frog*	*Ascaphus truei*	SC	–
Van Dyke's salamander	*Plethodon vandykei*	SC	C
Western toad	*Bufo boreas*	SC	C
	Bird		
Bald eagle	*Haliaeetus leucocephalus*	T	T
Marbled murrelet	*Brachyramphus marmoratus*	T	T
Northern goshawk	*Accipiter gentilis*	SC	C
Northern spotted owl*	*Strix occidentalis caurina*	T	E
Olive-sided flycatcher	*Contopus borealis*	SC	–
Oregon vesper sparrow	*Pooectetes gramineus affinis*	SC	C
Peregrine falcon	*Falco peregrinus*	SC	S
Slender-billed, white-breasted nuthatch	*Sitta carolinensis aculeata*	SC	C
Streaked horned lark	*Eremophila alpestris strigata*	C	C
	Mammal		
California wolverine*	*Gulo gulo luteus*	SC	C
Long-eared myotis	*Myotis evotis*	SC	–
Long-legged myotis	*Myotis volans*	SC	–
Mazama pocket gopher	*Thomomys mazama*	C	C
Pacific fisher*	*Martes pennanti pacifica*	SC	E
Pacific Townsend's big-eared bat	*Corynorhinus townsendii townsendii*	SC	C
Western gray squirrel	*Sciurus griseus griseus*	SC	T

E = endangered; T = threatened; C = candidate; S = sensitive; and SC = species of concern.
* = species not known to occur on Fort Lewis, but potential habitat is present.
Sources: Adapted from USFWS (2005a, b) and WDFW (2005).

Two protected upland species occur in the Murray/Sequalitchew watershed: the bald eagle (*Haliaeetus leucocephalus*), a federal and state threatened species, and the streaked horned lark (*Eremophila alpestris strigata*), a candidate for federal and state listing. In addition, critical habitat for the northern spotted owl is located within the Murray/Sequalitchew watershed. These critical habitat designations within the Murray/Sequalitchew watershed are depicted on Figure 3.6-1.

Habitat for bald eagles includes mature or old-growth stands of trees that are generally close to open water and that offer good nesting sites, perch trees, and night roosts. There are three bald eagle nesting territories within the American Lake subbasin of the Murray/Sequalitchew watershed (nine overall on Fort Lewis [Stalmaster and ENSR 2003]) as shown in Figure 3.6-1. During the last decade, both nesting and wintering numbers of bald eagles on Fort Lewis have increased.

Bald eagle nest success and productivity at Fort Lewis between 1974 and 2005 have been high on the Nisqually River (80 percent success and 1.37 young per occupied nest) and marshes (80 percent success and 1.20 young per occupied nest), but low on American Lake (49 percent success and 0.75 young per occupied nest), particularly in recent years (Stalmaster and ENSR 2005). Of the 137 young produced at Fort Lewis since 1974, 67 (49 percent) were from nests on the Nisqually River, 40 (29 percent) were from nests on American Lake, and 30 (22 percent) were from nests on marshes. Between 1974 and 2005, success and productivity of Fort Lewis eagle nests have been 67 percent and 1.08 young per occupied nest, respectively; both of these values are higher than the prescribed recovery goals of 65 percent success and 1.0 young per occupied nest.

Eagle nest buffers have been mapped along the American Lake shoreline within the Murray/Sequalitchew watershed. As identified in Fort Lewis Regulation 420-5, protection measures are in place within primary (1,312 feet [400 meters]) and secondary (2,624 feet [800 meters]) zones around nests and communal night roosts on Fort Lewis to avoid impacts on eagles. In addition, there are specific protection measures for each nest, which primarily entail restrictions on aviation activities. All aircraft will fly no lower than 1,000 feet (305 meters) above ground level within 1,000 feet (305 meters) of the Nisqually River between Clear Creek Hatchery and the mouth of Muck Creek from December 15 to March 31. Parachute training on American Lake may be scheduled outside the bald eagle nesting season (breeding period from February 1 to August 15), when human activity has the highest potential to disturb nesting eagles.

Habitat for the streaked horned lark includes the remnant grasslands on open prairies with sparse, low vegetation. The streaked horned lark uses these areas for breeding (U.S. Army 2005c). In the watershed, streaked horned lark habitat has been mapped at Gray Army Airfield.

Historically, the northern spotted owl inhabited most of the major types of coniferous forests in the Pacific Northwest, including coastal Douglas-fir and western hemlock forests, and Pacific silver fir (*Abies amabilis*) forests at higher elevations in western Washington. The loss and modification of suitable habitat as a result of timber harvesting throughout the Pacific Northwest

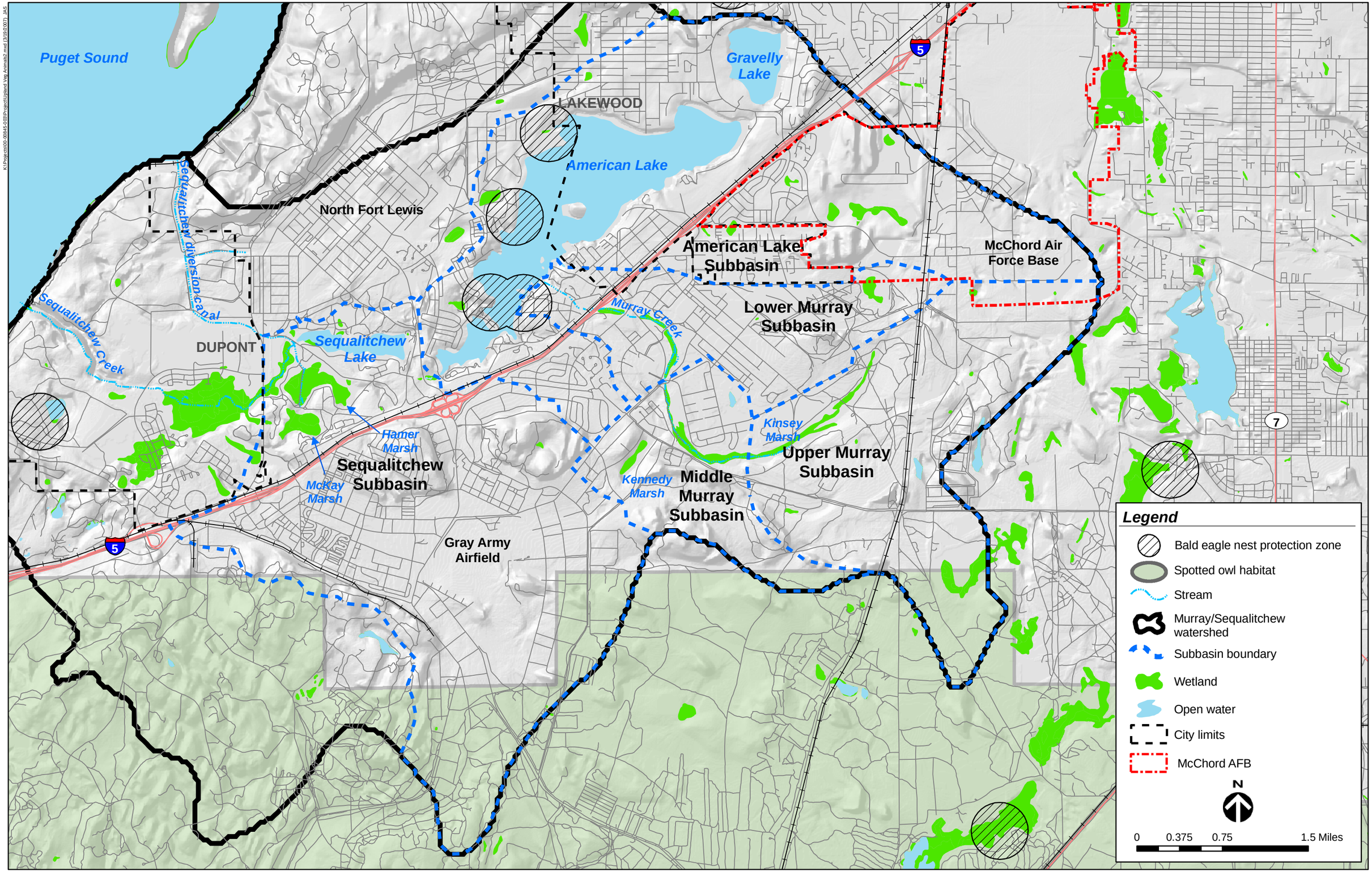

Figure 3.6-1 Upland Habitat Areas Within the Murray/Sequalitchew Watershed.

now threatens the subspecies (U.S. Army 2005c). Fort Lewis is considered a strategic location between known spotted owl populations on the Olympic Peninsula and the western Cascade Range. Suitable habitat for the northern spotted owl on Fort Lewis was identified and mapped by the U.S. Fish and Wildlife Service in 1991 and 1992, resulting in just over 52,000 acres of Fort Lewis being designated as critical habitat. The designated critical habitat for spotted owl extends into the forested areas occupying the southern tips of the Upper Murray, Middle Murray, and Sequalitchew subbasins within the Murray/Sequalitchew watershed (see Figure 3.6-1). To protect northern spotted owl habitat on the installation, the Army considers spotted owl habitat requirements when implementing forest management practices, emphasizing thinning regimes that create a diverse forest structure of mixed age (Bottorff 1994). No observations of spotted owls have been documented in the Murray/Sequalitchew watershed since surveys began in 1991 (ENSR 2003).

Although they have not been observed on the installation, marbled murrelets (*Brachyramphus marmoratus*) have been observed near Fort Lewis on the Nisqually River and along the shorelines of Puget Sound west of the Murray/Sequalitchew watershed and near the mouth of Sequalitchew Creek. The marbled murrelet is a marine bird species that nests in the upper branches of coniferous trees in older forests along the marine coast and inland up to approximately 40 miles (Hamer and Cummins 1991). Marbled murrelets spend most of their lives on the ocean, and come inland to nest, although they visit some inland forests during all months of the year. In Washington, nest sites are located in stands dominated by Douglas-fir. The murrelets seem to prefer stands of old growth covering greater than 500 acres (Hamer and Cummins 1990).

Upland Habitat Supporting Game Fish and Wildlife Species

Where it does not interfere with military training activities, hunting and fishing are allowed throughout much of Fort Lewis. Upland game species present at Fort Lewis include black bear and black-tailed deer, small game such as rabbit and coyote, and upland birds. Recent surveys suggested that there are approximately 10 to 12 black bears at Fort Lewis. Black-tailed deer are common throughout most of the installation, especially in wooded areas and near grassland edges.

Bobwhite quail (*Colinus virginianus*) and ring-necked pheasant (*Phasianus colchicus*) are the most common upland game species on the installation. Approximately 2,000 to 5,000 pheasants are released annually on controlled hunting areas during October and November; most of these pheasants are killed by hunters.

Game fish are stocked in American Lake, and are accessible to sport fishermen in portions of the lake that are outside the Fort Lewis boundary (ENSR 2000). More information on fisheries is provided in the Aquatic Habitat and Fisheries section of this plan (see Section 3.9).

Context for Managing Upland Habitat in the Murray/Sequalitchew Watershed

Currently, management of the extensive upland habitat at Fort Lewis is implemented within the broader context of the Fort's mission as a military installation, rather than within a watershed

framework. As described in the *Final Integrated Natural Resources Management Plan* (ENSR 2000), the Forestry and Fish and Wildlife programs manage upland forest and prairie lands on the installation to meet multiple goals, including:

- Improving troop training opportunities
- Developing and maintaining late-successional forests
- Maintaining and restoring native biological diversity and unique plant communities
- Maintaining low risk of catastrophic fire
- Maintaining and enhancing fish, wildlife, and wetland habitats

Watershed management efforts will need to address and incorporate these goals for maintaining and restoring upland habitat. The *Prairie Management Plan for Fort Lewis Military Installation* (Altman 2003) and the *Management Strategy for Oak Woodlands on the Fort Lewis Military Reservation* (GBA Forestry 2002) provide the foundation for the protection and management of these upland habitats by Fort Lewis.

3.6.3 Primary Upland Habitat Data Sources and Data Gaps

Data Sources

Primary information sources used in this section on upland plants and animals at Fort Lewis include the following:

- *Final Integrated Natural Resources Management Plan* (ENSR 2000)
- *2005 Fish and Wildlife Management Plan* (U.S. Army 2005c)
- GIS data for Fort Lewis (U.S. Army 2005d)
- *Endangered, Threatened, and Sensitive Plants of Fort Lewis, Washington* (Thomas and Carey 1996)

In addition, Fort Lewis, The Nature Conservancy, WDFW, the University of Washington, Camp Murray, and others have carried out numerous joint projects at Fort Lewis, including species inventories, vegetation mapping, ecological restoration of pine savannahs and oak woodlands, and research on how to best manage some of the forest types on Fort Lewis for timber harvest and enhancement of biological diversity.

Data Gaps

Inventories and information about the prairie and forest habitat resources within the Murray/Sequalitchew watershed are lacking. Army personnel should work with GIS support staff to update records and make sure existing information is readily available.

3.6.4 Previous Study Recommendations for Upland Habitat

The Thomas and Carey (1996) study made several recommendations:

- Protect populations of special status plants from military training and vehicles; establish biodiversity preserves; improve and maintain critical prairie areas that contain protected species or that have high percentages of native species and little or no evidence of competition with invasive species or disturbance by military training or historical grazing.

- Analyze the amount of genetic variation within Fort Lewis white-top aster populations and its effect on a population's ability to respond to environmental pressures and change.

- Perform basic monitoring, tailored to each of the protected species, to facilitate an adaptive management approach to protecting endangered flora at Fort Lewis. This is currently being conducted.

Other recommendations have included the following:

- Promote the development of uneven-aged stands, thereby providing a greater diversity of forest habitat. Fort Lewis has recognized that most forests within the installation are of a similar age and do not contain stands that have developed the structural characteristics of mature and old growth forests. However, silvicultural practices have been implemented that promote more habitat diversity, in accordance with the Northern Spotted Owl Habitat Management Plan (Bottorff 1994).

- Manage forestlands in to develop the characteristics of northern spotted owl habitat as detailed in the *Northern Spotted Owl Habitat Management Plan for Designated Conservation Area WA-43, Fort Lewis, Washington* (Bottorff 1994). This recommendation is currently being conducted, as described in the Forest Management Strategy (U.S. Army 2005b).

- Address low water levels in Murray Creek and Sequalitchew Creek (see detailed discussion in the surface water section of this plan). Shapiro (1997b) recommended that stormwater runoff from developed areas throughout the watershed be infiltrated whenever site conditions permit to maximize ground water recharge. Infiltration is naturally promoted in open upland areas with vegetation. Stormwater outfalls of low flow could be directed to open natural buffer areas (i.e., prairies and forests, as well as grassy open spaces in the cantonment area) and infiltration ponds, where effective infiltration could occur.

3.6.5 Key Upland Habitat Issues

The following summarizes major issues for upland areas applicable throughout the installation (not specifically in the Murray/Sequalitchew watershed).

The intensity of use at Fort Lewis will continue to increase in the coming years, increasing the likelihood that important upland habitat areas will become disconnected from one another, and from riparian areas. More study is needed to determine how to best preserve this connectivity to help with future preservation and survival of a number of important species within the installation.

Fort Lewis has little late-successional forest (at least 200 years old). Existing forest stands are primarily even-aged, resulting in a less biodiversity than mixed-age stands. Fort Lewis planners are aware of these conditions and have implemented management actions.

Invasion of prairies by trees and invasive shrubs, such as Douglas-fir and Scotch broom, is changing open prairie grasslands into shrub or forest land, and displacing prairie-dependent flora and fauna (Fort Lewis 2005). Preliminary analysis of data collected by the Land Condition Trend Analysis (LCTA) (now known as Range and Training Land Assessment [RTLA]) component of ITAM in 2001 indicated detrimental effects of training activities on Fort Lewis prairies, including soil compaction, loss of soil crusts, decrease in native grass cover, and increase in nonnative grass and forb cover (Wolford 2001).

The continued loss of prairie and oak habitat is a threat to the streaked horned lark, prairie butterflies, Mazama pocket gopher, and western gray squirrel. The regional *South Puget Sound Prairies Site Conservation Plan* (Nature Conservancy 2002) lists the streaked horned lark as a species of concern. Streaked horned larks use habitat that is sparsely vegetated with relatively short annual grasses; they avoid areas dominated by shrubs, perennial bunchgrasses, and sod-forming perennial grasses.

Fort Lewis plans to enhance certain areas of habitat for this species by removing Scotch broom and other nonnative species, controlling prairie invasion by Douglas-fir, restoring prairies damaged by troop training activities, and increasing native prairie vegetation through replanting efforts (U.S. Army 2005c).

White-top aster cover grows less densely in areas with tree cover than in areas with an open canopy. Native species such as Douglas-fir are encroaching on prairie habitat, which threatens white-top aster. Other threats to white-top aster include nonnative species and physical disturbance by off-road vehicles and military training activities (Thomas and Carey 1996). The small range for pine-foot in Washington and the small number of known occurrences are a concern for this species. Any disturbance to the immediate habitat, such as timber harvest, recreational activities, or military training exercises could constitute a threat to pine-foot (WDNR 2003).

3.6.6 Potential Solutions for Upland Habitat

- Continue the active program of monitoring and tracking monitoring data for special status species and their habitat at Fort Lewis. Use this information to facilitate an adaptive management approach for protecting special status species and critical habitat in coordination with the Fort Lewis training mission.
- Ensure ongoing communications with training area managers regarding monitoring results for Endangered Species Act listed and candidate species and other species of special interest. This communication is beneficial in the coordination of the training mission with current habitat protection and restoration efforts.
- Continue to seek opportunities to conduct collaborative studies on Fort Lewis property with outside entities (e.g., The Nature Conservancy and University of Washington) to add to the knowledge base for species of special interest and to identify and test innovative methods for protecting critical habitat within the Fort Lewis boundaries.
- Use native prairie seed when replanting open patches or newly disturbed upland areas within the installation.
- Continue the active program to remove Scotch broom and other invasive exotic species in upland forests and prairies.

3.7 Wetlands

Wetlands are habitats that are characterized by being moist or wet during the growing season, having soils that show evidence of past or current saturation, and having plants that are tolerant of water within the root zone during all or extended portions of the year. Wetland habitat has been lost at an alarming rate in North America during the past century, primarily because of conversion to upland habitat for agriculture, commercial, and residential development, some of the same factors that have affected wetlands on Fort Lewis. Wetlands provide unique environmental training and educational opportunities, habitat for fish and wildlife, and recreational opportunities. Many fish and wildlife species spend all or a portion of their lives in wetlands. Because of their unique characteristics, wetlands have been given special protection under the Clean Water Act.

3.7.1 Historical Wetland Conditions

Many wetlands historically located in the vicinity of present-day Fort Lewis, were ditched and drained for agricultural purposes prior to the establishment of the Fort Lewis Military Reservation in 1917. Under Army stewardship, some wetlands have been degraded by military activities, primarily maneuvers into and near wetlands that disturb wetland structure, soil, vegetation, and habitat. In addition, invasive vegetation has impacted many wetlands on the installation.

However, projects on the installation have reclaimed lost wetland habitat and created more open water habitat. Recent efforts have focused on controlling invasive vegetation and improving fish habitat, especially for anadromous fish. Reclamation efforts have included water level manipulation through dike construction and mechanical vegetation removal. This reclamation was intended to improve habitat for species dependent upon wetlands to meet life requisites, including waterfowl, amphibians, and fish.

Most wetland restoration at Fort Lewis occurred in the 1970s and 1980s, including the restoration of approximately 600 acres of wetland habitat (Kerschke 1997). For example, the Army installed dikes for water level manipulation in Johnson, Watkins, Hardhack, and Spanaway marshes, and on Chambers Lake (U.S. Army 1998a).

Existing Wetland Conditions

Fort Lewis has approximately 4,500 acres of wetlands and open water habitat, accounting for about 5 percent of the Fort Lewis land base. Wetlands are widely distributed throughout Fort Lewis as shallow marshes and riparian corridors associated with rivers and creeks (CH2M Hill 1994; Kerschke 1997). Freshwater wetlands consist of both kettle (small freshwater glacially formed wetlands) and large wetland systems. Many lakes and marshes are surface expressions of ground water and have no inlet or outlet streams. These wetlands may act as ground water discharge or recharge areas, depending on seasonal changes in the water table and the direction of ground water flow.

Approximately 38 percent of Fort Lewis wetlands, including the surface areas of Gravelly, American, and Sequalitchew lakes, are located in the watershed. Approximately 77 percent of the wetlands in the watershed are open water and lacustrine wetlands. The remaining wetlands include emergent and aquatic beds (2 percent), scrub/shrub (13 percent) and forested (8 percent) wetlands (Figure 3.7-1).

Wetlands in the Murray Subbasins

Wetlands in Upper, Middle and Lower Murray subbasins primarily consist of forested wetlands (112 acres) associated with Kinsey Marsh, and with the Murray Creek riparian zone in the upper and middle subbasins (USFWS 1981; Hall 2005).

Wetlands in the American Lake Subbasin

The American Lake subbasin wetlands primarily consist of 1,236 acres of open water and lacustrine wetlands associated with American and Gravelly Lake, including the surface areas of American and Gravelly lakes (1,233 acres). In addition, there are 5 acres of emergent and aquatic bed wetlands, 50 acres of scrub/shrub wetlands, and 6 acres of forested wetlands (USFWS 1981, Hall 2005).

Wetlands in the Sequalitchew Subbasin

The Sequalitchew subbasin wetlands primarily consist of 118 acres of scrub/shrub wetlands with a large open-water and lacustrine wetland component, 80 acres of which are associated with

Sequalitchew Lake. Four acres are emergent and aquatic bed wetlands, and 15 acres are forested wetlands. The wetlands are well-clustered downstream (southwest) of Sequalitchew Lake on the north side of Interstate 5. Only one small scrub/shrub wetland is located to the southeast of Interstate 5, with two artificially flooded ponds that total 1.1 acres (USFWS 1981, Hall 2005).

McKay Marsh

McKay Marsh is a 37-acre marsh located between DuPont-Steilacoom Road and Interstate 5. McKay Marsh is bounded by higher ground to the south, west, and east, and by a road grade to the north. McKay Marsh has a different plant community than the other marshes at Fort Lewis, possibly because of its historic bog hydrology and its previous use as farmland (Newling 2004). The primary inflow to the marsh is from a small channel draining from Bell Marsh. The channel drains toward the northern edge of the marsh where beavers have constructed a dam that controls water levels before draining into Hamer Marsh. McKay Marsh has an extensive invasion of reed canarygrass (*Phalaris arundinacea*) due to fluctuations in hydrology that have reduced the competitiveness of native bog plants such as western bog-laurel (*Kalmia microphylla*) and Labrador tea (*Ledum groenlandicum*; Gilbert 2005).

Hamer Marsh

Hamer Marsh is a 69-acre marsh located immediately downstream of McKay Marsh. Hamer Marsh is fed by McKay Marsh and stormwater runoff from Fort Lewis. An active beaver dam controls the water elevation in Hamer Marsh, before the water drains into the diversion channel.

Sequalitchew Creek Marsh

Hamer Marsh is separated from Sequalitchew Creek Marsh, which is a 32-acre marsh with an open central channel, by a gravel roadway where the marshes were previously connected. Subsurface flow connects the two marshes currently. A beaver dam separates the Sequalitchew Creek marsh from the outlet on the west end of the lake, retaining water in the marsh at a higher elevation than that of Sequalitchew Lake's surface.

3.7.2 Wetland Management and Protection at Fort Lewis

Wetlands within Fort Lewis are managed by the Fish and Wildlife Management Program. Wetland hydrology has been recorded and plant community types and boundaries were identified. Information from wetland mapping was entered into the Fort Lewis GIS database for future retrieval when evaluating training activities and other activities that affect wetlands (see Figure 3.7-1).

Several wetlands that were drained or ditched in the past have been restored to open water conditions with the use of dikes and other water control structures. The Army has removed invasive aquatic vegetation, such as reed canarygrass from streams and wetlands, and has installed logs and other natural fish habitat features in streams. These activities have greatly benefited the fish and wildlife and recreational users of these wetlands.

The Army evaluates the potential impacts of training activities and construction projects that may impact wetlands on Fort Lewis. These actions may involve wetland permits, including WDFW hydraulic project approvals and federal Clean Water Act Section 401 and Section 404 permits.

Stream and river crossings are restricted to authorized ford sites, and this restriction may require changes in training activities. Fort Lewis regulation 200-1 (U.S. Army 1997b, 1998b) mandates a 50-meter buffer around wetlands, limiting vehicular travel to existing roads within this buffer zone. All activities that may impact wetlands with known populations of water howellia (*Howellia aquatilis*; a federal threatened species) are prohibited or require review to determine the potential impacts on this plant. The Army routinely monitors forestry activities near wetlands during its review of proposed timber sales.

One of the goals of wetland management at Fort Lewis has been to create approximately 50 percent open-water habitat in unforested wetlands to increase wetland habitat diversity. Mechanical vegetation removal and herbicide spraying have been used in some wetlands to reduce the amount of aquatic vegetation and to create more open water. This goal has not been achieved, however, because the acreage of invasive vegetation continues to increase and there are limited funding and personnel.

Wetland Interpretation at McKay Marsh

The McKay Marsh interpretative trail has been developed to spotlight the unique features of a wetland environment. The trail is located adjacent to McKay Marsh, just north of the Fort Lewis military museum, in the Sequalitchew Lake drainage. The marsh area supports a variety of plants and animals, and with the exception of an occasional foot soldier or vehicle on nearby roads, the area is relatively undisturbed by humans. The goal of the trail is to introduce visitors to a relatively undisturbed wetland environment and the plant and animal species found therein.

Threatened, Endangered, and Special Concern Plants in Fort Lewis Wetlands

Surveys at Fort Lewis have found three rare wetland plant species that are listed by the Washington Natural Heritage Information System as federal or state species of concern. These are listed in Table 3.7-1.

Table 3.7-1 Rare Wetland Plants at Fort Lewis.

Common Name	Scientific Name	Federal Status [a]	State Status [b]
Water howellia	*Howellia aquatilis*	FT	ST
Bristly sedge	*Carex comosa*	SC	SS
Small-flowered trillium	*Trillium parviflorum*	–	SS

Sources: USFWS (2005) and WDNR (1998a).
[a] FT = federal threatened; and SC = federal species of concern.
[b] ST = state threatened; and SS = state sensitive.

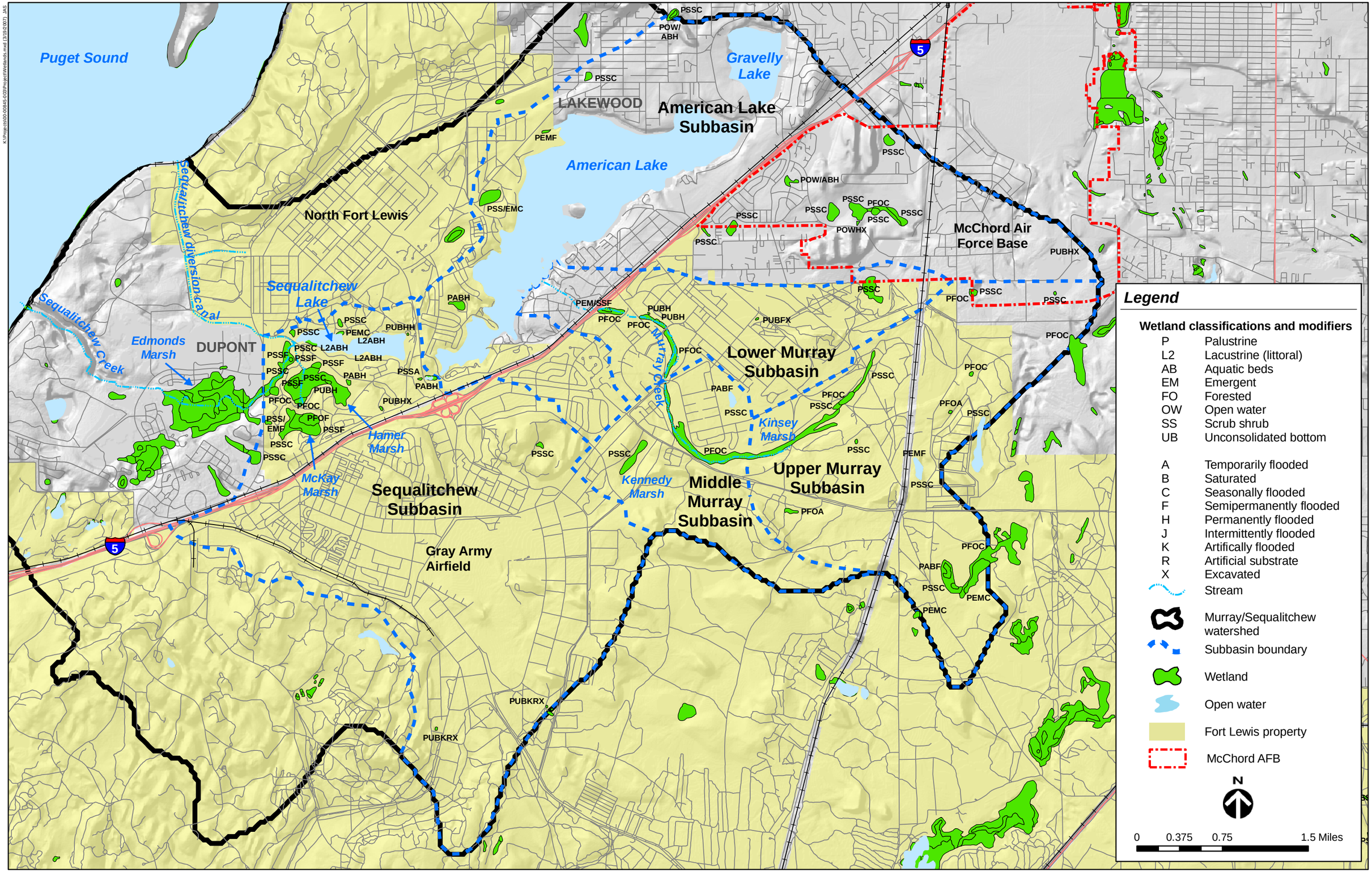

Figure 3.7-1 Wetlands in the American Lake, Murray Creek, and Sequalitchew Subbasins at Fort Lewis.

Water Howellia

Water howellia is an annual aquatic herb with fragile, submerged and floating stems that produce small, white flowers. It has a scattered distribution in the Pacific Northwest, where it is known to be extant in Idaho, Montana, and Washington, and historically known from California and Oregon. In western Washington, the greatest number of occurrences of this species is at Fort Lewis, where it is found in 22 wetlands, near deciduous hardwood canopies. These wetlands occur within the Ammunition Storage Area and in Training Areas 6, 8, 11, 12, and 13 in the American Lake and Upper Murray subbasins. These populations have been monitored since 1998 and appear to be stable (U.S. Army 2005c). Other occurrences of water howellia in the region include two locations on McChord Air Force Base, one location in Thurston County, and one location in Clark County.

Water howellia grows in firm, consolidated clay and organic sediments that occur in freshwater wetlands filled by spring rains and snowmelt runoff and exhibit some drying during the growing season. The species' microhabitat consists of shallow water and the edges of deep ponds that are partially surrounded by broadleaf deciduous trees. One of the key habitat features necessary for water howellia survival is the drying of wetlands during the autumn to allow seed germination, followed by submergence of the wetland in the spring to permit growth and flowering. At Fort Lewis, the plant is generally restricted to wetlands that are seasonally inundated and bordered by Douglas-fir dominated forests that also have Oregon ash (*Fraxinus latifolia*). Water howellia has been found in relatively open wetlands near Chambers Lake that have little surrounding deciduous forest (Kerschke 1997).

The wetlands at Fort Lewis that have populations of water howellia range in size from less than 1 acre to 40 acres, contain substrate of either Tanwax peat or Semiahmoo muck, and undergo significant annual fluctuations in water level (Gamon 1998). No water howellia sightings have been reported in the North Fort Lewis area.

Activities affecting either the surface or subsurface hydrology of wetlands can negatively impact this species. Thus, indirect impacts to wetlands from timber harvests and road construction near wetlands, and direct impacts from wetland alteration, pose threats to water howellia at Fort Lewis. Genetic variability between populations of water howellia appears to be quite low and adds to the vulnerability of the species (U.S. Army 2005c).

The Washington state population has declined due to competition with introduced plants, loss of wetland habitat, and changes in habitat caused by timber harvesting, livestock grazing, and residential development.

The Washington Natural Heritage Program developed and implemented a monitoring strategy for water howellia at Fort Lewis during 1998. The Fish and Wildlife Program surveys water howellia populations and determines the relative abundance of water howellia in wetlands, monitors populations over time, and installs signs where plants are present to discourage intrusion by humans into these areas.

Bristly Sedge

Bristly sedge (*Carex comosa*), a densely tufted, perennial grass-like herb up to 24 inches tall, often forming large clumps, is a federal species of concern. Bristly sedge is found from Quebec south to Florida and Louisiana, with distinct populations in Washington, Oregon, California, and northern Idaho, where it is rarely found. Bristly sedge prefers freshwater marshes, swamps, lakeshores, ditches, and wet meadows. Bristly sedge grows in open areas of standing water that are not shaded by forbs or woody plants. It flowers and produces fruits from late May through August.

Thomas and Carey (1996) found bristly sedge at McKay Marsh in 1992 and at Sequalitchew Lake in 1993 during surveys at Fort Lewis. They found 20 clumps (individuals) on the south side of Sequalitchew Lake and six clumps spread over a broad area on the north side of McKay Marsh. The substrate in which bristly sedge was found consisted of sandy loam or fine silt over gravely glacial outwash. Later surveys by Fort Lewis found 108 individual plants at McKay Marsh and 5 individuals at Sequalitchew Lake. The survey also determined that 22 of the McKay Marsh individuals were fruiting, which suggests a healthy, reproducing population.

Small-Flowered Trillium

Small-flowered trillium (*Trillium parviflorum*) is a Washington state sensitive species. It is an erect perennial up to 12 inches tall with three large mottled leaves at the top of the stem. A single flower, with three narrow white petals, rests directly atop leaves. The flower has a pleasant clove-like fragrance. The primary factors responsible for small-flowered trillium's protected status include its small range, the isolated nature of its habitat, and the vulnerability of the habitat to change. Small-flowered trillium is regionally endemic and is found from Pierce and Thurston counties southward into Lewis and Clark counties, Washington, and into the Willamette Valley in Oregon. Small-flowered trillium is an uncommon species with local distributions of only a few, widely scattered populations.

Small-flowered trillium requires a moist, shady environment. Many sites where it occurs are within a riparian zone, but near the upland edge of the zone. Sites where small-flowered trillium is found may undergo periodic winter flooding. Hydrologic change, development, and grazing pressure are the primary threats to the species' habitat. The keys to retaining populations of small-flowered trillium include retaining the hardwood overstory, minimizing human disturbance, and preventing the introduction of invasive plant species (U.S. Army 2005c).

3.7.3 Primary Wetland Data Sources and Data Gaps

Although there have been many natural resource and wetland studies at Fort Lewis, there is not one consistent set of baseline data for all wetlands on the installation. Once established, the baseline wetland information for Fort Lewis as a whole can then be used to define goals and objectives for management of the remaining wetland resources.

Recommendations for wetlands have been presented in the *Fort Lewis Fish and Wildlife Five-Year Management Plan* (U.S. Army 2005c). They are in the form of generic strategies to avoid

impacts, control invasive plants, and improve habitat through several actions. Those most applicable to watershed wetlands include enforcement of a 50-meter buffer around wetlands and control of reed canarygrass. More specific strategies for wetlands include:

- Maintain 50 to 75 percent woody and emergent vegetation in shallow wetlands
- Manage for up to 50 percent open water habitat in major wetlands

3.7.4 Key Wetland Issues

Lack of Cohesive Mapping

Lack of cohesive baseline data presents challenges for managing wetlands in relationship to the military mission. Improved data would help implement the wetland maintenance and restoration strategies contained in the Fish and Wildlife Management Plan (U.S. Army 1998a).

Noxious Weeds in Fort Lewis Wetlands

Pierce County currently targets over 80 noxious weeds in the Fort Lewis area, and noxious weed control is the first priority of the installation's Pest Management Program (U.S. Army 2001b). Among those of greatest threat to Fort Lewis wetlands and open waters are populations of Eurasian watermilfoil (*Myriophyllum spicatum*), reed canarygrass, purple loosestrife (*Lythrum salicaria*), and yellow-flag iris (*Iris pseudacorus*). These plants, when not controlled, crowd out native vegetation and make aquatic systems less suitable for fish and wildlife. The Fish and Wildlife Management Program surveys wetlands for invasive species, and controls invasive species with assistance from the Pest Management Program and the Forestry Program, as needed.

Reed canarygrass is a highly invasive species, with little fish and wildlife habitat value, that replaces native wetland plant species of higher value. This plant tends to block stream channels, reduce flow, and bind spawning gravel within its root system. Past management efforts have focused on removal with mechanical harvesting equipment to create more open water within wetlands. This method, combined with aquatic herbicides certified by the USEPA as safe for use in aquatic habitats, is used to control reed canarygrass within wetlands at Fort Lewis.

Purple loosestrife is found sporadically at Fort Lewis and is controlled by mechanical removal, herbicide, and biological controls.

Eurasian watermilfoil is found on the installation. The Outdoor Recreation Program provides information to boaters on Fort Lewis describing the impacts of Eurasian watermilfoil on wetland habitats and encouraging them to remove milfoil from their boats before entering and leaving lakes on the base.

Animal Pests in Fort Lewis Wetlands

Bullfrogs (*Rana catesbeiana*) are not native to the Puget Sound region. They are found in several wetlands on the base, however, and prey upon fish, ducklings, and other aquatic organisms. Bullfrog populations are indirectly controlled through manipulation of wetland vegetation to increase shading along the shoreline to reduce the availability of loafing sites exposed to sunlight that are favored by bullfrogs. Bullfrogs are edible, but are not a popular game species at Fort Lewis.

Low Availability of Fort Lewis Staff Resources

Natural resources staff has been reduced in recent years and all natural resources tasks are currently shared between two staff members. This level of staffing in natural resources limits the abilities of Fort Lewis to conduct education, monitoring, maintenance, restoration, and preservation activities within its wetland communities. The ability of the natural resources staff to develop a cohesive wetland plan and coordinate with the other departments at Fort Lewis is also limited by lack of resources (U.S. Army 2005c).

Loss of Bog Hydrology in McKay Marsh

McKay Marsh has a large population of reed canarygrass due to fluctuations in hydrology that have reduced the competitiveness of native bog plants such as bog laurel (*Kalmia microphylla*) and Labrador tea (Gilbert 2005).

3.7.5 Potential Solutions for Wetlands

- Continue mapping and documenting each wetland complex to determine functions provided, source of hydrology, flow paths to receiving waters, plant communities, hydrologic stability, presence of weeds, presence of native species and habitat value. The source of wetland information shown in Figure 3.7-1 is National Wetlands Inventory data (USFWS 1981). The map is based on aerial photographs, and while wetlands are generally located correctly, their extent and condition should be verified in the field to develop good baseline data.

- Continue to maintain maps of threatened, endangered, or special concern plants in wetlands across the base. In particular, small-flowered trillium has not been surveyed and mapped across the entire installation.

- Fort Lewis should monitor existing weed populations and identify new populations and species of weeds in Fort Lewis wetlands. This information will enable appropriate weed control methods, ensure that weeds are treated, and determine the success of control methods. This information would be used to develop appropriate weed control programs that are most appropriate for wetlands containing rare plant species, amphibian breeding areas, and fish spawning habitat.

- Determine connectivity, preservation and enhancement opportunities for each wetland to provide needed functions. Develop a maintenance and enhancement plan for each wetland in the three subbasins to provide these improved functions.

- Develop a signage program for each wetland and coordinate with the Environmental Awareness Program to educate the troops regarding the economic and environmental value of wetlands. This education would encourage troops to protect wetlands at their home base as well as in other assigned locations.

- Continue or intensify weed control efforts, especially in wetland areas. Historically, much of the emphasis has been placed on weed control in landscaped areas.

- Determine the extent of coverage of weed populations in wetlands and monitor weeds over time to better assess the effectiveness of control methods. Removal of reed canarygrass may also improve flow and decrease sediment buildup along some sections of Murray Creek.

- While coordination among programs is good, coordination can always be improved. For example, there appears to be no plan that coordinates the resources of programs addressing weed control in wetland areas. The pooling of resources and a long-term, coordinated weed control strategy will be needed to bring invasive weed populations at Fort Lewis under control.

- Fund additional staff positions for natural resources to provide additional resources to document, maintain, and enhance the existing Fort Lewis wetlands.

- Restore bog hydrology to McKay Marsh by rerouting stormwater outfalls currently discharging to McKay Marsh to reduce water level fluctuation and nutrient enrichment to this historical bog system.

3.8 Riparian Habitat

The habitat lying within the stream corridor is known as riparian habitat. A healthy riparian habitat provides a corridor for wildlife movement. Riparian plants provide food for animals along the stream corridor, and trees and shrubs shade the stream and lower water temperatures. Leaves and woody debris from vegetation in the riparian habitat provide organic material to the stream. Larger woody debris that falls into the stream provides shelter for aquatic organisms. Because of its many functions, an assessment of riparian habitat is important to the watershed management plan. There is some overlap between riparian habitat and wetlands. For example,

there are extensive riparian wetlands associated with Murray and Sequalitchew Creeks. However, riparian habitat is treated separately from wetlands in this document because there are distinctions in the management and regulations of wetlands and riparian areas.

3.8.1 Historical Riparian Habitat Conditions

Prior to the formation of Fort Lewis in 1917, the Murray Creek and Sequalitchew Creek areas were likely logged as the area was used for homesteads, ranchland, and agriculture. These riparian forests were likely stands of native conifers and shrubs. A 1975 report on Washington streams and salmon utilization (Williams et al. 1975) described the riparian area of Sequalitchew Creek as large second growth firs, heavy stands of brush, and blackberry vines.

One anthropogenic alteration to riparian vegetation on Fort Lewis was the construction of a diversion structure, which directs streamflow to the Sequalitchew diversion canal draining northward to Puget Sound. The connection between the diversion canal and Sequalitchew Creek at the outlet of Sequalitchew Lake is complex. Because the diversion canal is lower in elevation than Sequalitchew Creek, it has diverted water out of the creek at the lake outlet for the last 50 years, reducing the water level of Sequalitchew Lake and water flow within Sequalitchew Creek. Beaver activity within Sequalitchew Creek frequently causes the creek to back up as well. (Additional information on the diversion canal may be found in the surface water resources section of this plan.) The reduction of the natural water level and flow within the Sequalitchew Creek drainage likely has resulted in a reduction in the vigor of riparian vegetation and riparian functions, and the invasion of nonnative species (Runge et al. 2003). Furthermore, development by Fort Lewis over the years has reduced riparian areas along American Lake and Murray Creek through the addition of impervious surfaces, including residential and commercial buildings, roads, parking lots, and other paved or compacted gravel surfaces. Fort Lewis has been trying to minimize development impacts during the last several years.

3.8.2 Existing Riparian Habitat Conditions

Murray Subbasins and American Lake Subbasin

The riparian areas associated with Murray Creek and American Lake consist of both native and nonnative plant communities. Developed areas, roads, and utility crossings extensively fragment plant cover in the riparian areas of Murray Creek. Additionally, urban land uses along the Murray Creek banks and American Lake shoreline have encroached upon riparian vegetation buffers in some locations (USGS 2005).

The riparian habitat along Murray Creek consists of western red cedar, western hemlock, red alder (*Alnus rubra*), black cottonwood (*Populus balsamifera*), big-leaf maple (*Acer macrophyllum*), salmonberry (*Rubus spectabilis*), red-osier dogwood (*Cornus stolonifera*), Himalayan blackberry and reed canarygrass (ENSR 1998c). Many of these species can be identified near the headwaters of Murray Creek (Figure 3.8-1).

Figure 3.8-1 Photograph of Murray Creek Headwater Riparian Corridor Downstream of Kinsey Marsh.

Several restoration projects have been implemented along Murray Creek (U.S. Army 2005c). Gravel was added to the stream in 1985 to create 300 feet of spawning habitat. Reed canarygrass was removed during the summer of 1994 from 600 feet of stream below MAMC. During the fall of 1994 over 200 trees were planted in that same stream reach. Murray Creek has received several other plantings of native vegetation. For instance, during a restoration project in 2000, Fort Lewis coordinated the removal of invasive weeds and planted native vegetation (Runge et al. 2003). In 2004, a grant allowed Camp Murray to enhance kokanee salmon spawning habitat by removing reed canarygrass, trapping beavers, removing a concrete barrier that restricted flows, and planting over 1,200 feet of Murray Creek with native trees, shrubs, and emergent plants (U.S. Army 2005c).

Other riparian areas provide considerably less habitat for fish and wildlife. The riparian habitat along American Lake consists of large second-growth conifers and dense areas of nonnative plants along the shoreline, including Himalayan blackberry and reed canarygrass (USGS 2005). Landscaped lawns and ornamental vegetation are present along the southeastern shore of the lake. Riparian vegetation along the southwestern lake shore has been removed for recreational waterfront development.

Invasive species appear to have re-established themselves along some sections of Murray Creek previously restored. At the public meeting for this watershed plan on September 7, 2005, it was reported that a large growth of reed canarygrass in Murray Creek at the Interstate 5 crossing had created a buildup of sediment. Without official approval, some guard members cut a channel through the reed canarygrass and sediment, substantially increasing streamflow in Murray Creek downstream of this point.

Sequalitchew Subbasin

The Sequalitchew Lake and Sequalitchew Creek riparian areas consist of both upland and wetland communities that include plant species such as cat-tails (*Typha* spp.), devil's club (*Oplopanax horridus*), salmonberry, vine maple (*Acer circinatum*) and aquatic weeds in the area of Hamer Marsh and Edmond Marsh (Runge et al. 2003; USGS 2005).

According to Williams et al. (1975), parts of the creek and marsh lands are impenetrable from the thick growth along the stream channel. Below Hamer and Edmonds marshes, the creek corridor is lined with red huckleberry (*Vaccinium parvifolium*), creeping buttercup (*Ranunculus repens*), salmonberry, second-growth Douglas-fir, western hemlock, and western red cedar. Riparian areas around Sequalitchew Lake have plant cover similar to that at Sequalitchew Creek below Hamer Marsh, including shrubs and second-growth conifers, as observed during the July11, 2005 site visit (Figure 3.8-2).

Small sections of riparian habitat along the shoreline of Sequalitchew Lake have been modified by military and recreational development, and have limited plant cover. Riparian vegetation along the western, northern, and southern shoreline has been reduced as a result of four different developments; however, small shrubs and trees are present in these areas (USGS 2005). Along the stream banks of Sequalitchew Creek between the outlet of Sequalitchew Lake and Hamer

Marsh, shrubs and trees are present that may provide a source of large woody debris recruitment to the stream channel. Woody debris is important for stream systems to form instream habitat.

3.8.3 Primary Riparian Habitat Data Sources and Data Gaps

Primary sources of information related to riparian habitat include the following:

- Site visit on July 11, 2005
- Runge et al. 2003 – *Salmonid Habitat Limiting Factors Analysis: Chambers-Clover Creek Watershed (Including Sequalitchew Creek and Independent Tributaries), Water Resource Inventory Area 12,* Prepared for Pierce County Conservation District, June 2003
- USGS 2005 – TerraServer aerial photographs. U.S. Geological Survey
- Williams, et al. 1975 – *A Catalog of Washington Streams and Salmon Utilization,* Volume 1: Puget Sound Region, Washington Department of Fisheries

One data gap is the lack of a recent stream survey along the length of Murray Creek to update the previous riparian assessment (Shapiro 1996; ENSR 1998b). Such a study would be useful for identifying key restoration areas and tracking changes over time.

3.8.4 Previous Study Recommendations and Ongoing Research

Recommendations for riparian areas have been presented in the *Fort Lewis Fish and Wildlife Five-Year Management Plan* (U.S. Army 2005c). Most of these recommendations are general strategies to avoid impacts, control invasive plants, and improve habitat through several actions. They include enforcing the 50-meter buffer, controlling reed canarygrass, providing adequate stream crossings, maintaining water control structures, planting native trees and shrubs along streams, and improving spawning habitat by cleaning or adding gravels to streams.

More specific strategies for riparian areas include:

- Maintain and/or create snags, especially near suitable wetlands
- Maintain mast producing trees and shrubs
- Retain patches of mature and old growth forest habitat within 100 meters of aquatic systems
- Leave woody debris within streams and add where absent
- Enhance anadromous fish habitat

Figure 3.8-2 Photograph of Sequalitchew Creek Riparian Corridor Downstream of Diversion Canal.

3.8.5 Key Riparian Habitat Issues

Riparian vegetation functions to regulate stream temperature and provide shade cover for aquatic organisms, as well as remove sediment or specific nutrients such as nitrogen from water entering streams and lakes (Castelle and Johnson 2000). A review of the literature indicates that riparian buffers that contain mature tree canopy cover can moderate stream temperatures similar to fully forested conditions (Knutson and Naef 1997). Breaks in riparian corridors along the shoreline of American Lake and Sequalitchew Lake and the banks of Murray Creek likely inhibit some of these functions. Recreation areas along the banks of American Lake and Sequalitchew Lake, where native vegetation has been replaced with lawns or gravel surfaces, have reduced the effectiveness of shoreline vegetation in removing sediments and pollutants washed from parking lots and roads. The reduced canopy cover along Murray Creek and the shoreline of American Lake limits critical shade habitat for rearing fish, including kokanee salmon, rainbow trout (*Salmo gairdneri*) and cutthroat trout (*Oncorhynchus clarki*).

Forested riparian areas provide a source of large woody debris that creates and maintains habitat complexity and structure, cover, and thermal refugia within the corresponding stream, and creates large woody debris jams that store sediment and moderate instream flood velocities (Christensen et al. 1996; Schindler et al. 2000). In addition, large woody debris occurring along the lake shoreline may help to retain sediments such as gravels, which are of particular importance to beach spawning salmon species (i.e., kokanee). Properly functioning riparian areas are capable of sustaining large woody debris recruitment within streams at a rate of 80 pieces per mile over the long term (National Marine Fisheries Service [NMFS] 1996). Under natural conditions, bank and shoreline erosion undercuts trees that then topple into the water to supply woody debris. Land management practices that reduce the number of standing and downed trees in riparian areas or reduce the width of riparian areas also reduce the ability of riparian areas to provide a source of wood to aquatic systems (May et al. 1997).

Removing the tree canopy from riparian areas encourages the proliferation of nonnative vegetation, which provides less habitat value than native vegetation. Development along Murray Creek has reduced large trees adjacent to the stream. The shoreline of American Lake has been stabilized for development, reducing potential large woody debris recruitment. Therefore, the near-term large woody debris recruitment potential is reduced along Murray Creek and likely compromised along American Lake. Development along the banks of Sequalitchew Lake and Sequalitchew Creek has not resulted in a substantial reduction of riparian areas. Thus, near-term large woody debris recruitment potential is high along Sequalitchew Lake and Sequalitchew Creek outside the marshes (USGS 2005).

3.8.6 Potential Solutions for Riparian Habitat

- Remove invasive vegetation. Invasive, nonnative vegetation should be removed from stream banks and lake shorelines not used for recreation or development to encourage the establishment of native riparian vegetation. This practice may also benefit streamflow.

- Plant trees on stream banks and shorelines. Plant native trees along open areas of streams and lake shorelines to provide shade, moderate water temperature, and provide a future source of large woody debris recruitment, especially in areas of coldwater refugia (see the aquatic habitat and fisheries section below).

3.9 Aquatic Habitat and Fisheries

The streams, wetlands, and lakes within the Murray/Sequalitchew watershed provide a number of benefits to fish and other aquatic organisms, including breeding and cover habitat for invertebrates. Because wetlands are regulated and managed separately from other aquatic habitat types, wetland habitat conditions at Fort Lewis are discussed separately in Section 3.7 of this document. Aquatic habitat is the product of the local geology and watershed hydrology, which influence the ability of a stream or lake to respond to other watershed changes, such as drought conditions. The aquatic habitat present in the Murray/Sequalitchew watershed is also a result of the land use and land cover changes that have occurred since the watershed first became influenced by development in the 19th century. In order to identify areas of habitat loss or gain and to develop recommended actions to recover and restore lost aquatic habitat, information regarding historical and current aquatic habitat locations and use was assembled and assessed.

Fish within the Murray/Sequalitchew watershed occur within Murray Creek, American Lake, Sequalitchew Lake, Sequalitchew Creek and adjacent wetlands. Degraded water quality, low-flow conditions, and invasive vegetation (reed canarygrass) in Murray Creek affect the natural distribution of fish within the channel during summer months (Runge et al. 2003).

3.9.1 Historical Aquatic Habitat and Fishery Conditions

A limited amount of quantitative information regarding the historical conditions of stream and lake habitat within the Murray/Sequalitchew watershed was available. However, historical accounts and the natural topography and geology of the watershed provide clues to what the aquatic habitat may have been like in the past.

Murray Subbasins

Much of the Upper Murray/Sequalitchew watershed has fairly flat topography and thus low stream gradients and lower rates of stream power, which reduce the ability of Murray Creek to recruit and transport sediment. Historically, there was likely very little variation in stream habitat throughout the Murray Creek portions of the watershed. Stream habitat throughout these reaches was most likely dominated by low-gradient glides (areas without surface turbulence with uniform channel bottoms), which are most often used as rearing habitat for trout and salmon, but are not generally used as spawning habitat. The habitat variation that occurred was most likely related to locations of beaver dams and ponding water, or where trees fell into the creek, creating localized scour and pooling. Historically, Murray Creek was not an ephemeral stream and experienced constant streamflow throughout its main stem during the entire calendar year (Andrews and Swint 1994; Clouse 2005).

No historical fish survey information exists for Murray Creek. Fish surveys were conducted in the late 1990s. The results of these surveys, which are thought to represent current fisheries in Murray Creek, are summarized under the existing conditions section.

American Lake Subbasin

The historical morphology of American Lake is much the same as it is today. However, the lake did not have a surface water connection to Puget Sound and thus was not used by anadromous salmon (ENSR 2000). In the 1960s, the water level was lowered when the surface connection between American and Sequalitchew lakes was constructed (Crown 2005b). This action reduced the amount of shoreline habitat available for fish spawning.

A literature review found that American Lake has supported warm-water fishes including largemouth bass (*Micropterus salmoides*), yellow perch (*Perca flavescens*), and common carp (*Cyprinus carpio*; Mueller and Downen 1999). In 1957, the Washington Department of Fisheries implemented a project to rehabilitate and manage American Lake to develop a salmon fishery by eliminating warm-water fishes through the use of a natural piscicide. Within a few years after treatment, populations of warm-water fishes reemerged and began to increase throughout the lake, including rock bass (*Ambloplites rupestris*). During the 1980s, the WDFW began stocking rainbow trout, cutthroat trout, and kokanee salmon annually into the lake to increase the success of recreational anglers (Jenkins 2005). In 1998, the WDFW stocked the lake with smallmouth bass (*Micropterus dolomieui*; Mueller and Downen 1999).

Sequalitchew Subbasin

Due to their varying natural topography, Sequalitchew Creek and Sequalitchew Lake historically provided a variety of aquatic habitat types. The flat topography and peat geology surrounding Sequalitchew Lake and upper Sequalitchew Creek likely provided long glide and pool (section of stream characterized by deep, slow-flowing water) habitat units that could be utilized as rearing habitat for resident salmon that historically accessed the area (Runge et al. 1993).

Sequalitchew Lake and Sequalitchew Creek have been used by anadromous and resident fish, partially because of stocking by the WDFW. Anadromous fish species include chum salmon (*Oncorhynchus keta*), coho salmon, and sea-run cutthroat trout (*Oncorhynchus clarkia*; Runge et al. 2003; Andrews and Swint 1994). Fish released in Sequalitchew Lake migrate down Sequalitchew Creek or through the Sequalitchew diversion canal maintained by Fort Lewis. The WDFW began the release of coho salmon in Sequalitchew Creek and Sequalitchew Lake in the late 1950s. In the late 1970s and early 1980s, up to two million coho fingerlings were released annually. During this time, the high quality of nutrient-rich food required to feed fish resulted in algal blooms and low oxygen levels in Sequalitchew Lake. In response to these problems, WDFW reduced the number of fingerlings released in Sequalitchew Lake to 230,000 smolts. The purpose of the juvenile salmon release program was to increase the quantity of sport and commercial harvest fish (Andrews and Swint 1994). Coho salmon are no longer released into Sequalitchew Lake.

3.9.2 Existing Aquatic Habitat and Fishery Conditions

Murray Subbasins and American Lake Subbasin

Murray Creek – Morphology

Murray Creek consists of three distinct geomorphologic types between Kinsey Marsh and American Lake: 1) a broad, unconfined, non-entrenched wetland; 2) a narrow, moderately confined and entrenched natural channel; and 3) a narrow, unconfined, and moderately entrenched managed channel (Shapiro 1996).

Most stream reaches surveyed in June 1996 were characterized as broad, unconfined, non-entrenched wetlands (Table 3.9-1). This geomorphologic type is found through most of the Upper Murray subbasin and in spots along the middle and Lower Murray subbasins. Wetland soils largely composed of silt and sand substrate (up to 3 feet deep in some places) dominate the surface sediment deposits. When surveyed in 1996, wetted widths throughout these reaches ranged between 26 and 39 feet, and combined with water depths between 1 and 5 feet to produce relatively slow flow velocities (less than 0.5 feet per second). Glides were the predominant habitat unit. There were no actively eroding or unstable areas within reaches of this morphology. Some reaches were swale-like in structure, with a low gradient, and poorly defined channel, while other reaches had defined, U-shaped channel geometry, with distinct beds and banks (Shapiro 1996).

Table 3.9-1 Summary of Murray Creek Channel Morphology.

Primary Geomorphic Type	Sub-Geomorphic Type	Channel Length (ft)	Channel Gradient	Dominant Substrate	Flow Velocity (ft/sec)	Range Width (ft)	Range Depth (ft)
Broad, unconfined, and non-entrenched wetland	Poorly defined and swale-like	600	≤1%	Silt, sand, and vegetation	≤0.5	26 - 39	1 - 5
	Well defined and broad, U-shaped	1,040	≤1%	Silt and sand	≤0.5	26 - 39	1 - 5
Narrow, moderately confined, and entrenched natural channel	U-shaped	650	1 - 3%	Medium - coarse gravel	≥1	10 - 20	0.2 - 1.6
	V-shaped	900	2 - 3%	Medium - coarse gravel	≥1	10 - 20	0.2 - 1.6
Narrow, moderately entrenched, unconfined, and managed	Shallowly entrenched	1,300	1 - 1.5%	Silt, sand on top of fine to coarse gravel, and coarse gravel to cobble	≥1	10 - 16	<1.6
	Moderately entrenched	3,100	1 - 1.5%	Silt, sand on top of fine to coarse gravel, and coarse gravel to cobble	≥1	10 - 16	<1.6

Source: Adapted from Table 2 of Shapiro (1996).

The least common geomorphologic unit consists of reaches with narrow, moderately confined, and moderately entrenched natural channel morphology (Table 3.9-1). These reaches are limited

to a few road crossings and the section of Lower Murray Creek draining into American Lake. These reaches typically have narrower (10 to 20 feet wide), U- to V-shaped channels, with steep banks that sloped between 3 and 8 feet high. Habitat units within this geomorphology are typically riffles (shallow areas in which water flows rapidly over a rocky or gravelly stream bed), with occasional scour pools. The three reaches with this type of geomorphology are located within three short segments upstream of Interstate 5, as well as an 800-foot segment immediately upstream of American Lake.

Reaches characterized as narrow, moderately entrenched, unconfined, and managed are found upstream and downstream of Interstate 5 interspersed with the wetland sections throughout the Middle and Lower Murray subbasins. These reaches typically have narrower (between 10 and 16 feet wide) U-shaped channels, are shallow to moderately entrenched, lack sinuosity, and have stream gradients ranging between 1 and 1.5 percent (Table 3.9-1). Stream substrate consists of thin top layers of silt and sand, overlying a sublayer of coarse gravel to coarse gravel and cobble. Habitat units within this geomorphologic type are typically glides or low-gradient riffles.

The Shapiro (1996) study included sediment core samples collected by hand augers at eight locations along Murray Creek between Kinsey Marsh and Interstate 5. Four of these samples were analyzed mechanically in order to determine particle size distribution. The grain size sieve analysis results are summarized in Table 3.9-2. The geomorphic reconnaissance combined with the sediment results indicate that the reach of Murray Creek between Kinsey Marsh and American Lake is incised into coarse sand, gravel, and cobble deposits that are part of the highly permeable Steilacoom gravel surface geology. A surface layer (up to 18 inches in thickness) of saturated, organic silt and clay is present throughout most of the Murray Creek channel within this reach (Shapiro 1996).

Table 3.9-2 Percentage of Grain Size of Streambed Gravel in Murray Creek Retained for Different Sieve Sizes.

	Sample Location and Depth			
	S3	S4	S5	S7
Sieve Size (inches)	Stream Sample Collected Downstream of Second Road Downstream of Kinsey Marsh (1 feet)	Stream Sample Collected ~¼ Mile Downstream of S3 (2 feet)	Stream Sample Collected ~¼ Mile Downstream of S4 (1.5 feet)	Stream Sample Collected Upstream of MAMC, ~1 Mile Downstream of S5 (1 feet)
0.132	98	64	97	56
0.094	98	68	97	69
0.066	99	71	97	62
0.047	99	74	98	64
0.033	99	80	98	68
0.023	100	83	98	72
0.012	100	90	98	90
0.004	100	97	98	98
Pan	100	100	100	100

Source: Adapted from data presented in Appendix F of Shapiro (1996).

Visual observations made during a field visit on July 11, 2005, confirmed the presence of fine sediments deposited over coarse materials at many of the culverts. Just downstream of Kinsey Marsh, the substrate of Murray Creek appeared to be characterized by coarse gravel overlain by small woody debris, as shown in Figure 3.9-1. The substrate just upstream of the tank trail crossing had deposits of larger gravels that were still surrounded by organic silt and clay, as shown in Figure 3.9-2. If not covered by the finer sediments, the gravel deposits represent a potential spawning area for fish.

Murray Creek – Habitat Characteristics

Murray Creek is characterized by low-gradient glide and run (or riffle) habitat types and an adjacent riparian zone. Cover is provided by aquatic plants and large woody debris. The bottom substrate, which is composed of silt, sand, and organic matter, is anchored by rooted aquatic vegetation (ENSR 1998a). There are limited amounts of large woody debris within Murray Creek, and the little that does exist consists primarily of smaller-diameter hardwoods, which are not large enough to create significant habitat features (Shapiro 1996). Some of the side channels, such as the one by the tank trail across from MAMC, have large woody debris. However, these side channels are dry during the summer months (as confirmed during the July 11, 2005, site visit), limiting their rearing habitat value for fish and other aquatic species.

Spawning gravels for fish are limited in Murray Creek because the existing gravel is mostly embedded in fine sediments consisting of a sand and silt mixture. Known fish spawning habitat occurs within two segments of the channel: 1) downstream of Kinsey Marsh (headwaters of the creek), and 2) the lower 0.1 mile of Murray Creek, downstream of Interstate 5, where the creek flows into American Lake. Other potential spawning habitat occurs in low-gradient riffles through the stream channel downstream of culvert crossings (ENSR 1998b). An earlier report (Shapiro 1996) indicated spawning habitat at a footbridge along Upper Murray Creek, but the text contained no information on this site. Good rearing habitat is provided by glides and low-gradient riffles, particularly those upstream of Interstate 5.

The dominant habitat type within Murray Creek is glide habitat with a few riffles and scour pools. Downstream of Kinsey Marsh, riffle habitat has experienced dry periods during most summers between 1994 and 1998 (ENSR 1998a). The physical habitat and geomorphology of Murray Creek are influenced by the presence of several road crossings. These crossings consist of either concrete or corrugated metal pipes, which have gradients of less than 2 percent (Shapiro 1996). These culverts appear to be sized only for water flow, rather than the sediment loads transported by the water. Therefore, where flows are constricted, the culverts become clogged by fine sediments, further constraining flow. During a brief survey in the summer of 2005, the culverts appeared to confine both sediment and water flow, although they were not observed to be clogged with sediments at that time. The culverts are associated with deep pools immediately upstream and low-gradient riffles immediately downstream (ENSR 1998a).

Murray Creek and American Lake – Fisheries

The Murray subbasins and the American Lake subbasin contain non-anadromous fish populations including kokanee salmon, rainbow trout, and cutthroat trout. Rainbow and cutthroat

Figure 3.9-1 Photograph of Murray Creek Substrate Downstream of the Combat Vehicle Trail Crossing.

Figure 3.9-2 Photograph of Murray Creek Substrate Upstream of the Tank Trail Crossing.

trout are expected to reside in Murray Creek throughout the entire year. Adult rainbow and cutthroat trout typically spawn in late winter (February to March) and the fry emerge in late summer. Kokanee is a form of landlocked sockeye salmon that spawns along lake shorelines and streams that flow into lakes (Wydoski and Whitney 1979). Adult kokanee salmon spawn along the shoreline of American Lake and the mouth of Murray Creek. Other fishes that may occur in Murray Creek include sculpin (*Cottus* spp.) and three-spine stickleback (*Gasterosteus aculeatus*; Shapiro 1996).

In 1997, the WDFW conducted an electrofishing survey of American Lake. The survey found the following resident fish species in the lake: cutthroat trout, kokanee salmon, largemouth bass, pumpkinseed (*Lepomis gibbosus*), rainbow trout, rock bass, sculpin, and yellow perch. The WDFW survey reported no kokanee salmon within the southwestern portion of the lake (Mueller and Downen 1999).

American Lake – Morphology and Habitat

American Lake consists of two basins: a smaller and shallower southern basin, and the main lake basin. The southern basin has a surface area of about 77 acres and a maximum depth of 40 feet, and the main lake basin has a surface area of 1,023 acres and a maximum depth of 90 feet. Ground water generally flows from east to west, and a narrow, shallow channel connects the two basins. A small surface channel provides an outlet from American Lake that connects to Sequalitchew Lake at high lake levels (KCM 1993). The near-shore habitat of American Lake is comprised of moderate to steep slopes, composed of gravel (Mueller and Downen 1999). The lake's morphology, in combination with its mesotrophic to eutrophic status, makes it well suited for warm-water fishes.

Sequalitchew Subbasin

Various aquatic habitat types occur along Sequalitchew Creek between Sequalitchew Lake and the creek's eventual discharge to Puget Sound. The uppermost reach of Sequalitchew Creek is channelized from where it exits Sequalitchew Lake to where it passes by Hamer Marsh and enters Edmond Marsh. The creek has limited lateral movement and limited access to its natural floodplain within this channelized section (Runge et al. 2003). There is little spawning habitat within Sequalitchew Creek immediately downstream of Sequalitchew Lake. It is expected that wetlands associated with the creek in this area provide limited rearing habitat for juvenile fish (Shapiro 1996). The habitat at the outlet of Edmond Marsh is characteristic of a low-gradient, slowly flowing system, with muddy, organic substrate. The reaches further downstream (west) of Edmond Marsh, are composed of long pool sections separated by short riffles and the substrate is typically small gravel mixed with sand and silt. The lower 1.5 miles of Sequalitchew Creek are characterized by a steep-sided canyon causing the creek to drop over 200 feet in elevation before discharging to Puget Sound through a culvert that is perched above the shoreline. This lower section is characterized by riffle habitat and gravel substrate (Dice et al. 1979 as cited by Andrews and Swint 1994; Runge et al. 2003).

Despite the steep elevation drop, the lower section of Sequalitchew Creek is passable by anadromous fish. The WRIA 12 Salmonid Habitat Limiting Factors Analysis (Runge et al. 2003)

included a description of fish access and barriers in Sequalitchew Creek. While the perched culvert at the creek outlet represents a barrier during low creek flows, the creek is passable between Puget Sound and Edmond and Hamer Marshes. The marshes are sometimes impassable due to beaver dams.

The WDFW no longer releases coho salmon in Sequalitchew Lake (Jenkins 2005). In the absence of stocking, resident fishes expected to occur in the Sequalitchew Creek subbasin include cutthroat trout, rainbow trout, sculpin, and western brook lamprey (*Lampetra richardsonii*; Huckell/Weinman 1993). Cutthroat and rainbow trout are also expected to use Sequalitchew Lake.

3.9.3 Aquatic Habitat and Fisheries Information Source and Data Gaps

There is no comprehensive source for aquatic habitat, geomorphic, or fisheries information for the entire watershed. Previous studies were completed by different parties at different periods and for different purposes over the last two decades, as shown by the list of primary data sources:

- Andrews and Swint. 1994. A Twentieth Century History of Sequalitchew Creek
- Jenkins, J. 2005. Personal communication (conversation with Grady, Herrera Environmental Consultants, regarding WDFW juvenile fish releases in American Lake and Sequalitchew Lake)
- Mueller, K. and M. Downen. 1999. American Lake Survey: The Warmwater Fish Community before Stocking Smallmouth Bass
- Runge, J., M. Marcantonio, and M. Mahan. 2003. Salmonid Habitat Limiting Factors Analysis: Chambers-Clover Creek Watershed (Including Sequalitchew Creek and Independent Tributaries), Water Resource Inventory Area 12
- ENSR. 1998a. Final Sequalitchew Lake Level Management Plan Environmental Assessment
- KCM. 1993. Tacoma-Pierce County Health Department, American Lake Phase I Restoration Project, Final report and Technical Appendices
- Shapiro. 1996. An Assessment of Murray Creek in Pierce County, Washington

It would be useful to complete a comprehensive habitat/geomorphic survey of the entire Murray/Sequalitchew watershed. These results could be correlated to reaches that are prone to drying out during late summer months in order to track seasonal habitat availability. This

information should also be related to the particular months of the year in which various salmon and other aquatic species need to use stream habitat.

Recent fish population assessments have not been conducted for the Murray and Sequalitchew subbasins. The quality and precise location of spawning gravels has not recently been assessed within Murray Creek or Sequalitchew Creek.

3.9.4 Previous Study Recommendations/ Ongoing Studies and Research

Runge et al. (2003) provided several recommendations for the Murray/Sequalitchew watershed to improve conditions that limit fish populations. The following actions were recommended to improve fish access and aquatic habitat:

- Conduct a comprehensive fish passage barrier and priority index survey to determine the most important areas for fish spawning and rearing.
- Remove salmonid-blocking culverts, dams, weirs, or other blockages, such as the barriers at the outlet of Sequalitchew Lake, at the railroad near the mouth of Sequalitchew Creek, and at the culvert under the railroad rights-of-way in Edmond Marsh, and replace them with fish-passable alternatives.
- Alter the diversion canal near the outlet of Sequalitchew Lake to prevent the loss of water that is essential to Sequalitchew Creek during the spawning season, and necessary throughout the year to prevent the loss of fingerlings in the stream.
- Promote collaboration between Fort Lewis and Pierce County to restore the historical connection between American Lake and Sequalitchew Lake to enable fish passage throughout the entire watershed. (Note: Fort Lewis personnel have questioned whether there ever was a historical surface water connection between the lakes.)
- Investigate options for dealing with fish passage barriers caused by beavers in Edmond Marsh.
- Restore stream processes and morphology (sinuosity [the amount of meandering in a stream], habitat complexity, sediment recruitment, etc.) to the upper, channelized portion of Sequalitchew Creek to mimic its historical natural condition.
- Add large woody debris in appropriate areas to increase channel complexity.
- Take actions to reduce the invasion of reed canarygrass within the Murray Creek channel.

Murray Subbasins

Two previous studies that focused on identifying causes for the loss in base flow to Murray Creek and options for restoring base flow also addressed issues related to aquatic habitat. The Murray Creek assessment completed by Shapiro (1996) included a recommendation to develop a streambed protection program along with measures to increase base flow in Murray Creek. An evaluation of options for restoring base flow to Murray Creek (ENSR 1998b) included an assessment of fish habitat issues associated with four alternatives for augmenting base flow to Murray Creek. The main impacts identified were temperature and temporary construction impacts.

As mentioned in the riparian habitat section (3.8.4) above, there has been previous work to improve habitat within Murray Creek (U.S. Army 2005c). Gravel was added to the stream in 1985 to create 300 feet of spawning habitat. Reed canarygrass was removed during the summer of 1994 from 600 feet of stream below the MAMC. In 2004, Camp Murray received a grant to enhance kokanee salmon spawning habitat by removing reed canarygrass, trapping beavers, removing a concrete barrier that restricted flows, and planting over 1,200 feet of Murray Creek with native trees, shrubs, and emergent plants. The U.S. Army (2005c) has identified that "future efforts in salmon enhancement will continue to focus on high-priority areas such as the Muck Creek, Exeter springs, and Halverson springs spawning complex." These priority areas are located in the southern part of the installation.

American Lake Subbasin

Mueller and Downen (1999) conducted a research survey of fish populations in American Lake for WDFW in 1998. The survey suggested that American Lake exhibits patches of distinct habitats with different assemblages of fish depending on factors such as life stage, species, and seasonality. The WDFW report suggested that the effective management of fish populations in American Lake would benefit from an inventory and quantification of important habitats and disturbances which affect these habitats.

A set of studies on American Lake, dealing mainly with the high levels of phosphorus in the lake, was completed by Woodward-Clyde in the mid-1990s (Woodward-Clyde 1995, 1996, 1997a, 1997b). These studies identified naturally-occurring phosphorus in the ground water as the main source of nutrients to the lake, and thus made only limited recommendations about septic system cleanup.

Sequalitchew Subbasin

In 1998, ENSR completed a study to assess the impacts of various alternatives for regulating the outflow of Sequalitchew Lake without threatening the water supplied to Fort Lewis by Sequalitchew Springs. The study determined that the preferred alternative, which included modifications to the outlet diversion weir and installation of an alarm and lake-level monitoring system, should have no impacts on Sequalitchew Lake habitat, as the lake would be maintained at or near current levels (ENSR 1998a).

Overall, the ENSR (1998a) study determined that without managing beaver dams and culvert inflow, the water flow into Sequalitchew Creek would diminish with time, while flow into the outlet diversion channel would increase. Diminished Sequalitchew Creek streamflow would reduce the quantity of water available to support wetland habitat, which would in turn allow woody, forested wetland vegetation to become more dominant, further restricting downstream flow to lower Sequalitchew Creek. However, the proposed management alternative could allow more flow to pass downstream to Sequalitchew Creek, helping to maintain wetland species and open more habitat to fish. Temporary sedimentation of gravels could occur during construction (ENSR 1998a).

The Sequalitchew Lake study (ENSR 1998a) also found that the preferred action would produce only minor impacts to geomorphic processes. Lake shoreline erosion would decrease slightly if the lake level were lowered. If the lake was maintained near current levels there would be some potential for a slight increase in lakeshore erosion if lake levels rose from current levels due to improvements made at the spring backflow diversion weir.

Fort Lewis is currently conducting a ground water and surface water assessment of the history of the stormwater diversion and entry to upper Sequalitchew Creek, which will provide a greater understanding of the altered hydrology of upper Sequalitchew Creek and present recommendations for actions to restore hydrologic processes to best support aquatic habitat (Crown 2005b).

Recent studies have been concerned with the lower portion of the Sequalitchew subbasin, where Glacier Northwest is pursuing a mine expansion that would require the ground water table to be lowered using an artificial open-channel tributary to transport excess ground water to lower Sequalitchew Creek. Since lower Sequalitchew Creek is outside Fort Lewis jurisdiction, additional details on the mine expansion and associated north Sequalitchew channel are not provided here. Additional information on the details of the proposed mine expansion and the construction of the north tributary channel will be available from the draft environmental impact statement, once it is completed.

3.9.5 Additional Considerations for Fisheries

A number of recent studies on salmon and resident fish movement related to low flow and stream temperature have been published. These studies may have some application for addressing fish-related concerns in this report, especially in terms of low-flow conditions in Murray Creek.

Kahler et al. (2001) conducted a study investigating juvenile salmon movement in three western Washington streams. The study determined that fish movement during summer months tends toward upstream rather than downstream dispersion. Coe (2001) found a high persistence of species and a similar proportion of species even during extreme low-flow events. The Coe (2001) study found that the young-of-the-year trout were more common in persistent wetted patches on the floodplain, while coho were more common in isolated patches in terrace tributaries. In Murray Creek, juvenile fish may move toward the Upper Murray subbasin during summer low-flow conditions where wet patches of stream habitat remain.

A study conducted by Hay (2004) found that temperature was the most important cause of salmon movement during low flows. Salmonids migrate from warm areas into deeper, cooler habitats (thermal refugia) during low flows; for instance, leaving riffle and run habitats in favor of deeper pools. Falling water levels and increasing temperatures also lead to upstream migration. Hay (2004) lists several examples of movement into refugia. These examples include rainbow trout abundance in Oregon streams decreasing with increasing temperature with many trout moving into areas of cooler water created by seeps, cool tributaries, and stratified pools. A study of low summer flows in three California rivers showed similar patterns, with both juveniles and summer-run adults moving into thermally stratified pools for the cooler water found at the bottom. Juvenile fish are expected to move to portions of Murray Creek that provide thermal refugia during months of elevated water temperatures.

Thermal refugia often occur in areas associated with hyporheic zones, which are areas of permeable alluvial sediments where ground water and surface water meet beneath streams and rivers. Hyporheic flows can be from surface water to ground water (a "losing" stream reach) or from ground water to surface water (a "gaining" reach). In the latter case, the ground water seep may help cool the stream, creating a thermal refuge. The cold, hyporheic water may also moderate water temperature in spawning areas and may provide a supply of invertebrates for food (Hay 2004). Upper Murray Creek has been reported as a gaining reach, while the lower reach of Murray Creek likely loses flow to ground water since this area has become dry during the summer months in several years recently.

Reidy (2004) examined hyporheic zone extent, water quality, and seasonal variability in Puget Sound lowland streams. Reidy confirmed the existence of hyporheic zones in these streams. The study also showed high variability in hyporheic characteristics that could not be completely explained by seasonal factors, channel configuration, or land use. However, there did appear to be a tendency for more gaining areas in unconfined stream reaches and during periods of low flows. Summer base flows in Lower Murray Creek may improve in unconfined reaches of the stream channel if ground water recharge processes are restored, resulting in enhanced hyporheic zone processes.

3.9.6 Key Aquatic Habitat and Fisheries Issues

Murray Creek and American Lake Subbasins

A primary challenge for Fort Lewis is protecting and restoring fish access to Murray Creek habitat, since sections of the creek channel are prone to drying up during the late summer months. More information, including potential causes of summer low flows, is provided in the climate and surface water sections of this watershed plan. Whenever the streamflow of Murray Creek becomes extremely low, fish may become stranded in isolated pools, and become stressed, die due to high water temperatures or low dissolved oxygen levels in isolated pools, or be subjected to increased predation rates. Another challenge is improving the shoreline features along American Lake that support resident fish and aquatic species, such as overhanging native vegetation, submerged root systems, emergent vegetation, woody debris, and substrate.

Beaver dams within the lower portion of Murray Creek just upstream of Interstate 5 and American Lake create flooding problems around culverts (Figure 3.9-3). Fort Lewis personnel would like to develop creative ways to promote beaver habitat while discouraging beavers from constructing dams in locations where they disrupt the operation of culverts (Clouse 2005).

Sequalitchew Subbasin

The tendency of Sequalitchew Creek to dry up in the late summer presents one of the greatest challenges to maintaining good aquatic habitat in the creek. Drying limits aquatic species, such as kokanee, from accessing necessary rearing habitat, as well as reduce the survivability of species, such as benthic macroinvertebrates, that are found in the diet of fish species (Dice et al. 1979 as cited by Runge et al. 2003). These downstream habitat needs are complicated by the water withdrawals at Sequalitchew Springs that are necessary to provide drinking water for Fort Lewis (Runge et al. 2003).

Another problem is beaver encroachment in upper Sequalitchew Creek where the gradient is relatively flat. Beaver dams in this area have combined with reed canarygrass and other invasive weeds to clog the stream channel. Because of the belief that beaver dams impede fish passage, the stream channel has occasionally been cleared with a mechanical device (Clouse 2005).

3.9.7 Potential Solutions for Aquatic Habitat and Fisheries

- Retrofit areas that currently drain to enclosed storm drains to promote infiltration. Stormwater runoff that is directed to the stormwater network and discharged to creeks during winter storms decreases infiltration and replenishes shallow aquifers that maintain a creek's base flow in the summer.

- Develop a streambed protection plan. Develop procedures for minimizing streambed disturbance and avoiding increased permeability during construction requiring stream channel crossings.

- Identify cold-water refugia locations to target fish habitat improvements in Murray and Sequalitchew creeks. Introduce large woody debris and other habitat features at selected locations in Murray Creek to increase habitat complexity and hydraulic connectivity/exchange with the hyporheic zone.

- Improve shoreline habitat in American Lake. Construct shoreline habitat enhancements where possible, including natural bank stabilization (avoid armoring with rock or concrete, however), native vegetation establishment, and large woody debris placement. The placement of large woody debris in the system should be performed in a way that avoids creating salmon predatory fish habitat, unless such habitat is desired for fisheries management purposes.

- Improve upper Sequalitchew Creek. Restore stream processes and morphology (sinuosity, habitat complexity, sediment bedload recruitment, etc.) to upper Sequalitchew Creek.

- Remove invasive weeds from Murray and Sequalitchew creeks. Invasive, nonnative vegetation, such as reed canarygrass, should be removed to encourage the establishment of native vegetation.

- Continue removal/management of beaver dams in Sequalitchew Creek. Fort Lewis has an ongoing program to remove beaver dams that impair flow to Sequalitchew Creek that should be continued.

- Identify and correct fish passage problems at existing Murray Creek culverts. Culverts that are plugged with sediment or otherwise impeding fish passage should be cleaned and maintained or replaced as needed. Culverts identified as replacement priorities should be replaced with natural-bottomed culverts or bridges where possible. Prioritize crossings where improvements are most necessary to promote fish passage and access to habitat.

Figure 3.9-3 Photograph of a Beaver Dam Located Just Upstream of the Fillmore Road Crossing, Posing Potential Flooding Problems.