

INSTREAM FLOW AND WATER REGIME OF SELECTED RIPARIAN HABITATS IN WEST-CENTRAL MONTANA

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1.0 INTRODUCTION/LITERATURE REVIEW

Groundwater and surface water extraction and diversion for agricultural and human use has become common practice in the arid and semi-arid western United States. Surface water and groundwater are often not effectively managed during these processes, and few laws exist to protect riparian vegetation in the case of depletion of in-stream flows. "Instream flow" is defined as waters that are "retained in their natural setting" rather than diverted for human uses (Gordon et al. 1999).

In general, riparian vegetation represents approximately 1 percent of the total land area, but provides greater biological density and diversity than upland vegetation (Hanson et al. 1996, Knopf et al. 1988). Riparian vegetation plays a critical role in the health of the stream ecosystem, providing fish habitat, water storage and aquifer recharge, filtering of sediments and wastes, bank building and stabilization, flow energy dissipation and primary biotic production (Ehrhart and Hansen, 1998, Rood et al. 1998). There is evidence to support the theory, however, that high flows and inundation duration are critical to the development and maintenance of riparian vegetation habitats, and that small changes in discharge and water availability greatly affect the abundance of riparian vegetation (Auble et al 1994, Rood and Mahoney 1990, Rood et al. 1994, Rood et al. 1998, Stromberg and Patten 1992, 1993, 1996, Stromberg et al. 1996, Smith et al. 1991, Henszey et al. 1991, Shafroth et al. 2000). The establishment of management guidelines for adequate riparian water supply is only possible following the documentation of specific community hydrologic requirements for establishment, development and survival (Stromberg et al. 1996). An essential aspect of understanding riparian habitat requirements is the "direct observation of surface flooding or seasonal water tables" (Carter et al. 1994, Soden 1999). The difficulty lies in knowing how much modification of instream flow for human use, combined with the ever-present threat of drought, will continue to support a specific riparian habitat.

Several studies have explored specific environmental relationships of riparian communities of Montana (Brichta 1987, Chadde 1988, Soden 1999). The purpose of this study was to help define the characteristics of the riparian water regime with both qualitative and quantitative instream flow and groundwater information. The water regime of a riparian community is

defined by the inundation duration associated with the community, dynamics of water table change, stream flow and the interaction of groundwater and surface water (Walker and Wehrhahn 1970, Dionigi et al. 1985, Shafroth et al. 2000).

The objectives of this study were to:

1. determine the interaction of in-stream flow in reference reaches with groundwater in surrounding riparian areas;
2. gain an understanding of flow and inundation duration on reference reaches and how they influence riparian vegetation distribution in surrounding riparian areas; and
3. define the dynamics of water table change in riparian habitats examined in this study.

1.1 INUNDATION/DURATION

The driving force behind the development and sustainability of riparian areas is the "recurrent, sustained saturation of the upper part of the substrate (Doss 1995, Soden 1999). Inundation duration is also a predictor of vegetation distribution due to the varying degrees of tolerance riparian species have to saturation in the soil. Soil "inundation" is defined as a water table that is at or above the ground surface. The 1987 Army Corps of Engineers Wetland Delineation Manual states that for the water table to significantly affect wetland vegetation, soil "saturation" must occur within 30 cm of the ground surface, or the plant root zone (Environmental Laboratory 1987). Saturated soils diffuse oxygen approximately four orders of magnitude slower than in air; therefore, riparian areas experiencing regularly high groundwater tables and extended inundation duration sustain riparian species tolerant of frequently saturated soils (Dionigi et al. 1985, Auble et al. 1994, Shafroth et al. 2000). Additionally, soil saturation greatly influences soil temperature, organic decomposition and soil chemistry (Brichta 1987). In semi-arid and arid areas of the western United States, water availability to riparian plant roots becomes a limiting factor in their distribution (Brichta 1986, Stromberg 1993, Auble et al. 1994, Scott et al. 1996). Several studies of the riparian *Populus* species indicate that a decrease in inundation duration on alluvial bars and stream banks limits cottonwood establishment, growth and survival (Stromberg and Patten 1996, Rood et al. 1994). In a wet meadow riparian environment, soils maintain a

relatively constant high-water table in the absence of a stream channel to convey water flow. Henszey et al. (1991) found that artificially elevated water tables in moist to wet meadows caused a shift to riparian plants tolerant of anaerobic soils. In Montana, Soden et al. (1999) determined that the herbaceous riparian types had a smaller ecological amplitude of water table height than woody or tree types, and that in general all wetland types in Montana correlated highly with depth to water less than 15 cm from the ground surface.

1.2 GROUNDWATER ELEVATION CHANGE

By definition, all riparian soils have a high water content relative to their upland counterparts for at least a portion of the year (Cowardin et al. 1979). The greatest water contributor to riparian soils is groundwater (Kozlowski 1968). Many riparian plants rely on the water table, capillary fringe and vadose zone for most of the year (Shafroth et al. 2000). Fluctuations in riparian water tables are affected in part by changes in stream flow and evapotranspiration by riparian plants (Shafroth et al. 2000). Water table declines can lead to reduced riparian plant establishment, growth and survivorship (Scott et al. 1999). The ratio of the water table maximum and minimum, or the amount of change in the water table experienced by a riparian community during the growing season, is an important factor in influencing the distribution and growth of riparian habitats in an area (Shafroth et al. 2000). Shafroth et al. (2000) concluded that the ratio of water table maximum and minimum has strong influence over the root architecture of riparian plants: riparian plant roots organize themselves laterally according to the water tables they historically experience. Inevitably, an increase in the ratio from historic norms will have significant impacts on water availability to riparian plants, and thus on plant growth and survivorship.

Henszey et al (1991) found that biomass for wet meadow sedges and other emergent vegetation was highest when the water table fluctuated naturally, allowing soils to receive oxygen for part of the growing season.

1.3 INSTREAM FLOW

Manipulating instream flow for water supply, hydropower production or flood control results in reduction of peak flow, shift in timing of peak flow and total annual flow volume (Gordon et al. 1999). Many studies have documented the effects these changes to instream flow have on the riparian species *Populus*. Effects of changes to in-stream flow range from the extreme, namely the loss of riparian ecosystems, to the subtle, such as physiological mutations or population level changes indicative of lower stress conditions (Kozlowski 1968, Taub 1987). Stromberg and Patten (1992) found that instream flow minima and maxima need to be maintained at managed streams to support establishment of *Populus* seedlings and reduce drought-caused mortality. Auble and Scott (1998) determined that disturbance due to flood volumes is necessary to ensure *Populus* recruitment. Additionally, pronounced peak flows for a portion of the growing season are necessary to remove algal layers and litter from riparian surfaces. Harris and Marshall (1963) found that recalcitrant algal mats in emergent riparian areas often retarded seedling establishment and growth. However, a primary influence of instream flow on riparian community health is its connection to the riparian water table.

This study occurred over a period of moderate to extreme drought in central Montana. This drought also coincided with increased groundwater withdrawal for irrigation in the study area; thirteen new pivot irrigation systems were installed on the area surrounding the Smith River in 1999. The study period arguably may have occurred over a time that defines the lowest groundwater and stream flow conditions the riparian communities in the study area have experienced. Figure 1-1 is a graph of typical historic stream discharge and discharge over the study period for the Smith and Musselshell Rivers, the two major drainages of the study area. The graph includes the full period of record for the Smith River gauging station and the last 10 years of record of the Musselshell River gauging station.

Flow Duration Curves Smith River and Musselshell River

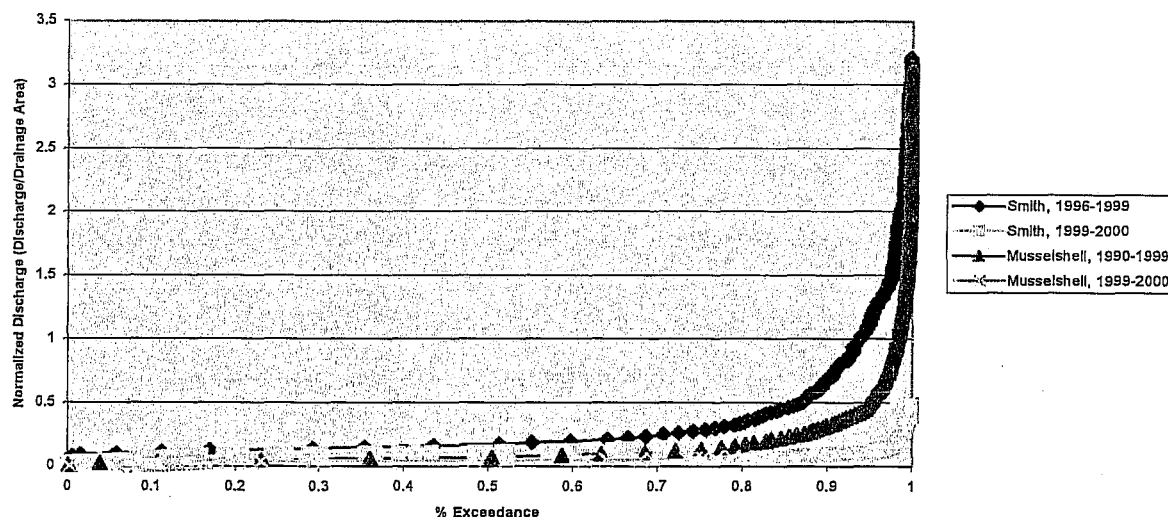


Figure 1-1. Flow Duration Curves depicting the percentage of time a certain discharge was met historically and during the study period (1999-2001).

Figure 1-1 demonstrates that the discharge in both rivers was significantly reduced from recorded historic levels during the study period. Both the base level of the rivers and the highest flows were greatly depressed during the study period. Peak flows occurred earlier and at much lower discharges during the study period than in past years (Figure 1-2).

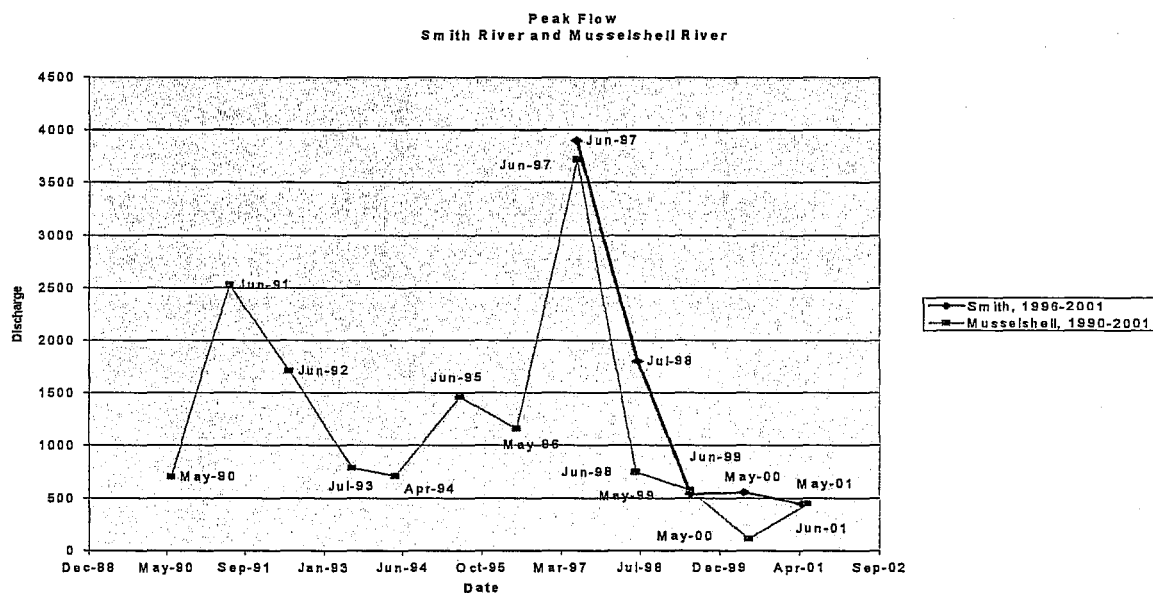


Figure 1-2. Peak Flows of the Smith and Musselshell River up to 2001.

1.4 GROUNDWATER/SURFACE WATER INTERACTION

It is now recognized that the interaction between groundwater and surface water has important implications for riparian habitat suitability (Kondolf et al, 1987; Castro and Hornberger, 1991; Henszey et al, 1991; Stromberg and Patten, 1990; Auble et al, 1994, Stromberg et al, 1996; Toner and Keddy, 1997). At times of seasonal low in the baseflow of the stream, the active exchange zone between the groundwater and surface water can extend to several meters from the stream channel (Castro and Hornberger, 1991). The baseflow of a stream is often directly linked with the local aquifer (Castro and Hornberger, 1991), therefore the effects of groundwater change are directly linked with the effects of in-stream flow variation. Riparian plants receive most of their moisture from groundwater-wet soils (Kozlowski 1968, Shafroth et al. 2000). It follows that riparian health is directly linked to the response of groundwater to changes in stream flow. According to Tabacci et al. (1998), groundwater availability in the riparian zone is essential to successful riparian seedling establishment. Furthermore, the interaction between groundwater dynamics and stream discharge appears to highly influence most stages of vegetation development (Tabacci et al, 1998). As previously discussed, fluctuations in water tables exert strong influences on distribution and survival of riparian species. Therefore, the linking of changes in instream flows to water table changes has important implications for riparian habitat suitability.

2.0 STUDY AREA

2.1 PHYSIOGRAPHY

The study area is located in the vicinity of White Sulphur Springs, Montana (Figure 2-1). White Sulphur Springs is located at the junction of Montana Routes 12 and 89 in west-central Montana. The study area is contained in the Lewis and Clark National Forest within the area bordered by Tenderfoot Creek in the north, the Smith River in the west-southwest and the Little Belt Mountains and Musselshell River to the east-southeast. White Sulphur Springs lies in a wide and deep intermontane basin, which is typical of basins east of the Continental divide (Kendy and Tresch, 1996). The basin trends to the north-northwest between the Big Belt Mountains to the west and the Little Belt Mountains to the east and north. Known as the Rocky Mountain Front, the area represents the border between the Rocky Mountains to the west and the Great Plains to the east. The principle streams draining the valley are the northward flowing Smith River in the western portion and the eastward flowing Musselshell River in the southeastern portion of the study area. Public lands in the White Sulphur Springs area are included in the Lewis and Clark National Forest and the Tenderfoot Creek Experimental Forest.

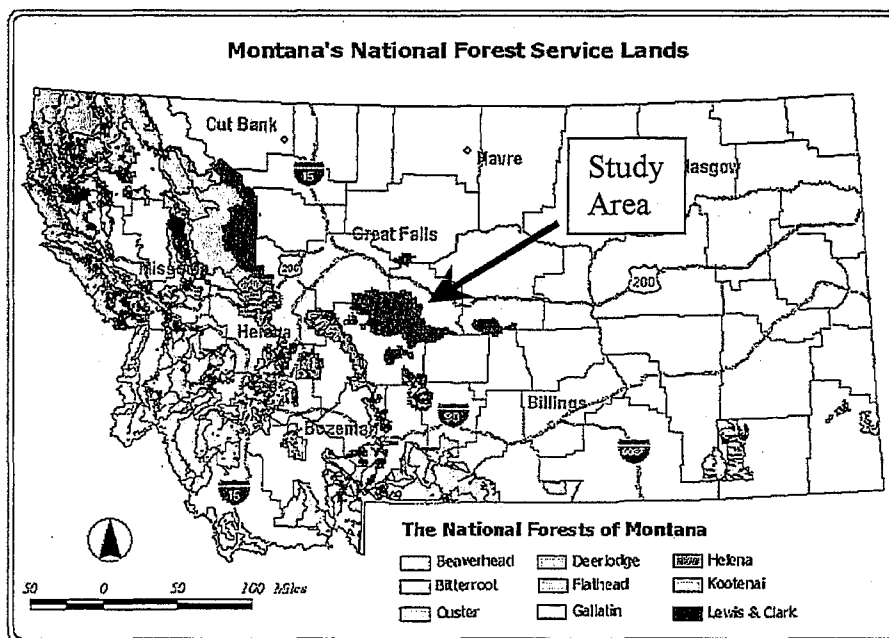


Figure 2-1. Study Area Location Map

2.2 TOPOGRAPHY

The area is characterized by mountains and rolling foothills of the Little Belt Mountains and river canyons. Elevation ranges from 4,200 feet at the Smith River to 7,800 feet at King's Hill Pass on MT Route 89 (Farnes et al, 1995). A relatively flat valley bottom characterizes the southern portion of the study area. As one moves northward, the terrain becomes steeper and more variable. Both the Smith River and Tenderfoot Creek have created deep canyons in the northern portion of the study area. A modified karst topography is associated with the limestone terrain in the Smith River canyon (Groff, 1965). In the higher elevation locations, mountain parks and wet meadows alternate with densely wooded rounded peaks. The western portion of the study area slopes west into the Smith River, which forms the western boundary. The eastern portion of the study area slopes southeast into the east-southeast boundary, the Musselshell River.

2.3 CLIMATE

The continental climate of the study area is typical of mid-elevation intermontane basins of Montana east of the Continental Divide, with dry summers; cool, moist springs; and cold winters (Braico and Botz, 1974; Kendy and Tresch, 1996). Average precipitation in the study area is extremely variable. In the semi-arid rolling hills and plains average precipitation is 10-15 inches per year; average precipitation in the highest elevation areas in Tenderfoot Creek Experimental Forest is 35 inches per year (Braico and Botz, 1974; Farnes et al, 1995). The greatest precipitation usually occurs in May to early June (Phelps, 1966). Average temperature in the study area is highly variable due to a large elevation gradient. Temperatures in summer months average approximately 65°F, with extremes of 90°F to 100+°F commonly occurring. Temperatures in winter months average approximately 30°F, with extremes up to -40°F (Blumer, 1969; Farnes et al, 1995; Phelps, 1966).

2.4 LAND USE

The town of White Sulphur Springs has approximately 1,000 permanent residents. The White Sulphur Springs area is principally managed as agricultural land for ranching of cattle and sheep and farming for wheat, clover and alfalfa. Extensive land in the Lewis and Clark National Forest and Tenderfoot Creek Experimental Forest is used recreationally year-round. Groundwater and surface water resources are therefore used for stock, domestic, municipal and irrigation purposes (Braico and Botz, 1974).

2.5 GEOLOGY

The study area lies in the valley between the Big Belt Uplift, the Little Belt Uplift and the Castle Mountain Dome. The valley also represents the convergence of three regional structural features: the central Montana arch, which is formed by four regional uplift zones; and the Disturbed Belt, a southeast-trending zone of imbricate thrust faulting (Groff, 1965). Therefore, the stratigraphic units in the area have been extensively folded and faulted in most areas.

Strata in the White Sulphur Springs area range from Archean to Tertiary in age (Dahl, 1969; Groff, 1965; McClernan, 1969; Phelps, 1966). The total thickness of these units is approximately 26,000 feet in western Meagher County (Groff, 1965).

The valley is filled with alluvium and colluvium deposits of Tertiary and Quaternary age (for the purposes of this report only the term alluvium will be used). Grains in these deposits range from boulder-size to clay (Dahl, 1969; McClernan, 1969; Phelps, 1966).

2.6 HYDROGEOLOGY

Groundwater in the study area is principally recharged by fractures in the regional bedrock system, snow melt from higher elevation areas in Tenderfoot Creek Experimental Forest, the Little Belt Mountains and the Big Belt Mountains, infiltration from tributary streams and by infiltration of surplus irrigation water (Kendy and Tresch, 1996). The principle aquifers in the White Sulphur Springs area are the Tertiary and Quaternary alluvium fill deposits, with small amounts of groundwater coming from the bedrock system (Braico and Botz, 1974; Groff, 1965). Nearly all of the rock units can yield water under the right conditions (Groff, 1965). Several fault and karst springs exist in the area, including geothermic springs associated with the Madison Limestone.

2.6 QUATERNARY ALLUVIUM

The quaternary-aged alluvium resting on the top of the valley floor creates an unconsolidated aquifer of moderate quality (Braico and Botz, 1974). This aquifer consists of unconsolidated gravel, sand, silt and clay deposited by area streams and rivers and by erosion of surrounding strata. Thickness ranges from zero to sixty feet (Groff, 1965). If the water table does not decline below the bottom of the Quaternary alluvium this layer will yield small to large amounts of water, depending on the thickness (Groff, 1965). In the study area, thick permeable gravel deposits occur in the valley of the North Fork of the Smith River and from there into some of the main valley floor. Only two miles west of White Sulphur Springs, a large borrow pit shows plentiful permeable gravel (Groff, 1965). One shallow town well finished in recent alluvium yielded an estimated 4,500 gallons per minute (gpm) in 1962 (Groff, 1965).

2.7 TERTIARY ALLUVIUM

A moderate supply of groundwater for the White Sulphur Springs area comes from the Tertiary alluvium of the Smith River valley (Braico and Botz, 1974; Groff, 1965). This aquifer can be considered unconfined unless overlaid by much-finer grained recent alluvial deposits (Kendy and Tresch, 1996). Tertiary alluvial deposits in the study area consist of unconsolidated to semi-consolidated sediments of variable grain size, and can range from one to 1,000 feet in thickness (Braico and Botz, 1974; Groff, 1965). This alluvial deposit contains lake sediments, stream sediments, volcanic ash, volcanic tuff, and detritus from local strata (Braico and Botz, 1974). The Tertiary alluvium also commonly contains relic sand and gravel stream channels that yield high amounts of groundwater if penetrated. Typically, the Tertiary alluvium has water-yielding characteristics of "great variation, generally very small yields, except from sand and gravel channels, where the yield may be moderate to large," (Groff, 1965). Several domestic wells have been completed in this alluvial layer in the town and surrounding area. A deep well in White Sulphur Springs penetrated 1,000 feet of Tertiary sediments (Groff, 1965). Groff, 1965 hypothesizes that Tertiary sediments in the valley center are at least twice the thickness of that penetrated by the deep well in the town. Reservoir storage should be very large. However, due to the unconsolidated to semi-consolidated nature of these deposits, unless a well is completed in a buried stream channel water yield from this aquifer is only considered to be fair to poor (Braico and Botz, 1974).

2.9 SIGNIFICANT BEDROCK FORMATIONS

In the presence of significant faulting, nearly all of the units found in the study area could yield water. According to Groff, 1965, the bedrock units that have significant water-yielding characteristics are the Sunburst Sandstone of the Kootenai Formation, the Amsden Limestone and the Madison Limestone. The Belt Formation also has the ability to transmit water in jointed or fractured zones.

A unit of particular importance is the Mississippian Madison Limestone, which transmits regional flow in the study area. Several springs in the White Sulphur Springs area are associated with this unit. This limestone dissolves to form caves, caverns and solution tunnels associated with karst topography in the Smith River canyon area and in the subsurface. High yields of water are possible from penetration of a cavern system or a deep fault system. However, limestone terrains may not have a good source of local water supply due to rapid deep drainage (Groff, 1965).

2.10 SPRINGS

Two fault springs located in the study area and described by Groff, 1965 are a result of the relationship between thrust faulting and the Madison Limestone. Trinity Spring is suspected to originate from nearby Fourmile Creek, where it drains into a cavernous portion of Madison Limestone. It then accesses the surface via a fault zone and discharges "remarkably pure", cold water at over 2,500 gpm. This water was reported to have very low Total Dissolved Solids (TDS) and element content (Groff, 1965), which is consistent with its local flow system. Catlin Springs rises from the Madison Limestone and discharges in several locations for a combined flow of 600 gpm. This spring also has low TDS and element content (Groff, 1965).

The town of White Sulphur Springs derives its name from the geothermic spring of the same name. The White Sulphur Spring heats a local bank and is used for a hot spring resort in the town (Grove and Dunn, 1980; Groff, 1965). Water rises to the surface in a deep fissure or fault in Precambrian shale (Groff, 1965). Hot water from the same deep source is tapped by an 875 foot deep well for the First National Bank of White Sulphur Springs, completed in 1980 (Grove and Dunn, 1980). The water from White Sulphur Spring is hot (117°F), very high in sodium, sulfate, bicarbonate and chloride, and has a relatively high TDS (Groff, 1965). This indicates that the water circulates in a deep regional system before emerging in the area of White Sulphur Springs.

2.11 GROUNDWATER QUANTITY

According to a sample of 100 wells in Township 9N, Range 6E (town of White Sulphur Springs), depth to water ranges from 3 feet to 80 feet (GWIC, 2000). The completion depths for this sample range from as shallow as 10 feet deep to as deep as 330 feet (GWIC, 2000). Detailed lithologic information was not provided for most of these wells. However, well yields are consistently between 10 and 50 gpm in the local wells.

The First National Bank of White Sulphur Springs is heated by 79 gpm of geothermic water from an 875 feet deep well finished in the Greyson Shale (Grove and Dunn, 1980).

There are several wells in the study area that have recorded yields of over 1,000 gpm. Two wells of 230 feet deep and 250 feet deep have water yields of 1,200 gpm and 1,850 gpm, respectively. Both of these wells are finished in Tertiary alluvium, presumably in buried stream channels that are capable of high yields in the otherwise fair to poor Tertiary aquifer (Groff, 1965; GWIC, 2000).

No study of changes in the local water table has been completed. However, according to many local ranchers the water table has significantly declined in the last ten years (DuPea, 2000). They cite the need to install more and more pivot irrigation systems with deeper and deeper wells as evidence that the rise in crop and grazing acreage has decreased the water table in the White Sulphur Springs area. Furthermore, ranchers that were once able to utilize flood irrigation on their land, which drains water directly from a water source and onto their fields, now have had to resort to well/pivot systems that draw water from depth (DuPea, 2000).

2.12 GROUNDWATER AND SURFACE WATER QUALITY

Potential sources of groundwater pollution in the study area are agricultural land management practices and septic/sewer effluent from White Sulphur Springs. Water quality in the Tenderfoot Creek Experimental forest is generally high, owing to its relatively remote location. Surface water quality is monitored regularly, and little to no long-term adverse affects have been

recorded due to timber harvest in this location (Farnes et al, 1995). No groundwater contamination has been reported from the lagoon sewage treatment system that services White Sulphur Springs; however, the effluent is discharged into the South Fork of the Smith River and Lone Willow Creek, raising possible surface water quality concerns (Braico and Botz, 1974).

3.0 METHODS

Field work was conducted in 2000 from mid-May to mid-October, in order to capture the greatest variation in stream flow and water table elevation. Unfortunately, due to early melt of the snowpack in 2000 peak runoff occurred relatively early on May 4, 2000. Well installation had not occurred at this time and the rising limb of the hydrograph for the study streams was not captured. Additional stream flow and water table data was collected in May 2001 to capture pre-run off hydrologic conditions. Eighteen permanent stream transects were installed at relative high, medium and low elevations in the Tenderfoot Creek, Smith River and Musselshell watersheds (Figure 3-1). Low elevation transects included the elevations of 1,280 m. to 1,500 m. Medium elevation transects ranged from 1,677 m. to 1,750 m. in elevation. High elevation transects included the elevations of 2,207 m. to 2,220 m.

3.1 FIELD METHODS

3.1.1 Transect Selection

Transects were selected on the basis of shallowly sloped flood plains, well defined wetland habitat types and the absence of land management that would impede plant development (e.g. livestock grazing), and were installed in river, stream and wet meadow habitats. These reaches include: 1) evidence of natural features involved in the development and maintenance of the flood plain, channel, bars, vegetation etc. and 2) evidence of several different vegetation habitats as one moves laterally away from the channel (Harrelson et al, 1994). Transects in wet meadows were established to include the best range of features to accurately portray the character of the meadow. The transects run perpendicular to the stream channel and end at the ecotone with upland vegetation. The length and elevation of each transect was recorded, and the cross-sectional profile of each transect was measured with a laser surveying level.

3.1.2 Surface water and groundwater observation

Water table and stream height measurements were made at approximately two-week intervals during the 2000 field season. Water table elevations were gauged by marked metal measuring tape in 1.5-meter long, 13-millimeter diameter slotted PVC pipes that were installed at the ecotones of different wetland habitat communities. Stream height was measured with marked metal measuring tape at a permanent staff on each transect.

3.1.3 Vegetation classification

To classify and record plant type and coverage in existing plant communities on each transect, vegetation plots were constructed at each habitat ecotone. Plots were usually 5 meters by 10 meters, for a total sample area of 50 m². Plot size was modified for long stringer communities to maintain a constant plot size of 50 m². Forest communities were sampled using a 375 m² circular plot (Hansen et al, 1995). Each plot was located on the up-transect side of the ecotone to capture only the plants in each succeeding habitat. In some cases, 50 m² plots were placed at the beginning of the habitat and at the end of the habitat in cases where large areas separated each ecotone. This ensured capture of any community changes across the large area. Each tree, shrub, forb, grass, sedge and rush plant type was recorded, and its canopy cover occularly estimated (Daubenmire, 1959). Any plants that were not identified in the field were collected and stored for later identification (Hansen et al, 1995).

Wells were located on the inside edge of each plot furthest from the stream channel. In some cases, wells were installed within an ecotone due to a misidentification of the ecotone boundaries before riparian plants had fully developed leaf/fruit structures.

3.2 OFFICE METHODS

To meet the objectives of this study, analysis of hydrologic and soil variables was not conducted for riparian community types. The qualifier "community type" indicates a seral or disclimax community with generally wide ecological amplitudes and plant associations (Hanson et al. 1995). Riparian "habitat types", representing a defined physical environment and plant association, were analyzed for hydrologic and soil variables (Hanson et al. 1995).

Graphs of water table vs. stream height over the study period were prepared for each transect. Graphs correlating water table change vs. stream height change in the wettest and driest plot were prepared for each habitat/community type. Box plots of applicable variables vs. habitat type were compiled using SPSS 10.0 statistical analysis software.

Plant type and canopy coverage was classified into wetland habitat types according to Hansen et al. (1995) (Table 1). Each plant's Wetland Status was recorded according to Reed (1988) (Appendix A).

Riparian Type	Habitat (h.t.) Type/Community (c.t.) Type	Abbreviation
Coniferous Forest Types	Abies lasiocarpa/Streptopus amplexifolius h.t., Streptopus amplexifolius phase	ABILAS/STRAMP h.t., STRAMP phase
	Picea engelmannii/Calamagrostis canadensis c.t.	PICENG/CALCAN c.t.
	Picea engelmannii/Equisetum arvense h.t.	PICENG/EQUARV h.t.
Deciduous Forest Types	Populus tremuloides/Calamagrostis canadensis h.t.	POPTRE/CALCAN h.t.
	Populus tremuloides/Cornus stolonifera h.t.	POPTRE/CORSTO h.t.
	Populus tremuloides/Poa pratensis c.t.	POPTRE/POAPRA c.t.
	Populus trichocarpa/Cornus stolonifera c.t.	POPTRI/CORSTO c.t.
	Populus trichocarpa/Symphoricarpos occidentalis c.t.	POPTRI/SYMOCC c.t.
	Pseudotsuga menziesii/Cornus stolonifera h.t.	PSEMEN/CORSTO h.t.
Willow Shrub Types	Salix drummondiana c.t.	SALDRU c.t.
	Salix drummondiana/Calamagrostis canadensis h.t.	SALDRU/CALCAN h.t.
	Salix drummondiana/Carex rostrata h.t.	SALDRU/CARROS h.t.
	Salix exigua c.t.	SALEXI c.t.
	Salix lutea c.t.	SALLUT c.t.
	Salix lutea/Calamagrostis canadensis h.t.	SALLUT/CALCAN h.t.
	Salix lutea/Carex rostrata h.t.	SALLUT/CARROS h.t.
Non-Willow Shrub Types	Cornus stolonifera c.t.	CORSTO c.t.
	Potentilla fruticosa/Deschampsia cespitosa h.t.	POTFRU/DESCES h.t.
	Rosa woodsii c.t.	ROSWOO c.t.
Sedge Types	Carex aquatilis h.t., Deschampsia cespitosa phase	CARAQU h.t., DESCES phase
	Carex lasiocarpa h.t.	CARLAS h.t.
	Carex rostrata h.t., Carex aquatilis phase	CARROS h.t., CARAQU phase
	Carex rostrata h.t., Carex rostrata phase	CARROS h.t., CARROS phase
	Carex rostrata h.t., Deschampsia cespitosa phase	CARROS h.t., DESCES phase
	Carex scopulorum h.t.	CARSCO h.t.
Non-Sedge Types	Calamagrostis canadensis h.t.	CALCAN h.t.
	Deschampsia cespitosa h.t.	DESCES h.t.
	Eleocharis palustris h.t.	ELEPAL h.t.
	Scirpus pungens h.t.	SCIPUN h.t.
	Senecio triangularis h.t.	SENTRI h.t.

Table 1-1. Riparian habitat/community types of the White Sulphur Springs area, central Montana (from Hanson et al, 1995).

3.3 DESCRIPTIONS OF TRANSECT SITES

Meagher County, Montana

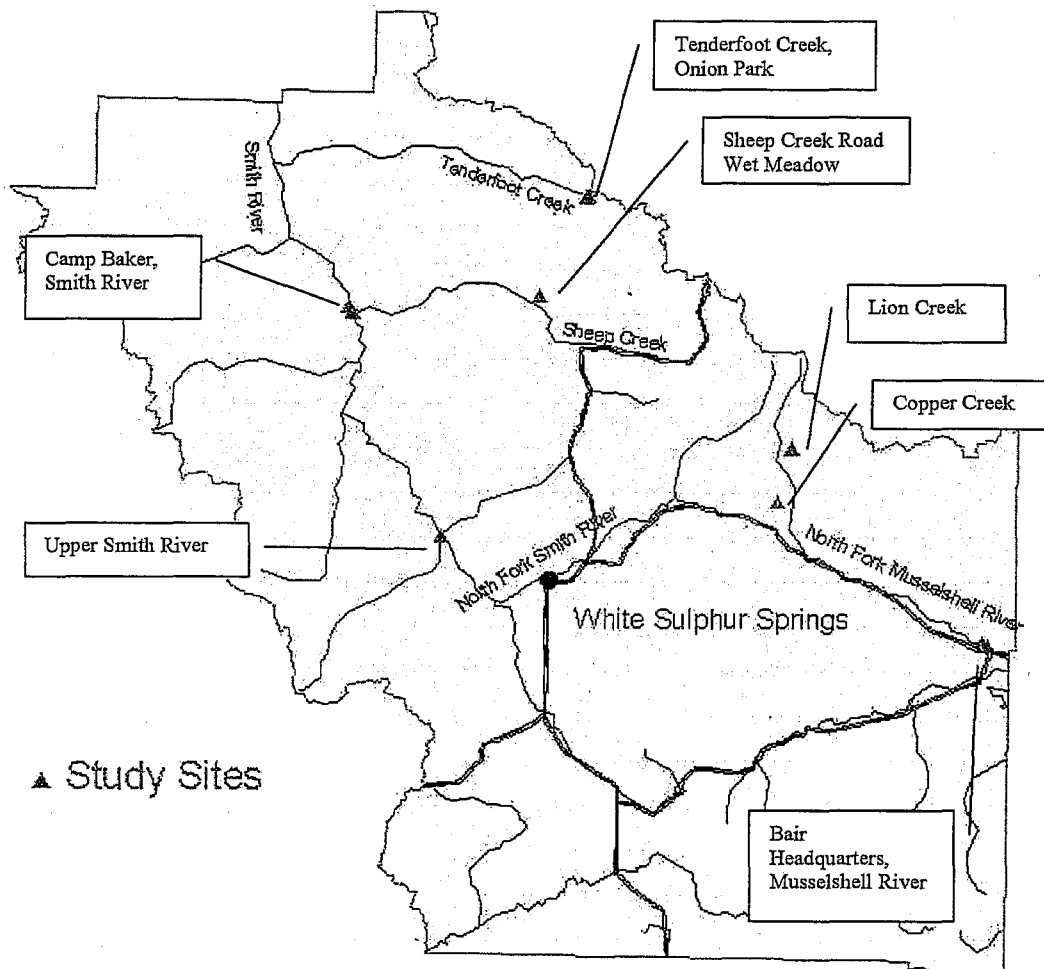


Figure 3-1. Transect Site Detail Map

3.3.1 Onion Park, Tenderfoot Creek Experimental Forest

Onion Park, Tenderfoot Creek Experimental Forest, is located in Township 13N, Range 7E, Section 4 in the Kings Hill Ranger District of Lewis and Clark National Forest. Onion Park contains the highest elevation transects of the study. Four transects range in elevation from 2,207 m. to 2,220 m. (7,240 ft. to 7,283 ft.). Onion Park is a moderately high elevation mountain environment that includes wet meadows, ephemeral streams and small, high gradient perennial streams. Tenderfoot Creek has its headwaters in Onion Park. The transect site is located in an area that is free of stream diversion or groundwater withdrawal.

3.3.2 Sheep Creek Road Wet Meadow

The Sheep Creek Road wet meadow is located approximately 5 miles west of Highway 89 on Sheep Creek Road. The wet meadow is in Township 11N, Range 6E, Section 27 in the Kings Hill Ranger District of Lewis and Clark National Forest. The Sheep Creek Road wet meadow contains moderate elevation transects. Two transects are located at an elevation of 1,750 m. The Sheep Creek Road wet meadow is a moderate elevation wet meadow with no perennial stream channel. There is no significant groundwater withdrawal in the area.

3.3.3 Lion Creek

Lion Creek is a moderate elevation perennial stream located in Township 10N, Range 9E, Section 27 in the Kings Hill Ranger District, Lewis and Clark National Forest. Two transects are located on Lion Creek at an elevation of 1,738 m. The transect environment includes alluvial terrace and gravel bar environments. The transect site is located in an area that is free of stream diversion or groundwater withdrawal.

3.3.4 Copper Creek

Copper Creek is a moderate elevation perennial stream located in Township 10N, Range 9E, Section 16 in the Kings Hill Ranger District, Lewis and Clark National Forest. One transect is located on Copper Creek at an elevation of 1,677 m. The transect environment is an alluvial terrace with a gentle slope. Copper Creek is influenced by small amounts of water diversion for irrigation.

3.3.5 Bair Headquarters, Musselshell River

The Musselshell River is a medium size, low gradient meandering river. Four transects are located on alluvial floodplain environments at an elevation of 1,372 m. The transects are located in Township 8N, Range 11E, Section 35 on private land just north of Martinsdale, Montana. The Musselshell River is strongly influenced by water diversion and groundwater withdrawal for irrigation.

3.3.6 Camp Baker, Smith River

The Smith River is a medium size, low to medium gradient river. Three transects are located on a meandering stretch of the Smith just before it enters the Smith River Canyon at 1,280 m. in elevation. The transects are located in Township 12N, Range 4E, Section 13 on Montana Fish, Wildlife and Parks land. The transects are located in an alluvial floodplain environment. The Smith River is strongly influenced by water diversion and groundwater withdrawal for irrigation.

3.3.7 Upper Smith River

Two transects are located on a meandering stretch of the Smith River upstream of Camp Baker. The transects are located in Township 9N, Range 5E, Section 36 on State of Montana land. The transects are located in an alluvial floodplain environment. The Smith River is strongly influenced by water diversion and groundwater withdrawal for irrigation.

4.0 RESULTS

4.1 DESCRIPTIONS OF WATER REGIME OF TRANSECT SITES

The study transect sites are located in relative low, moderate and high elevations in the Smith and Musselshell watersheds (Figure 3-1). Representative transects were selected in each transect site and described below. Graphs of the water table of selected transects (Figures 4-1a through 4-7a) depict the range of water table elevations in comparison to the transect topography over the study period. Cross-sections of all the study transects are provided as Appendix B. Figures 4-1b through 4-7b depict the hydrograph of the stream at the selected transect. The stream stage was gauged at a surveyed point and is presented relative to a surveyed datum point.

4.1.1 Upper Smith River – Transect L1.

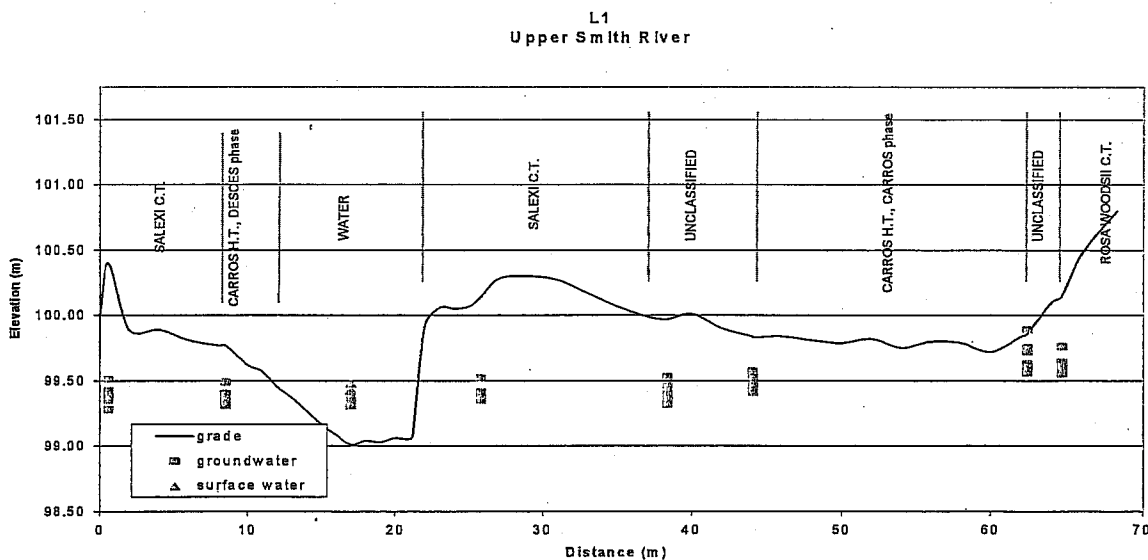


Figure 4-1a. Water table regime of Upper Smith River, Transect L1

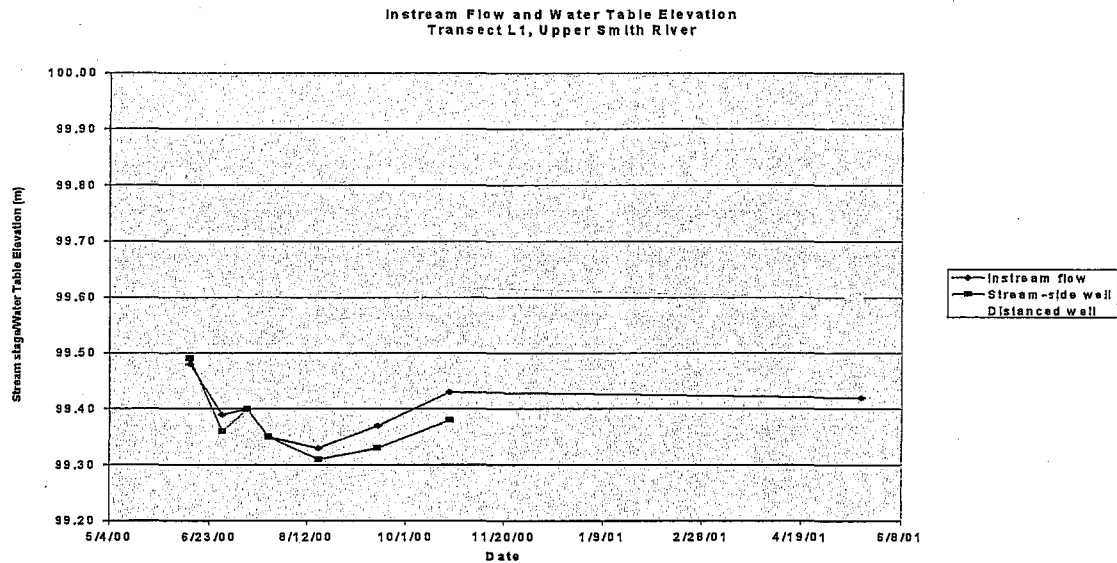


Figure 4-1b. Hydrograph and Water Table Elevations of the Upper Smith River at Transect L1. The stream-side well is located at meter marker 26 and the distanced well is located at meter marker 62 (Figure 4-1a). The stream-side well was frozen during the May 2001 gauging round.

The Upper Smith River is located in a relative low elevation zone of the study area. During the peak of the growing season (June-July) the Smith River is dewatered for irrigation. The stream-side well reflected the reduction in instream flow with decreased water table elevations. The influence of the river on groundwater decreases with distance from the channel. The range of groundwater elevations observed in wells further from the stream channel was greater than that observed in wells closer to the stream (Figures 4-1a and 4-1b). The elevation range of stream-side wells was less variable and reflected the rate and magnitude of change of river stage (Figure 4-1b). In general, water table elevations increased with distance from the stream from meter marker 20 to the end, indicating that the far bank was discharging water to the Smith River. From meter marker 0 to 20 the water table appears relatively flat, but inadequate length of the riparian zone on that bank does not provide adequate information (Figure 4-1a).

The CARROS h.t., DESCES phase was observed in the wettest portion of the transect. The depth to water did not exceed 50 cm during the field season and was near or at the ground surface for the entire field season where the habitat interfaced with surface water. The SALEXI c.t. occurred on the driest portions of Transect L1, where depth to water did not occur less than

approximately 50 cm from the ground surface and occurred as deep as approximately 150 cm below the ground surface (bgs) (Figure 4-1a).

4.1.2 Camp Baker, Smith River – Transect L3

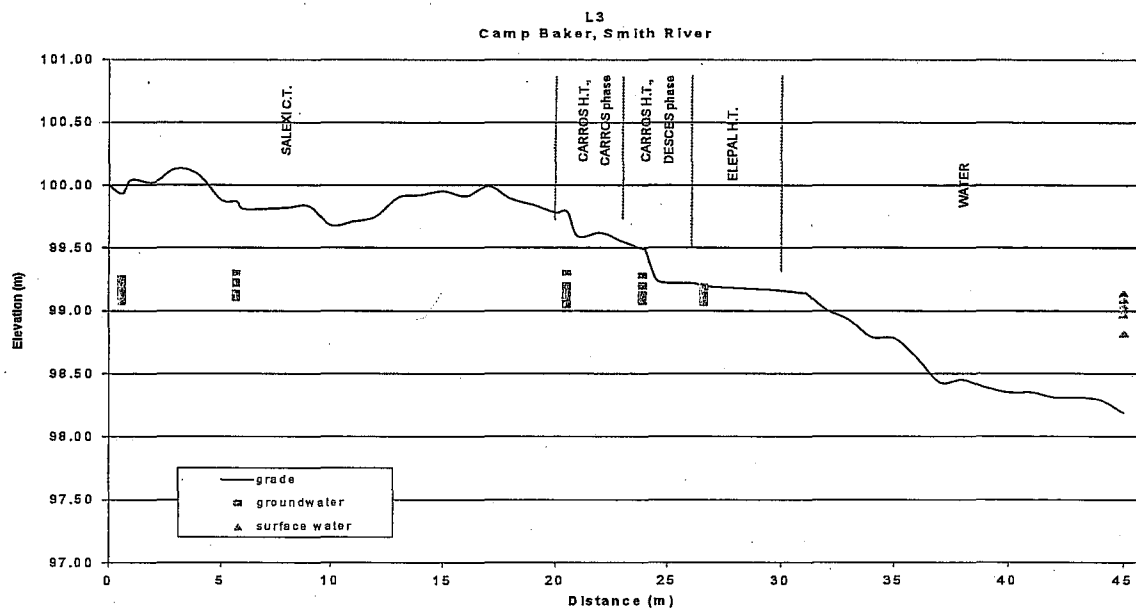


Figure 4-2a. Water table regime of Camp Baker, Smith River at Transect L3.

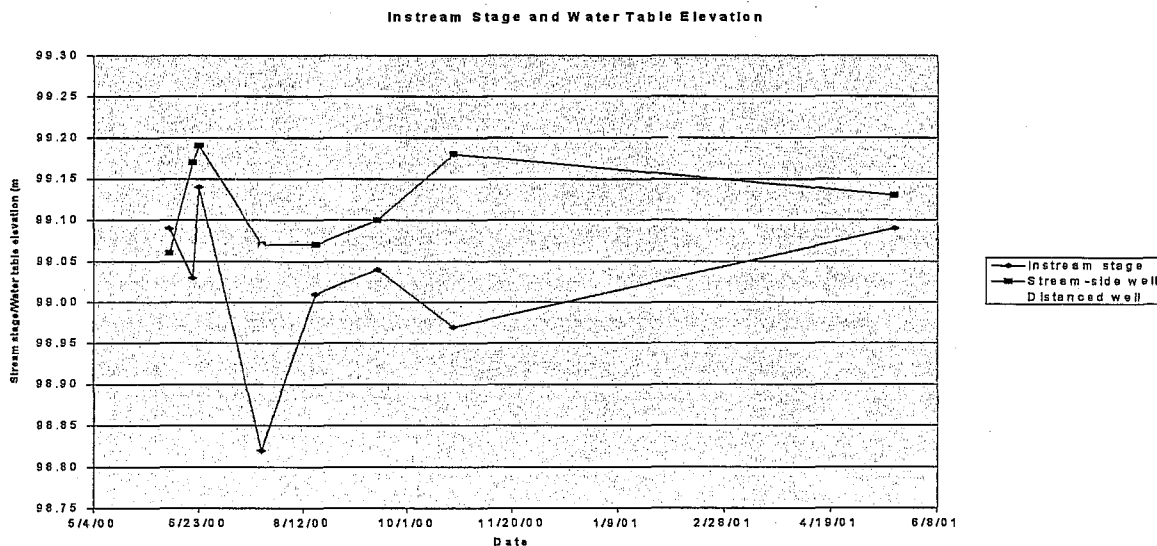


Figure 4-2b. Hydrograph and Water Table Elevations of Camp Baker, Smith River at Transect L3. The stream-side well is located at meter marker 27 and the distanced well is located at meter marker 0.6 (Figure 4-2a).

4.1.4 Copper Creek – Transect M2

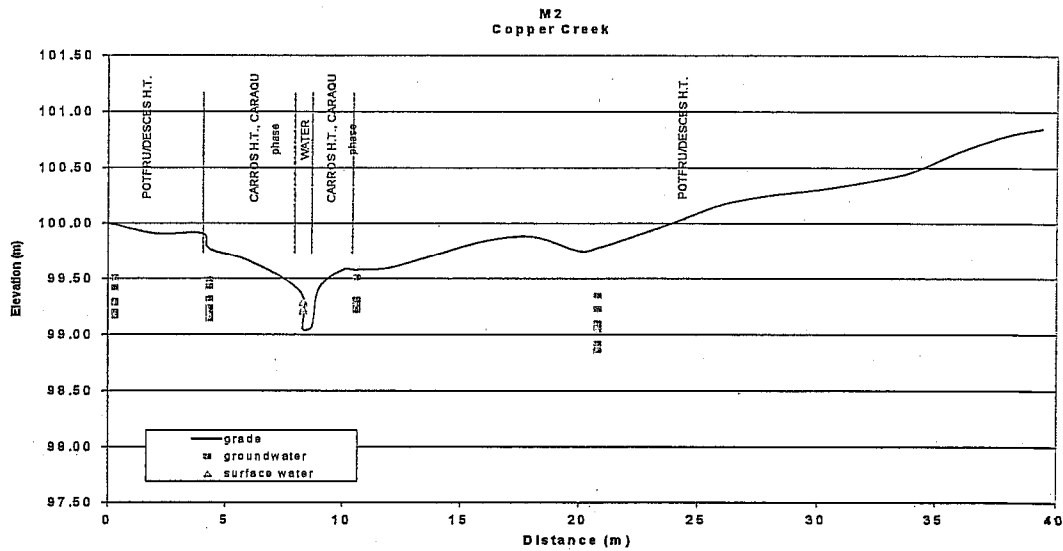


Figure 4-4a. Water table regime of Copper Creek at Transect M2.

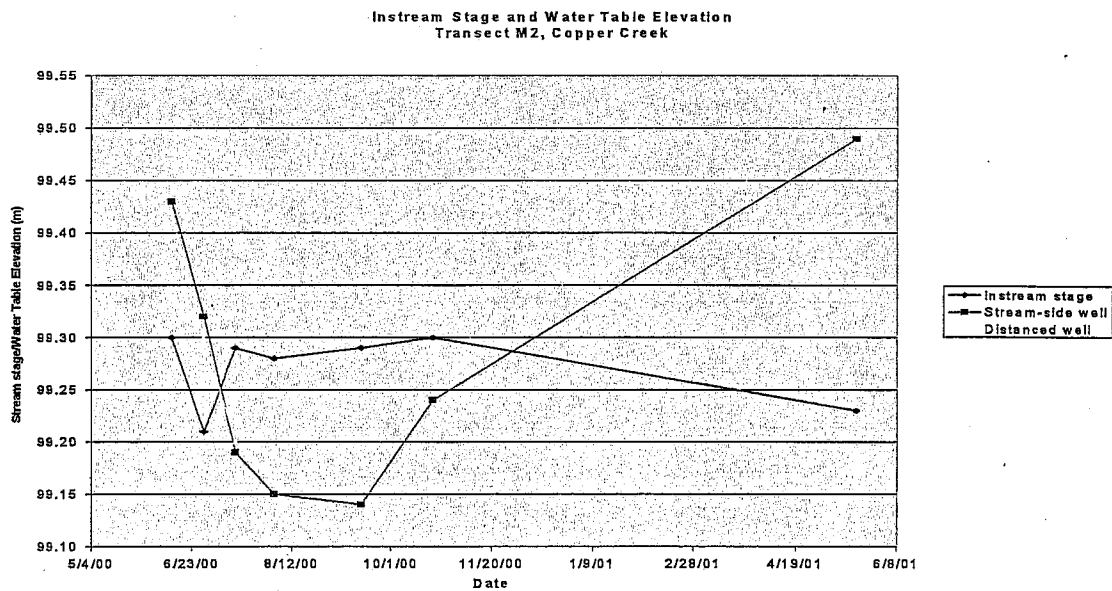


Figure 4-4b. Hydrograph and Water Table Elevations of Copper Creek at Transect M2. The stream-side well is located at meter marker 10.6 and the distanced well is located at meter marker 20 (Figure 4-4a).

The range of groundwater elevations in wells closer to the stream was less than that in wells further from the stream (Figure 4-4a). The wells on this transect did not appear to have a strong connection with the stream; however, the water table did follow the timing of change in the

stream but had greater magnitudes of change (Figure 4-4b). The stream reflects a discharge condition in the winter and spring, i.e. the stream was gaining water from groundwater and a recharge condition in the summer/fall, i.e. the stream was losing water to the groundwater system (Figure 4-4b). The stream stage was relatively stable in comparison to the water table.

The CARROS h.t., CARAQU phase occurred on the wettest portion of the transect. Depth to water ranged from approximately 25 cm bgs to 60 cm bgs. The POTFRU/DESCES h.t. occurred on the driest portions of the transect. Depth to water ranged from 25 cm bgs to 100 cm bgs (Figure 4-4a).

4.1.5 Lion Creek – Transect M4

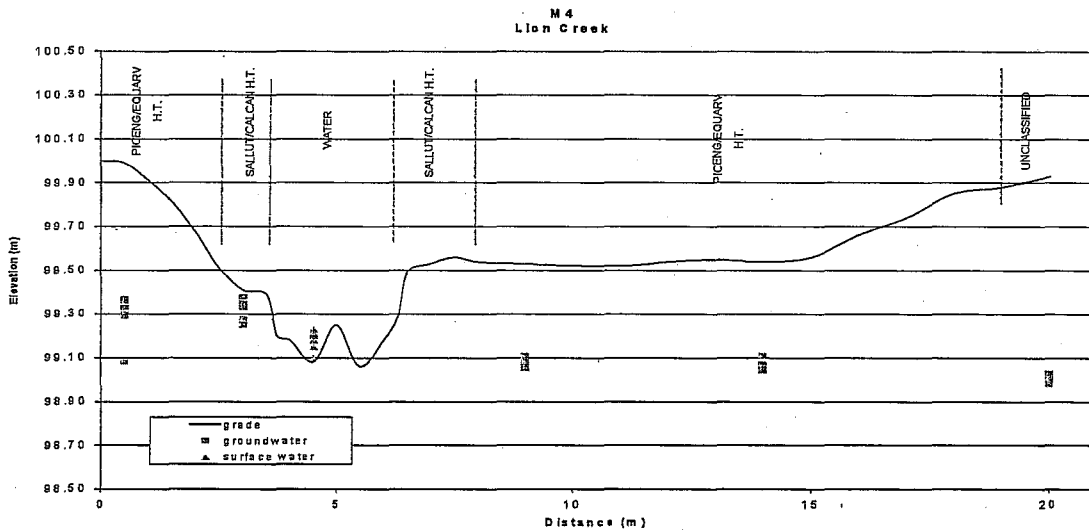


Figure 4-5a. Water table regime of Lion Creek at Transect M4.

4.2 DESCRIPTIONS OF RIPARIAN HABITAT ENVIRONMENTS

Out of 22 riparian habitats mapped in this study, the 10 most frequently occurring habitats over the three elevation zones were selected for further description and analysis. The selection was also made to represent the habitats with the greatest number of hydrologic observations ($n > 14$) and to encompass the six riparian types: coniferous forest, deciduous forest, willow shrub, non-willow shrub, sedge and non-sedge types (Table 4-1).

Riparian Type	Habitat Type (h.t.)	Abbreviation
Coniferous Forest Types	<i>Picea engelmannii</i> / <i>Equisetum arvense</i> h.t.	PICENG/EQUARV h.t.
Deciduous Forest Types	<i>Populus tremuloides</i> / <i>Calamagrostis canadensis</i> h.t.	POPTRE/CALCAN h.t.
Willow Shrub Types	<i>Salix drummondiana</i> / <i>Carex rostrata</i> h.t.	SALDRU/CARROS h.t.
	<i>Salix lutea</i> / <i>Calamagrostis canadensis</i> h.t.	SALLUT/CALCAN h.t.
	<i>Potentilla fruticosa</i> / <i>Deschampsia cespitosa</i> h.t.	POTFRU/DESCES h.t.
Sedge Types	<i>Carex rostrata</i> h.t., <i>Carex rostrata</i> phase	CARROS h.t., CARROS phase
	<i>Carex rostrata</i> h.t., <i>Deschampsia cespitosa</i> phase	CARROS h.t., DESCES phase
	<i>Carex scopulorum</i> h.t.	CARSCO h.t.
	<i>Eleocharis palustris</i> h.t.	ELEPAL h.t.
Non-Sedge Types	<i>Deschampsia cespitosa</i> h.t.	DESCES h.t.

Table 4-1. Riparian habitat types selected for comparison.

4.2.1 CARROS h.t., CARROS phase

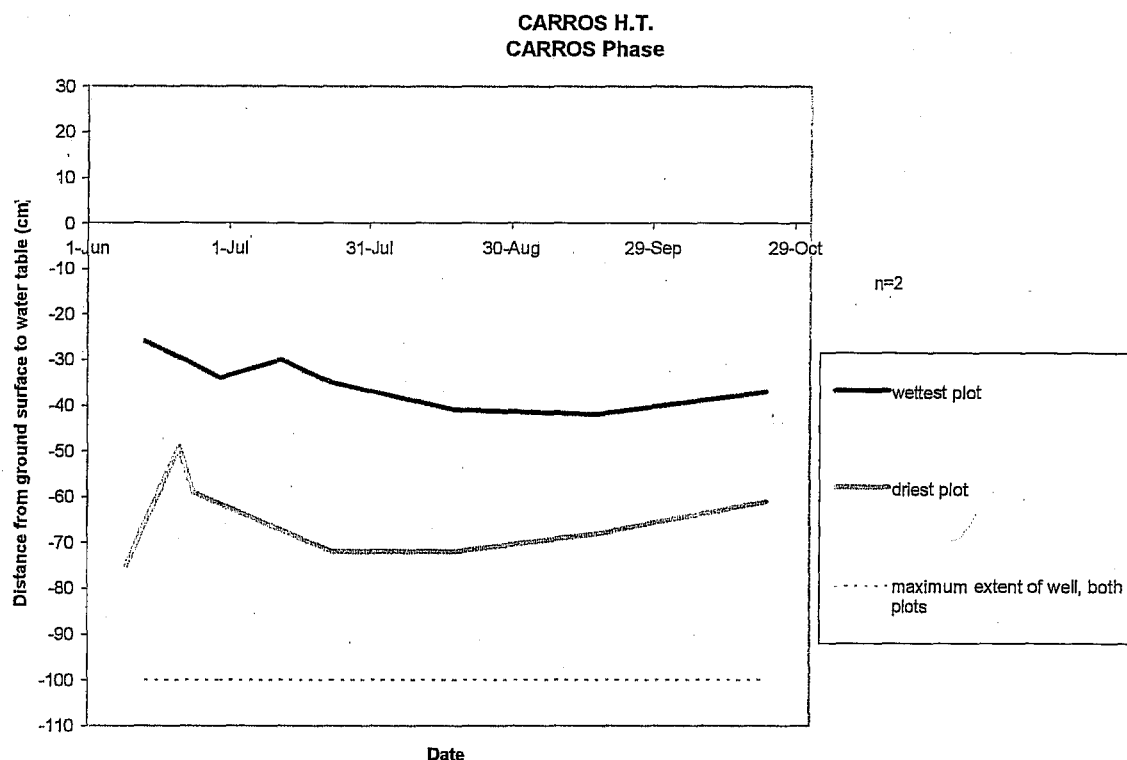


Figure 4-8. Groundwater Regime of the CARROS habitat type, CARROS phase.

This habitat was represented by two plots in the study area. Both plots occurred on the Smith River floodplain; one at Camp Baker and one on the Upper Smith River. Elevations of the plots ranged from 1,280 m. to 1,500 m.

Groundwater in both the wettest and driest plots stayed beneath the average root zone for nearly the entire study period. Groundwater in both plots was relatively stable over the study period and did not have a wide range in either plot (Figure 4-8).

Surface soils of the CARROS h.t., CARROS phase were relatively fine-grained. There were no soils greater than 2 mm in diameter. Of the remaining samples, 50.7% to 76% was silt and clay. Redoximorphic features were observed from 6 cm to 55 cm bgs. Gleying occurred within 39 cm on the wettest plot and not within 55 cm on the dry plot.

Brichta et al (1987), Chadde et al (1988) and Hanson et al (1995) described the habitat as occurring at higher elevations on a variety of riparian environments. Plots occurred on sites that were wet during the entire summer and dry by mid-June.

4.2.2 CARROS h.t., DESCES phase

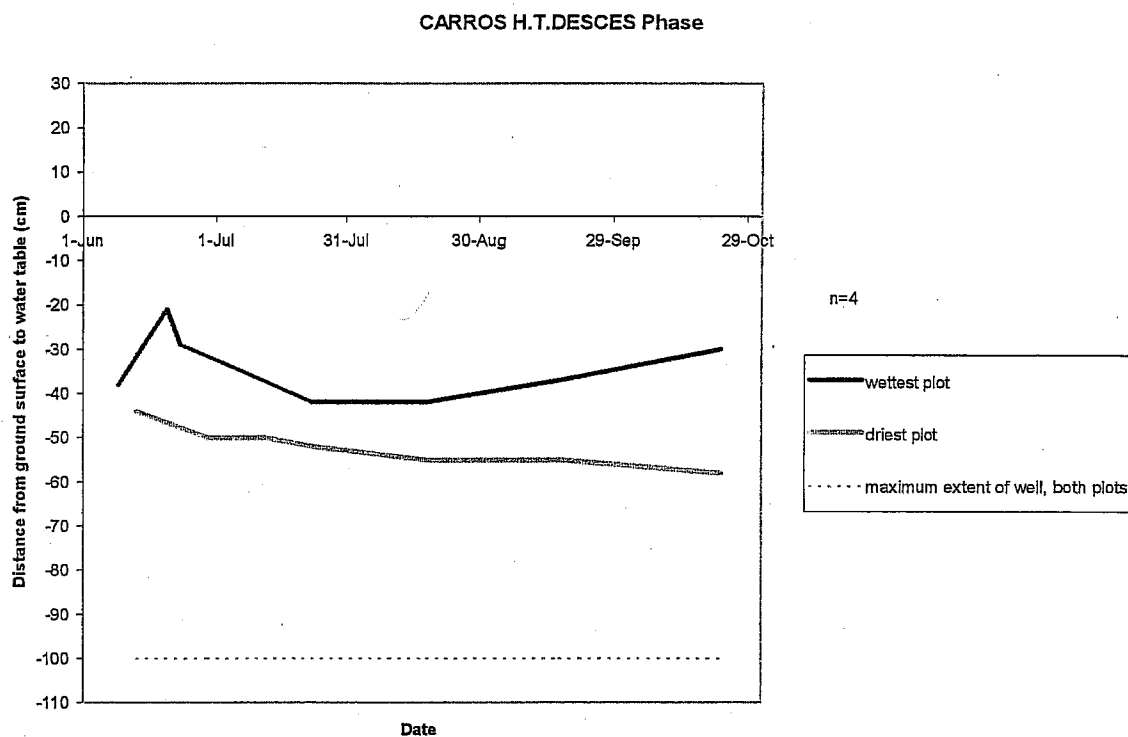


Figure 4-9. Groundwater Regime of the CARROS habitat type, DESCES phase.

This habitat was represented by four plots in the study area. Plots occurred on the Smith River floodplain and on the Sheep Creek Road wet meadow. Elevations of the plots ranged from 1,500 m. to 1,750 m.

Groundwater in both the wettest and driest plots stayed beneath the average root zone for nearly the entire study period. Groundwater in the driest plot was relatively stable over the study period, and generally followed a decreasing trend. Groundwater in both the wettest and driest plot was relatively stable over the study period (Figure 4-8).

Surface soils of the CARROS h.t., DESCES phase varied greatly across the plots. Coarse soils greater than 2 mm ranged from 0% to 8%. Of the remaining sample, fine silt and clay accounted for 26% to 82%. Redoximorphic features occurred from 0 to 6 cm bgs. Gleying occurred from 6 cm to 63 cm bgs.

Chadde (1988) and Hanson (1995) described the DESCES phase of the CARROS h.t. as the driest of the CARROS association, occurring at higher elevations. Brichta (1987) described the habitat as occurring from 2,030 to 2,210 m. on saturated flood plains and on the center of glacial depression. Water tables of this habitat in the Brichta study were within 20 cm of the ground surface for much of the summer and did not drop below 50 cm bgs.

4.2.3 CARSCO h.t.

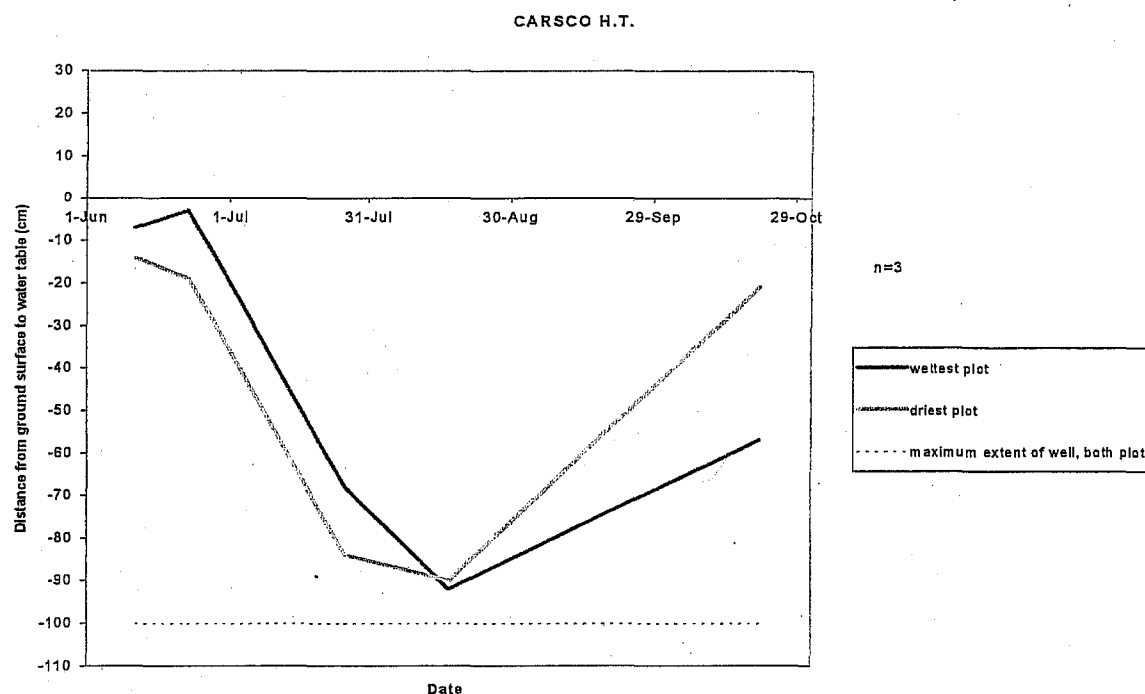


Figure 4-10. Groundwater Regime of the CARSCO habitat type.

This habitat was represented by three plots in the study area. All of the plots occurred on an unnamed stream in the Onion Park area of TCEF at an elevation of 2,220 m.

Groundwater was present within the average root zone in the first third of the growing season in both the wettest and driest plots. Groundwater fluctuated widely in both the wettest and driest plots; the water table ranged from less than 15 cm from the ground surface to greater than 90 cm bgs (Figure 4-10).

Surface soils of the CARSCO h.t. were relatively poorly sorted with a moderately high coarse fraction. Coarse soils greater than 2 mm ranged from 0.3% to 8%. Of the remaining sample, fine silt and clay accounted for 82% to 91.3%. Redoximorphic features were observed as occurring from 0 to 23 bgs. Gleying was observed at 15 cm in one plot and not within 14 cm and 23 cm on the other two plots.

Hanson et al (1995) described the CARSCO h.t. as occurring from 1,983 to 2,532 m. on cold, moist, mountain meadows or basins and seeps.

4.2.4 DESCES h.t.

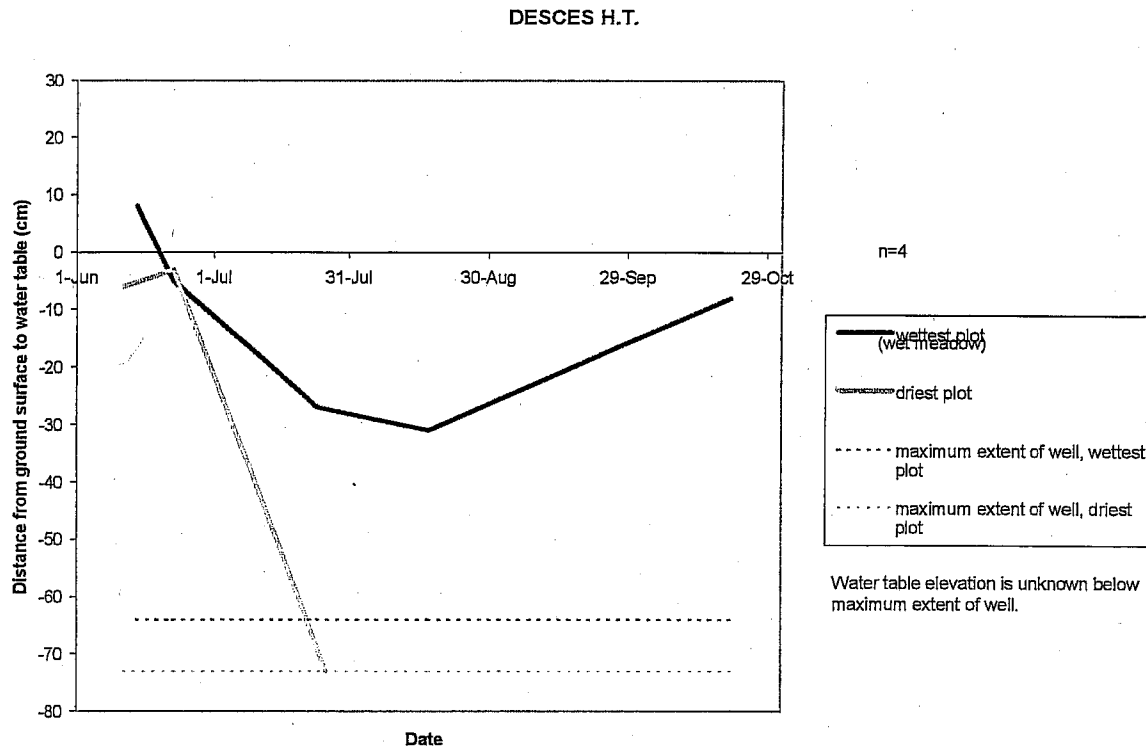


Figure 4-11. Groundwater Regime of the DESCES habitat type.

This habitat was represented by five plots in the study area. The plots were located in the Onion Park area of TCEF and the Sheep Creek Road wet meadow. Elevations of the plots ranged from 1,750 m to 2,220 m.

Groundwater data was available for only four of the five plots in the study area. Depth to water between the wettest and driest plots had a large range. Groundwater in the wettest plot (wet meadow) was above the ground surface for the first three weeks of the study period, and stayed relatively high throughout the study period. Groundwater in the driest plot had a very large magnitude of change; the water table was within 10 cm of the ground surface in the beginning of the growing season and dropped very quickly by the end of July. Groundwater in the driest plot

dropped below the extent of the well by the end of July and did not occur in the well again in the study period (Figure 4-11).

Surface soils of the DESCES h.t. were moderately sorted and uniform across the plots. Coarse soils greater than 2 mm ranged from 1% to 2%. Of the remaining sample, fine silt and clay accounted for 78% to 98%. Gleying occurred from 6 cm to 40 cm in three of the five plots. The remaining two plots did not have gleying within 42 cm, but did exhibit redoximorphic features starting at the ground surface.

Hanson et al (1995) describe this habitat as occurring at mid to high elevations of 1,533 to 3,079 m. The habitat occurs on a variety of environments; commonly those that are flooded by snow melt.

4.2.5 ELEPAL h.t.

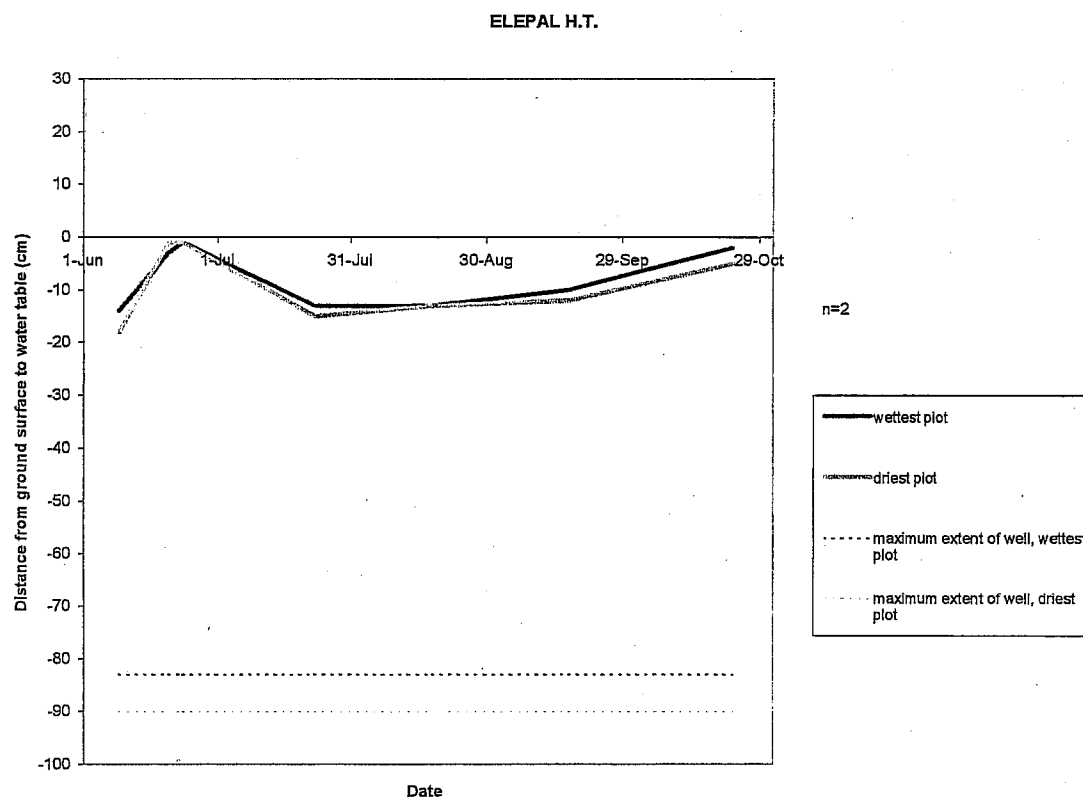


Figure 4-12. Groundwater Regime of the ELEPAL habitat type.

The ELEPAL habitat type was represented by two plots in the study area. Both of the plots were located at Camp Baker on the Smith River at an elevation of 1,280 m.

Groundwater in both plots was within 20 cm of the ground surface during the entire study period. Groundwater elevation and rate and magnitude of change was nearly identical in both plots. (Figure 4-12). In both plots, fine soils appeared to slow recharge into the well upon installation.

Surface soils of the ELEPAL h.t. were extremely variable. Coarse soils greater than 2 mm ranged from 0% to 83%. Of the remaining samples, fine silt and clay accounted for 45.3% to 84%. Gleying was not observed in either plot; however, soils could not be collected in these plots beyond 15 cm in depth. Redoximorphic features were observed from the surface to 15 cm bgs on both plots.

Chadde (1988) described this habitat as occurring in limited areas from an elevation of 1,810 to 2,070 m.; the habitat was observed on pond edges and glacial basins. Hanson et al (1995) describes the ELEPAL habitat as occurring at a wide range of elevations of 671 to 2,477 m. Sites supporting this habitat included stream, river and lake margins and those prone to seasonal flooding.

4.2.6 PICENG/EQUARV h.t.

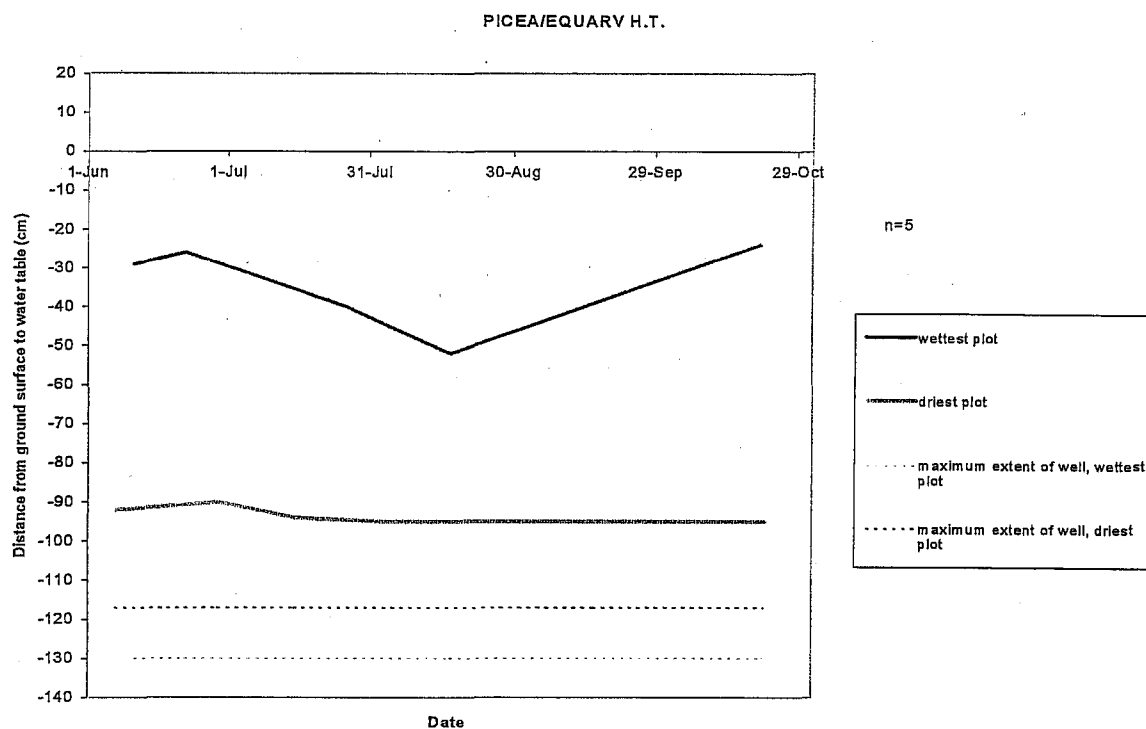


Figure 4-13. Groundwater Regime of the PICENG/EQUARV habitat type.

This habitat was represented by five plots in the study area. The plots were located on an unnamed stream in the Onion Park area of TCEF and on Lion Creek. Elevations ranged from 1,738 m to 2,207 m.

Groundwater information was only available for four of the five plots in the habitat. The water table was not available within the average root zone during most of the growing season in both the wettest and driest plots. Groundwater in the driest plot was stable during the study period (Figure 4-13). There was a large range in water table elevations represented by the wettest and driest plots.

Surface soils of the PICENG/EQUARV h.t. were relatively coarse but uniform across the plots. Coarse soils greater than 2 mm ranged from 5% to 20%. Of the remaining samples, fine silt and clay accounted for 64% to 74.7%. Redoximorphic features were observed in one plot beginning at 6 cm; two plots had redoximorphic features from 66 cm bgs. Gleying was observed ranging

from 26 cm to 39 cm bgs in two of the plots; in the remaining three plots gleying was not observed within 37 cm of the ground surface.

Brichta et al (1987) described the PICENG/EQUARV h.t. as occurring adjacent to active streams at elevations from 2,000 to 2,255 m. Water tables in the habitat were moist only in June; in all but one plot the water table was below 1 meter bgs during the summer. Hanson (1995) described the habitat as having a wider elevation range; 878 to 2,257 m. The habitat occurred on areas with poor drainage, e.g. wet meadows, seeps and low gradient streams.

4.2.7 POPTRE/CALCAN h.t.

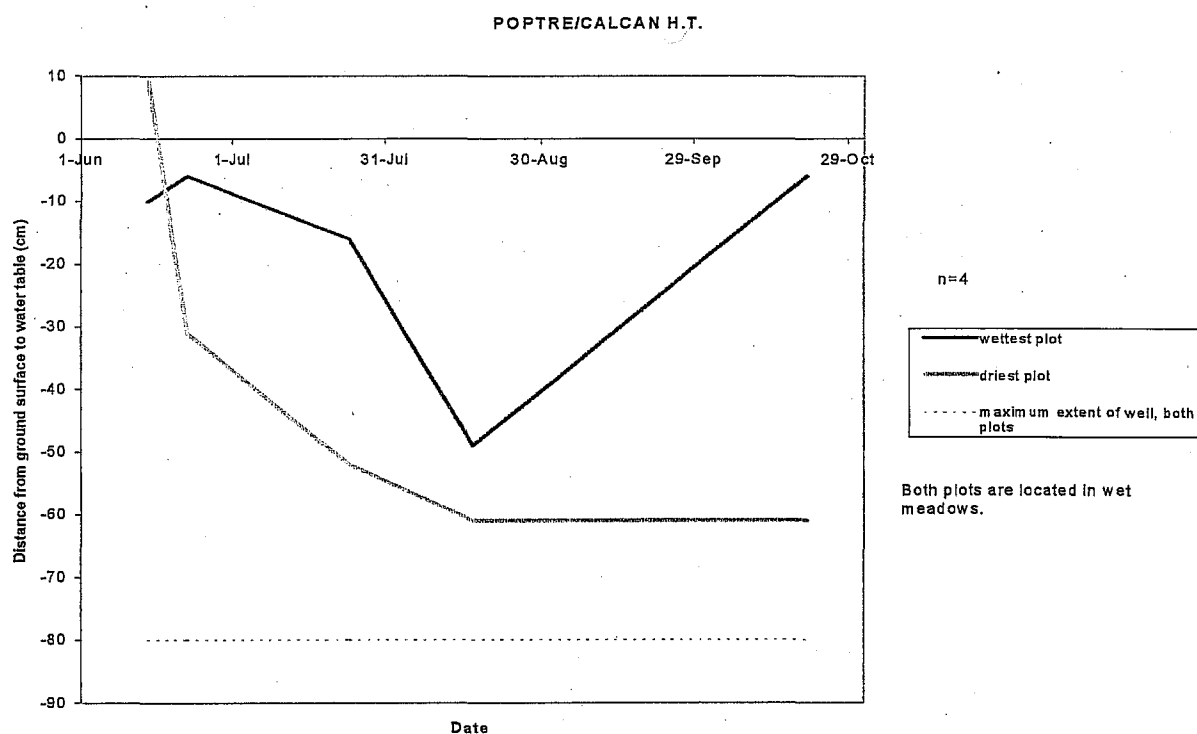


Figure 4-14. Groundwater Regime of the POPTRE/CALCAN habitat type.

This habitat was represented by four plots in the study area. All of the plots were located on the Sheep Creek Road wet meadow at an elevation of 1,750 m.

Groundwater in both the wettest and driest plot had a large range during the study period. Groundwater in the wettest plot was less than 10 cm from the ground surface during the first and

last month of the study period and dropped as low as half a meter over the study period. Groundwater in the driest plot ranged as high as 9 cm above the ground surface and as low as 61 cm below the ground surface during the study period (Figure 4-14). The water table was available in the average root zone for most of the growing season.

Surface soils of the POPTRE/CALCAN h.t. were relatively coarse and variable across the plots. Coarse soils greater than 2 mm ranged from 0% to 22%. Of the remaining samples, fine silt and clay accounted for 54.6% to 82.7%. Redoximorphic features were observed throughout the soil column sampled. Gleying was observed ranging from 21 cm to 38 cm bgs in three of the plots; in the remaining plot gleying was not observed within 85 cm of the ground surface.

Hanson et al (1995) described the POPTRE/CALCAN h.t. as typically occurring adjacent to streams and rivers on alluvial terraces. Surface soils had a high coarse fragment that provided high aeration and rapid water movement.

4.2.8 POTFRU/DESCES h.t.

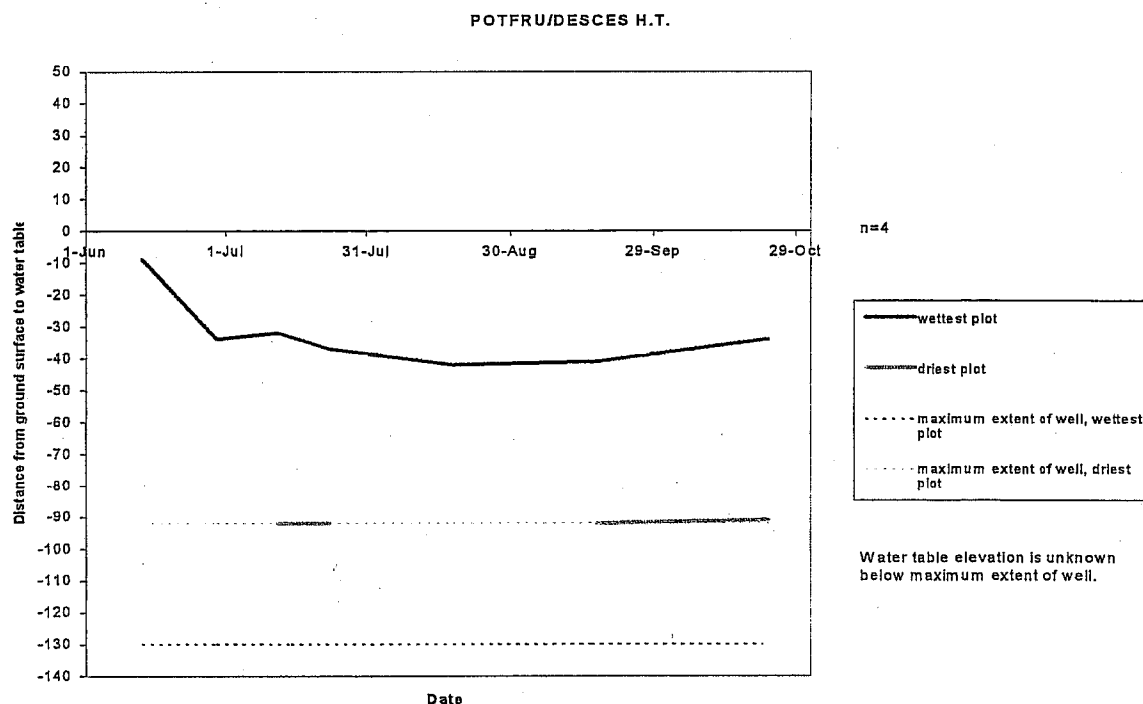


Figure 4-15. Groundwater Regime of the POTFRU/DESCES habitat type.

This habitat was represented by six plots in the study area. The plots were located on the upper Smith River floodplain and on Copper Creek. Elevations of the plots ranged from 1,500 m to 1,680 m.

Groundwater in the wettest plot was at or just below the average root zone for the entire study period. Groundwater in the driest plot was observed within the extent of the well four times during the study period, at minimal levels (Figure 4-15).

Surface soils of the POTFRU/DESCES h.t. were moderately sorted and uniform across the plots. Coarse soils greater than 2 mm ranged from 0.2% to 2%. Of the remaining sample, fine silt and clay accounted for 70% to 90.6%. Gleying or other redoximorphic features did not occur within 80 cm of the ground surface in any plots.

Brichta et al (1987), Chadde et al (1988) and Hanson et al (1995) described this habitat as occurring on slightly higher, drier ground surrounding glacial depressions, along slow streams and on gentle slopes surrounding streams. Water tables fluctuate widely throughout the summer and commonly drop to greater than 1 meter by late summer.

4.2.9 SALDRU/CARROS h.t.

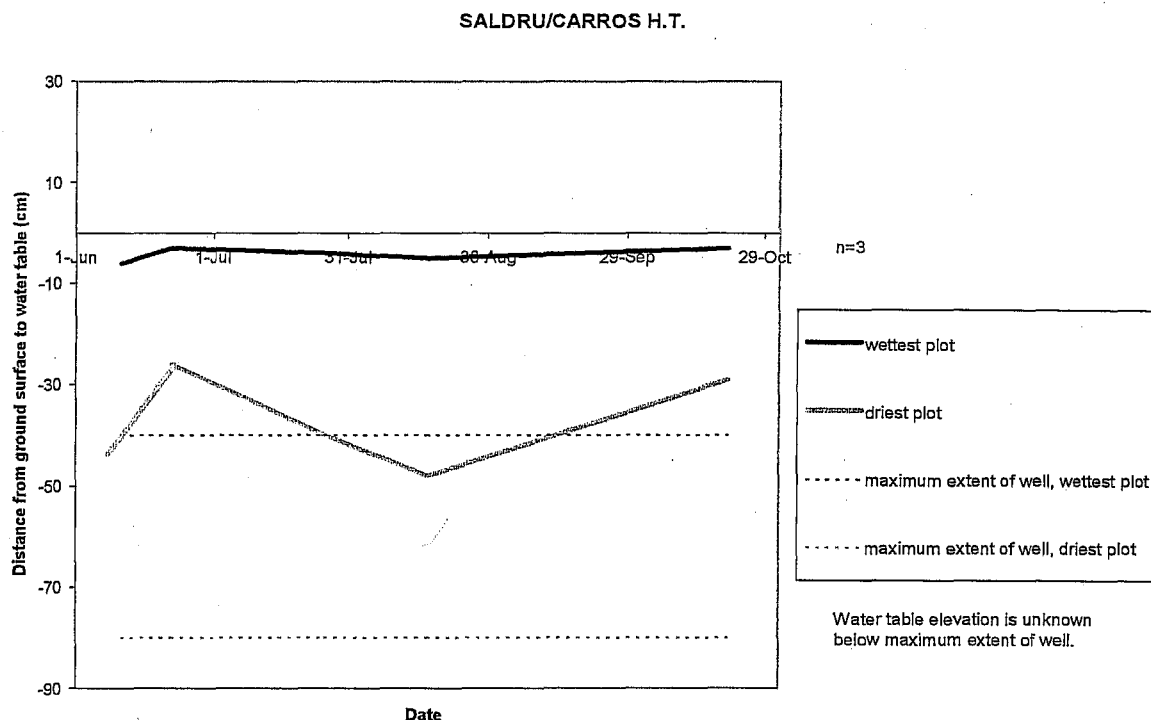


Figure 4-16. Groundwater Regime of the SALDRU/CARROS habitat type.

This habitat was represented by four plots in the study area. All of the plots were located on an unnamed stream in the Onion Park area of TCEF.

Depth to water was highly variable across the SALDRU/CARROS habitat. Groundwater in the wettest plot was relatively stable over the entire study period and stayed within 6 cm of the ground surface. The water table was only within the average root zone for a small portion of the growing season (Figure 4-16).

Surface soils of the SALDRU/CARROS h.t. were relatively fine and uniform across the plots. Coarse soils greater than 2 mm ranged from 0% to 1%. Of the remaining samples, fine silt and clay accounted for 72% to 86%. Gleying was not observed in any of the plots within 20 cm; however, redoximorphic features were observed from the ground surface throughout the sampled soil column.

Hanson et al (1995) described this habitat type as occurring next to ponds or marshes, seeps, springs and adjacent to mountain streams from 707 to 2,378 m. Surface soils and water tables can vary substantially.

4.2.10 SALLUT/CALCAN h.t.

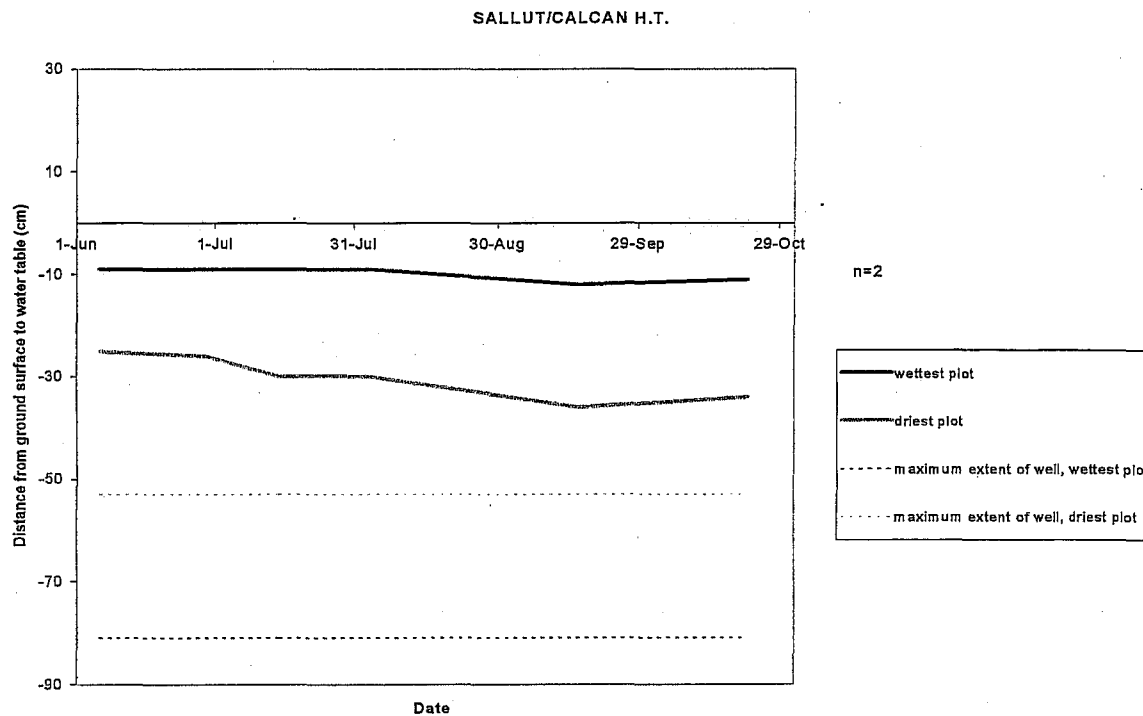


Figure 4-17. Groundwater Regime of the SALLUT/CALCAN habitat type.

This SALLUT/CALCAN habitat type was represented by three plots in the study area. All of the plots occurred on Lion Creek at an elevation of 1,740 m.

Groundwater was within 15 cm of the ground surface on the wettest plot for the entire growing season and varied very little over the study period. Groundwater on the driest plot remained within the average root zone until approximately the end of July and then dropped gradually but stayed within 6 cm of the root zone (Figure 4-17).

Surface soils of the SALLUT/CALCAN h.t. were relatively coarse and variable across the plots. Coarse soils greater than 2 mm ranged from 0.2% to 37%. Of the remaining samples, fine silt

and clay accounted for 58.7% to 75.3%. Gleying was observed in two of the three plots at a range of 9 cm to 10 cm bgs.

Hanson et al (1995) described this community type as typically occurring on stream and river edges, seeps and moist alluvial terraces from 1,116 to 1,341 m. Water tables in this community fluctuate widely through the summer but are seasonally high.

4.3 INUNDATION/DURATION

Figures 4-18 through 4-20 depict the percent exceedence levels for depth to saturation in the selected riparian habitats. The percent exceedence, or frequency, demonstrates the percentage of time a certain depth to saturation was met or exceeded in the habitat during the study period.

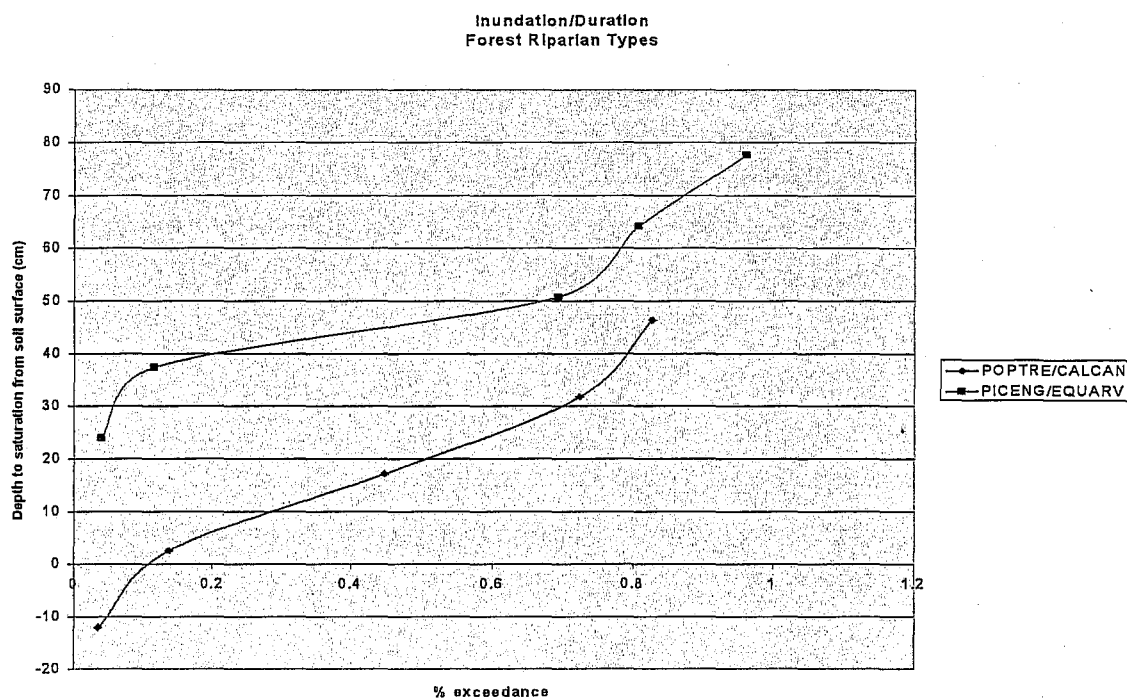


Figure 4-18. Percent exceedence of depth to saturation of the forest riparian habitat types.

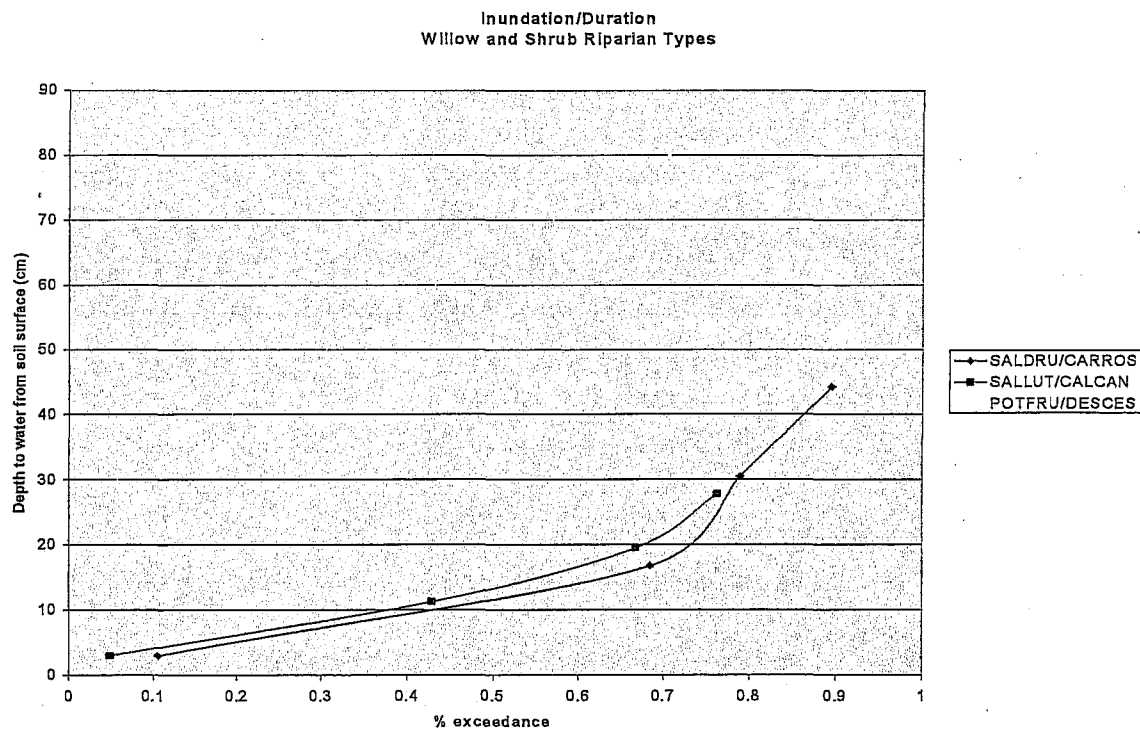


Figure 4-19. Percent exceedance of depth to saturation of the willow and shrub riparian habitat types.

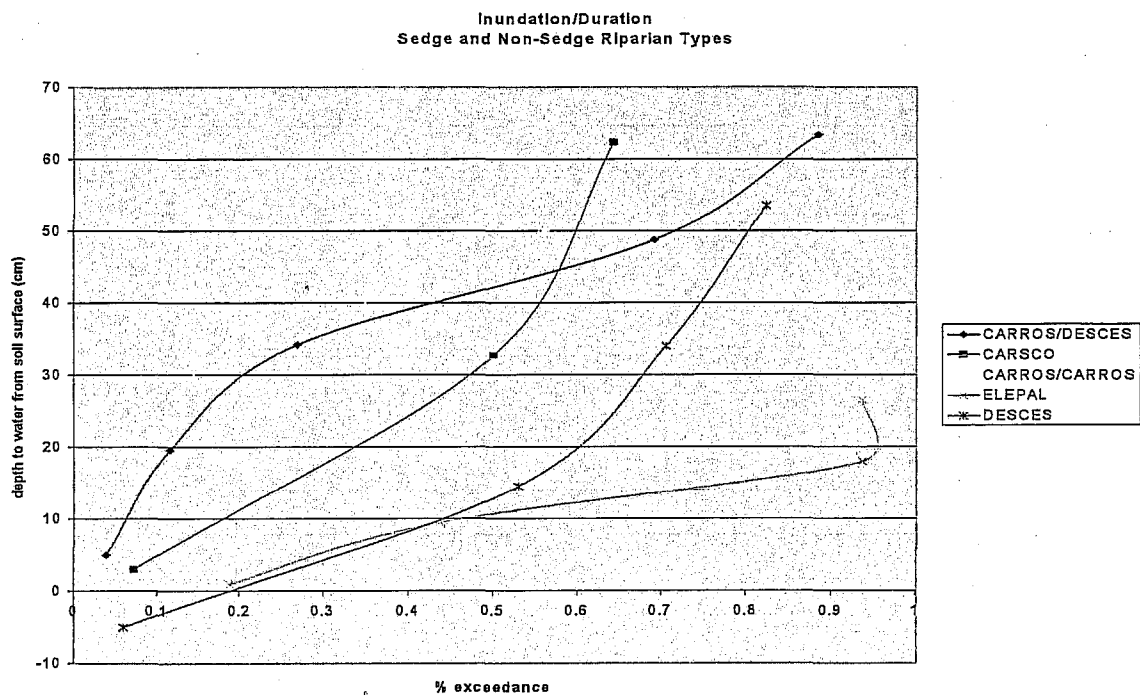


Figure 4-20. Percent exceedance of depth to saturation of the sedge and non-sedge riparian habitat types.

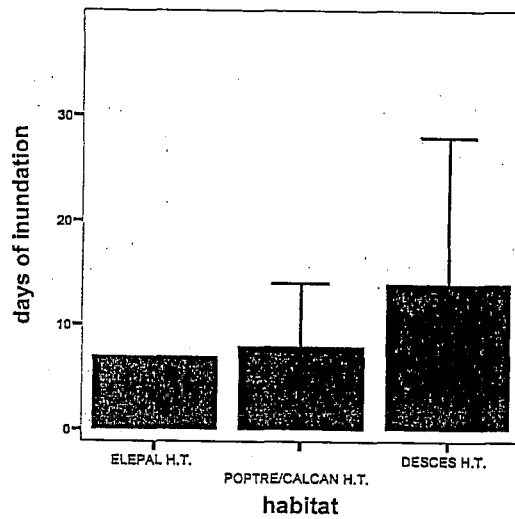


Figure 4-21. Inundation duration of riparian habitats that had water at or above the ground surface during the study.

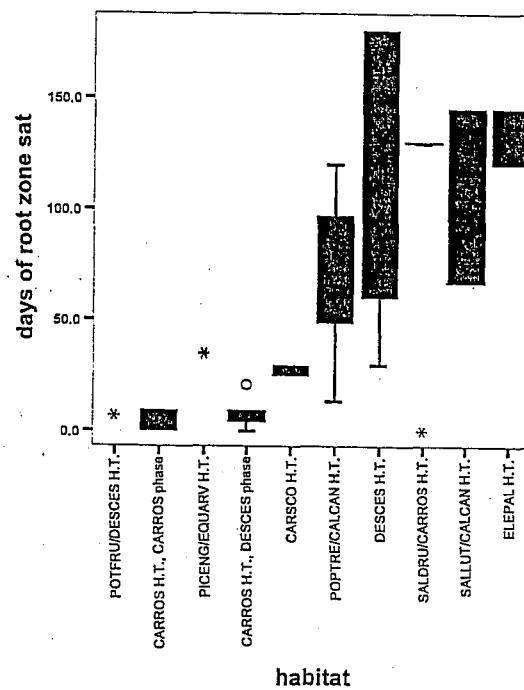


Figure 4-22. Duration of saturation within the root zone (<30 cm) of selected riparian habitats.

Three of the riparian habitats experienced inundation during the study period (Figure 4-21). The willow/shrub riparian type did not have any habitats that were flooded during the study period. The DESCES habitat type had the largest range of days of seasonal inundation. Up to 28 days of inundation was observed on the DESCES habitat type. The POPTRE/CALCAN habitat type was inundated for up to 14 days and the ELEPAL habitat was inundated for up to 7 days.

All of the selected riparian habitats experienced saturated conditions within the average root zone (<30 cm) during some part of the study period (Figure 4-22). The sedge type was the most variable; the days of saturation at 30 cm or less ranged from 0 to 145 days for the entire type. The ELEPAL habitat had the longest duration of root saturation; the soil was saturated to at least 30 cm during the entire study period. The POTFRU/DESCES habitat had the least amount of days of a saturated root zone; only one plot was saturated to at least 30 cm and for only 7 days.

4.4 DEPTH TO GROUNDWATER

The depth to groundwater data was tied to the inundation frequency and duration data. Figure 4-23 displays the range of depth to groundwater values for the selected riparian habitats.

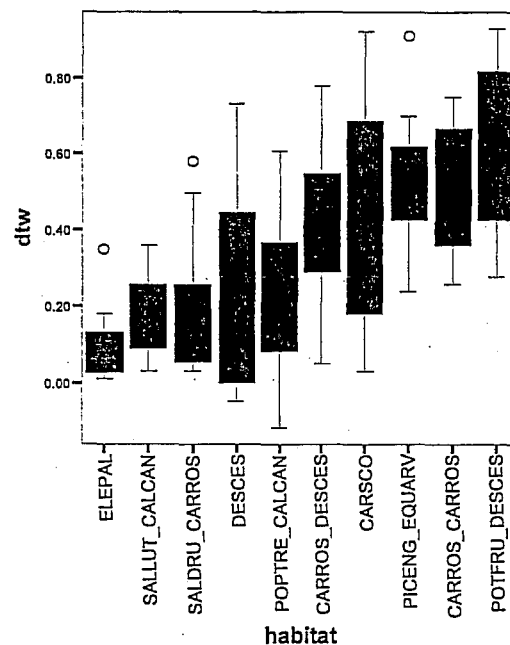


Figure 4-23. Range of depth to groundwater of selected riparian habitats.

Water table elevations on the study transects ranged from at or above the ground surface to greater than 150 cm bgs. The ELEPAL habitat type had the highest water table and smallest range of values of the selected riparian habitats. The POTFRU/DESCES habitat type showed the greatest depth to groundwater and had a relatively large range of values. The sedge types showed the greatest variability of depth to water. Both of the willow types were in the upper 1/3 of the distribution. In general, an increasing range of depth to water values correlated with deeper groundwater environments.

In general, the willow types had the smallest depths to water overall. Both of the willow types (SALLUT/CALCAN and SALDRU/CARROS) had a mean depth to water of 17 cm.

The sedge types had a wide range of depth to water observations, but all of the sedge types had water tables within 70 cm of the ground surface. The mean depth to water for the sedge types ranged from 10 cm to 51 cm bgs.

The deciduous and conifer forest types had a wide range of mean depth to water. The PICENG/CALCAN h.t. had the narrowest range and smallest values of depth to water observations. Mean depth to water of the forest types ranged from 23 cm to 50 cm.

5.0 DISCUSSION AND CONCLUSION

The purpose of this study was to help define the characteristics of the riparian water regime with both qualitative and quantitative instream flow and groundwater information. The objectives were to:

1. determine the interaction of in-stream flow in reference reaches with groundwater in surrounding riparian areas;
2. gain an understanding of flow and inundation duration on reference reaches and how they influence riparian vegetation distribution in surrounding riparian areas; and
3. define the dynamics of water table change in riparian habitats examined in this study.

5.1 WATER REGIME AND RIPARIAN HABITAT DISTRIBUTION

Groundwater in the study had less of a connection with surface water as one increased through the elevation zones. The gradient of the elevation of surface water and the water table became more pronounced in moderate and high elevation transect sites.

Further investigation of the relationship between elevation and habitats that experienced inundated conditions revealed moderate evidence that elevation played a large part in where inundated conditions; and thus plants tolerant of those conditions; would occur. Eight of the twenty-two riparian habitats observed in this study experienced inundated conditions during this study. All of these habitats occurred in wet meadow or medium to high gradient streams of moderate to high elevations, or elevations ranging from 1,667 m. to 2,220 m. However, as a result of the moderate to high elevation, these transects were also located in areas that do not experience the impacts of dewatering and groundwater withdrawal. Transects on the lower elevation Smith and Musselshell Rivers were also subject to increased water withdrawal in addition to drought conditions. With the exception of POTFRU/DESCES, every selected riparian habitat type exhibited redoximorphic features at or just below the ground surface. The redoximorphic features are indicative of a fluctuating water table that in this case, remains at or

Because this study occurred in a year of record low water table elevation and stream flow, riparian plants were subjected to conditions that may well represent the minimum frequency and duration of hydrologic conditions for habitat sustainability. Further observation of these communities on established transects sites will allow researchers and managers to see the implications of drought conditions on riparian habitats, especially the more responsive herbaceous layer.

Continued investigation of specific hydrologic requirements of Montana's riparian habitats is essential to ensure a balance between the water needs of land managers and the need to sustain the riparian zone. Without a sound database of the hydrologic requirements of Montana's riparian habitats, further loss of riparian areas and the benefits they provide could occur as a result of misguided land management decisions.

REFERENCES CITED

- Auble, G.T., J. M. Friedman and M. L. Scott. 1994. Relating riparian vegetation to present and future streamflows. *Ecological Applications*, 4. 544-554.
- Auble, G.T. and M.L. Scott. 1998. Fluvial disturbance patches and cottonwood recruitment along the Upper Missouri River, Montana. *Wetlands*. 18(4). 546-556.
- Blumer, J.W. 1969. Geology of the Deadman Canyon-Copperopolis area, Meagher County, Montana. Montana College of Mineral Science and Technology, Master's Thesis.
- Braico, R.D. and M.K. Botz. 1974. Water quality inventory and management plan: Missouri-Sun-Smith Basin, Montana. Water Quality Bureau, Environmental Sciences Division, Montana Dept. of Health and Environmental Sciences.
- Brichta, P.H. 1987. Environmental relationships among wetland community types of the Northern Range, Yellowstone National Park. University of Montana School of Forestry Master's Thesis.
- Carter, V., P.T. Gammon, M.K. Garrett. 1994. Ecotone dynamics and boundary determination in the Great Dismal Swamp. *Ecological Applications*. 4(1), 189-203.
- Castro, N. M. and G. M. Hornberger. 1991. Surface-subsurface water interactions in an alluviated mountain stream channel. *Water Resources*, 27, 1613-1621.
- Chadde, S.W., P.L. Hanson and R.D. Pfister. 1988. Wetland plant communities of the Northern Range, Yellowstone National Park. Final Contract Report, School of Forestry, University of Montana.
- Cowardin, L.M., V. Carter, F.C. Golet and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Service FWS/OBS-7731.
- Dahl, G.G. Jr. 1969. General geology of the area drained by the North Fork of the Smith River; Meagher County, Montana. Montana College of Mineral Science and Technology, Master's Thesis.
- Dionigi, C.P., I.A. Mendelssohn and V.I. Sullivan. 1985. Effects of soil waterlogging on the energy status and distribution of *Salix Negra* and *S. Exigua* (Salicaceae) in the Atchafalaya River basin of Louisiana. *American Journal of Botany*. 72(1). 109-119.
- Doss, Paul K. 1995. Physical-hydrogeologic processes in wetlands. *Natural Areas Journal*. 15:216-226
- DuPea, Robert. 2000. Personal communication.

Ehrhart, R. C. and P. L. Hansen. 1998. Successful strategies for grazing cattle in riparian zones. *Montana BLM, Riparian Technical Bulletin*. 4. 1-4.

Environmental Laboratory. 1987. Corps of Engineers wetlands delineation manual. Technical Report Y-87-1. U.S. Army Engineer Waterways Experiment Station.

Farnes, P.E., W.W. McCaughey and K.J. Hansen. 1995. Hydrologic and geologic characterization of Tenderfoot Creek Experimental Forest, Montana. USDA *Intermountain Research Station and Montana State University, Department of Earth Sciences, Final Report RJVA-INT-92734*.

Faulkner, S.P. and W.H. Patrick. 1992. Redox processes and diagnostic wetland soil indicators in bottomland hardwood forests. *Soil Science Society of America Journal*. 56. 856-865.

Fetter, C.W. 1994. *Applied Hydrogeology*. Upper Saddle River, NJ: Prentice Hall.

Gordon, N.D., T.A. McMahon, B.L. Finlayson. 1992. Stream Hydrology: An Introduction for Ecologists. Wiley and Sons, NY.

Groeneveld, D.P. and T.E. Griepentrog. 1985. Interdependence of groundwater, riparian vegetation and streambank stability: a case study. *Symposium on Riparian Ecosystems and Their Management*. Tuscon, Arizona.

Groff, S.L. 1965. Reconnaissance ground-water and geological studies, western Meagher County, Montana. *State of Montana, BMG, Special Publication*. 35(3).

Grove, M. and D. Dunn. 1980. Geothermal heating system for the First National Bank of White Sulphur Springs, Montana. Montana DNRC, Renewal Energy and Conservation Program, GAN 503-771.

Hansen, P. L., R. D. Pfister, K. Boggs, B.J. Cook, J. Joy and D. K. Hinckley. 1995. Classification and Management of Montana's Riparian and Wetland Sites. *Montana Forest and Conservation Experiment Station, School of Forestry, University of Montana, Miscellaneous Publication*. 54, 1-72.

Harrelson, C. C., C. L. Rawlins and J. P. Potyondy. 1994. Stream channel reference sites: an illustrated guide to field technique. *Rocky Mountain Forest and Range Experiment Station*. RM-245. 1-59.

Harris, S.W. and W.H. Marshall. 1963. Ecology of water-level manipulations on a northern marsh. *Ecology*. 44(2). 331-343.

Henszey, R. J., Q. D. Skinner and T. A. Wesche. 1991. Response of montane meadow vegetation after two years of streamflow augmentation. *Regulated rivers: Research and Management*. 6. 29-38.

Kendy, E. and R.E. Tresch. 1996. Geographic, geologic and hydrologic summaries of intermontane basins of the northern Rocky Mountains, Montana. *USGS Water Resources Investigations Report* 96-4025.

Knopf, F. L., R. R. Johnson, T. Rich, F. B. Samson and R. C. Szaro. 1988. Conservation of riparian ecosystems in the United States. *Wilson Bulletin*. **100(2)**. 272-284.

Kondolf, G. M., J. W. Webb, M. J. Sale and T. Felando. 1987. Basic hydrologic studies for assessing impacts of flow diversions on riparian vegetation: examples from streams of the eastern Sierra Nevada, California, USA. *Environmental Management*. **11**. 757-769.

Kozłowski, T.T. 1968. Water Deficits and Plant Growth. New York Academic Press. **(2)**.

McCaughey, W. W. 1999. Tenderfoot Creek Experimental Forest. TCEF brochure.

McClernan, H.G. 1967. Geology of the Sheep Creek area, Meagher County, Montana. Montana College of Mineral Science and Technology, Master's Thesis.

Phelps, G.B. 1966. Geology of the Newlan Creek area, Meagher County, Montana. Montana College of Mineral Science and Technology, Master's Thesis.

RMRS. 1997. Tenderfoot Research Project. *Rocky Mountain Research Station*. **RWU-4151**. 1-22.

Rood, S.B., A.R. Kalischuk and J.M. Mahoney. 1998. Initial cottonwood seedling recruitment following the flood of the century of the Oldman River, Alberta, Canada. *Wetlands*. **18 (4)**. 557-570.

Rood, S.B. and J.M. Mahoney. 1990. Collapse of riparian poplar forests downstream from dams in western prairies: probable causes and prospects for mitigation. *Environmental Management*. **14**. 451-464.

Rood, S.B., J.M. Mahoney, D.E. Reid, L. Zilm. 1994. Instream flows and the decline of riparian cottonwoods along the St. Mary River, Alberta. *Canadian Journal of Botany*. **73**. 1250-1260.

Shafroth, P.B., J.C. Stromberg and D.T. Patten. 2000. Woody vegetation response to different alluvial water table regimes. *Western North American Naturalist*. **60(1)**. 66-76.

Scott, M.L., J.M. Friedman and G.T. Auble. 1996. Fluvial Process and the establishment of bottomland trees. *Geomorphology*. **14**. 327-339.

Smith, S.D., A.B. Wellington, J.L. Nachlinger and C.A. Fox. 1991. Functional responses of riparian vegetation to streamflow diversion in the eastern Sierra Nevada. *Ecological Applications*. **1(1)**. 89-97.

Soden, J. 1999. Application of the United States Army Corps of Engineers wetland delineation field indicators within subalpine zone wetland of western Montana. University of Montana, School of Forestry.

Stromberg, J. C. and D. T. Patten. 1990. Riparian vegetation instream flow requirements: a case study from a diverted stream in the eastern Sierra Nevada, California. *Environmental Management*. **14**. 185-194.

Stromberg, J. C. and D. T. Patten. 1992. Mortality and age of black cottonwood stands along diverted and undiverted streams in the eastern Sierra Nevada, California. *Madrono*. **39**, **3**. 205-233.

Stromberg, J.C. and D.T. Patten. 1996. Instream flow and cottonwood growth in the eastern Sierra Nevada of California, USA. *Regulated Rivers: Research and Management*. **12**. 1-12.

Stromberg, J. C. 1992. Instream models for mixed deciduous riparian vegetation within a semiarid region. *Regulated Rivers: Research and Management*. **8**. 225-235.

Stromberg, J.C. 1993. Instream flow models for mixed deciduous riparian vegetation within a semi arid region. *Regulated Rivers: Research and Management*. **8**. 225-235.

Stromberg, J. C., R. Tiller and B. Richter. 1996. Effects of groundwater decline on riparian vegetation of semiarid regions: the San Pedro, Arizona. *Ecological Applications*. **6**(1). 113-131.

Tabacci, E., D. L. Correll, R. Hauer, G. Pinay, A. Planty-Tabacci and R. C. Wissmar. 1998. Development, maintenance and role of riparian vegetation in the river landscape. *Freshwater Biology*. **40**. 497-516.

Taub, F. B. 1987. Indicators of change in natural and human-impacted ecosystems. Pp. 115-144 in S. Draggan, J. J. Cochrane and R. E. Morrison (eds.), Preserving ecological systems: the agenda for long-term research and development. Praeger Press, New York.

Toner, M. and P. Keddy. 1997. River hydrology and riparian wetlands: a predictive model for ecological assembly. *Ecological Applications*. **7**(1). 236-246.

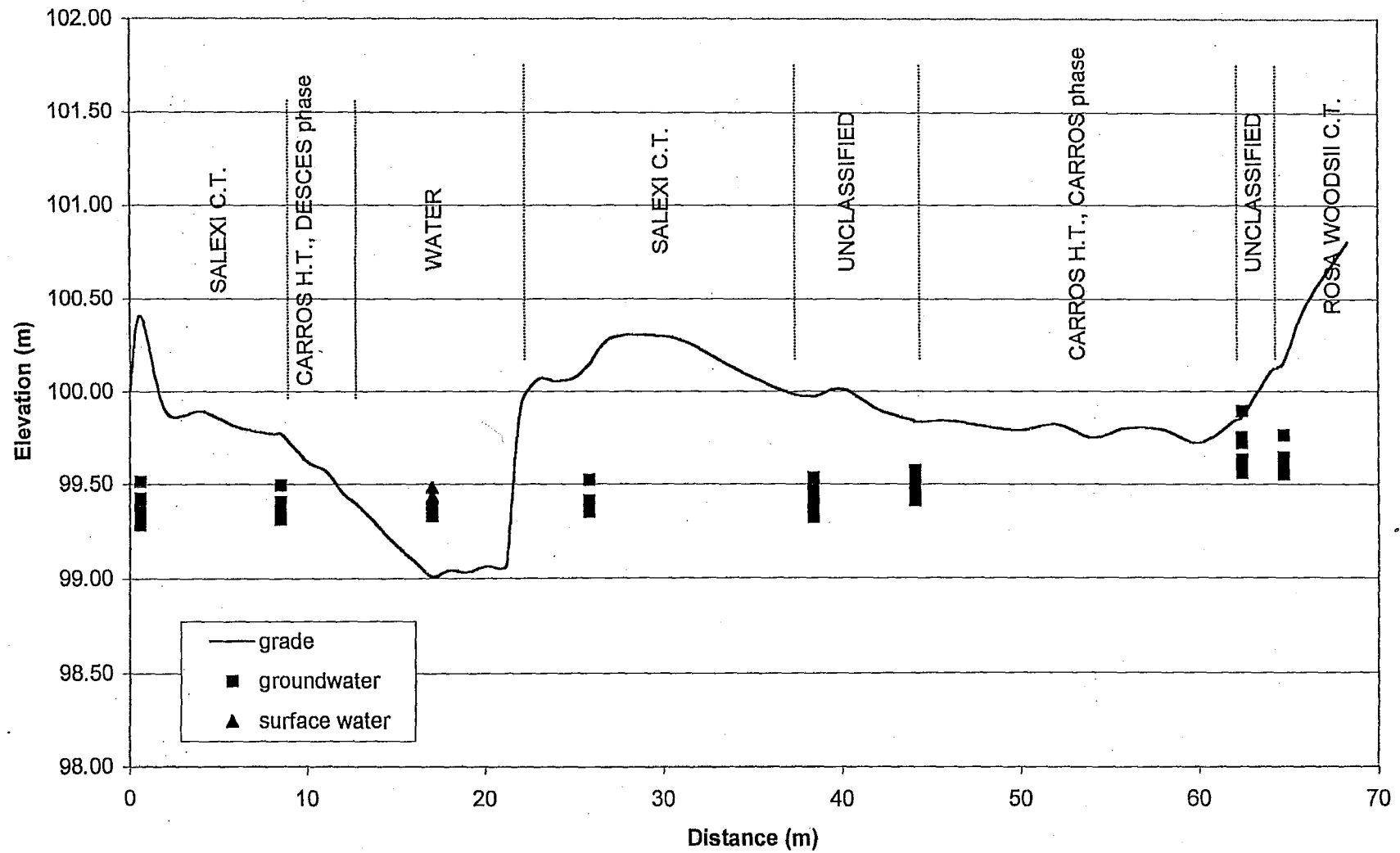
Walker, B.H. and C.F. Wehrhahn. 1970. Relationships between derived vegetation gradients and measured environmental variables in Saskatchewan wetlands. *Ecology*. **52**(1). 85-95.

Wroblicky, G.J., M.E. Campana, H.M. Valett and C.N. Dahm. 1998. Seasonal variation in surface-subsurface water exchange and lateral hyporheic area of two stream-aquifer systems. *Water Resources Research*. **34**(3). 317-328.

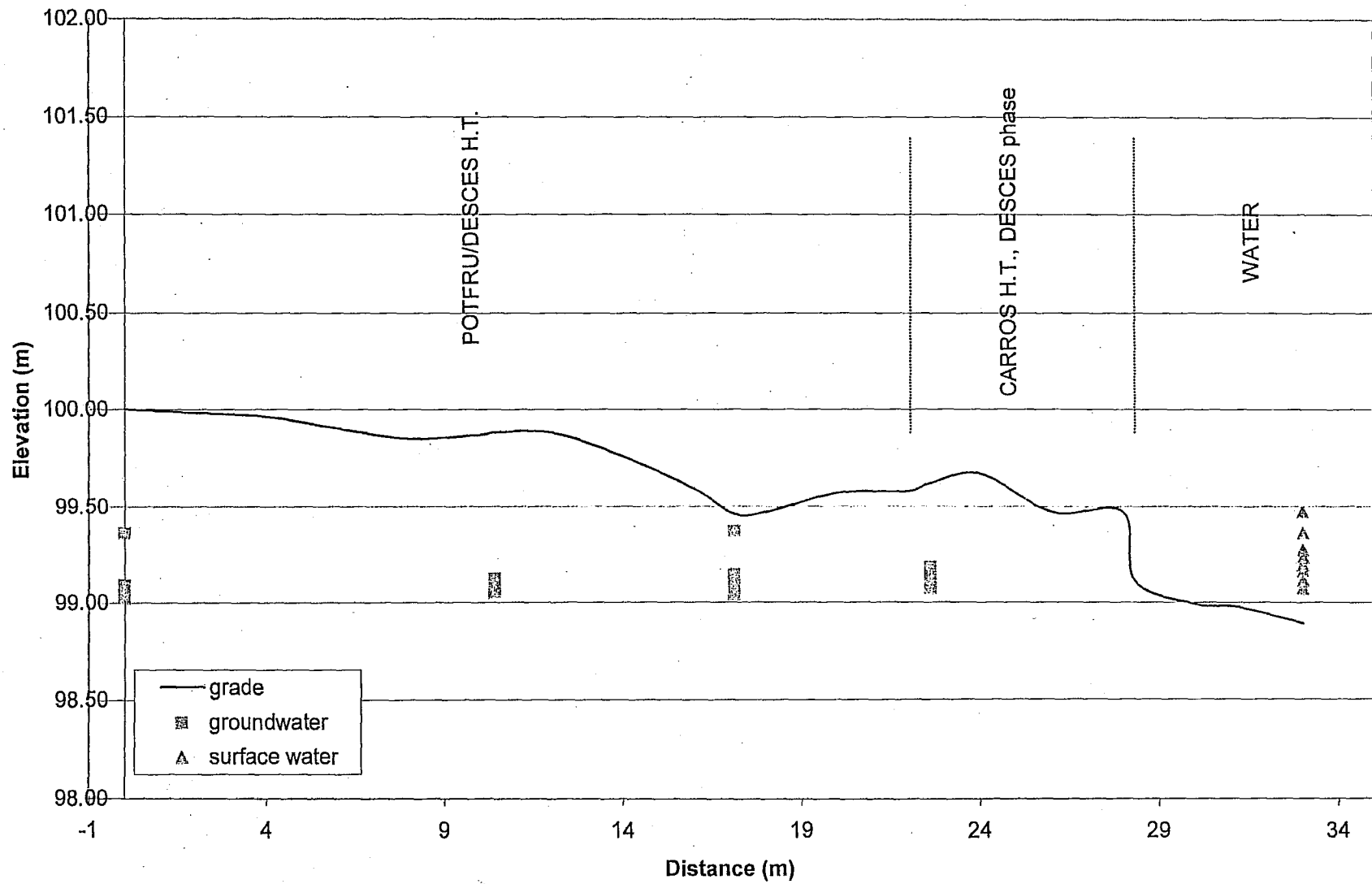
Appendix A. Riparian Vegetation Spreadsheet

Appendix B. Cross-sections of Study Transects

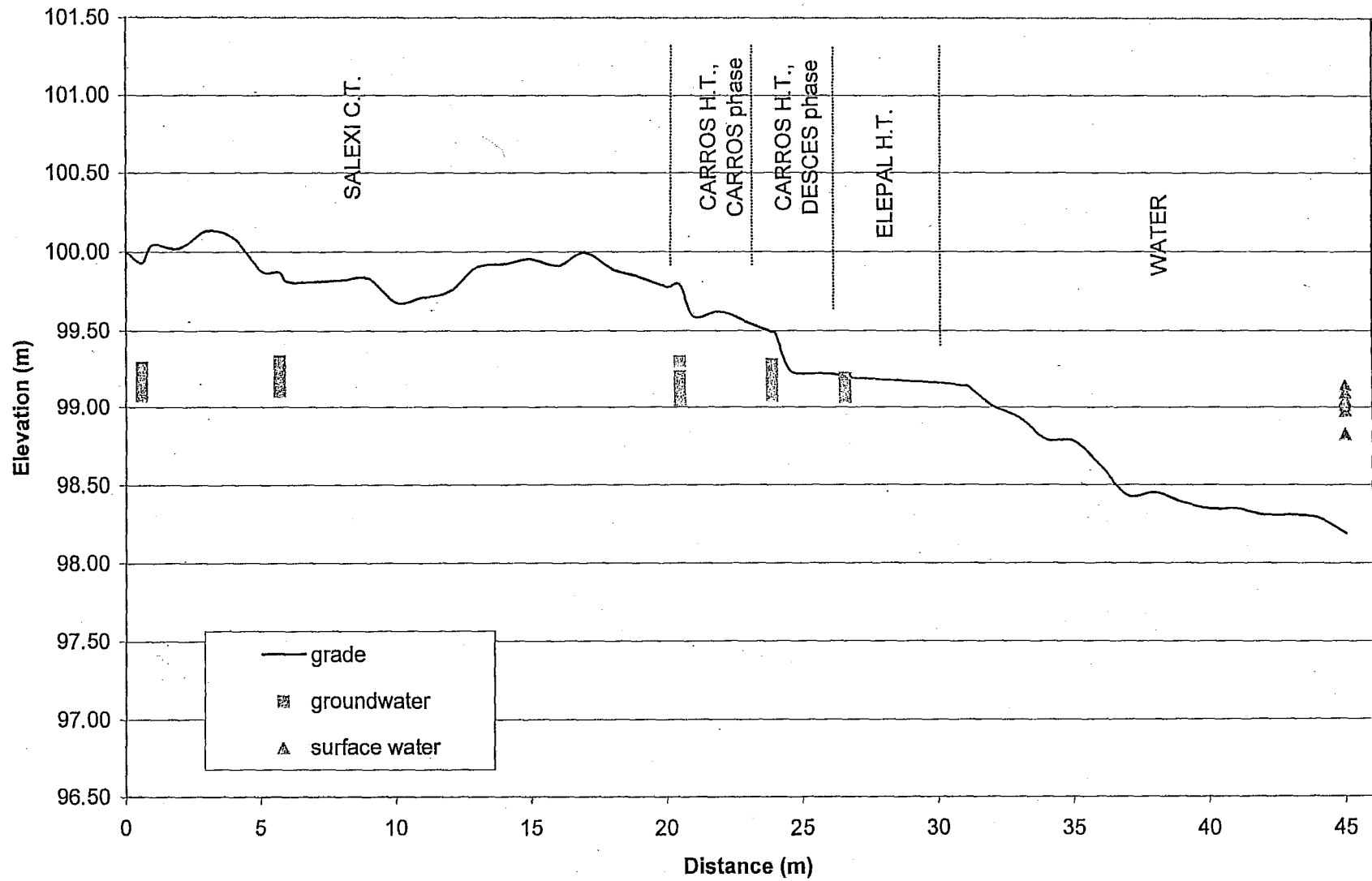
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Upper Smith River



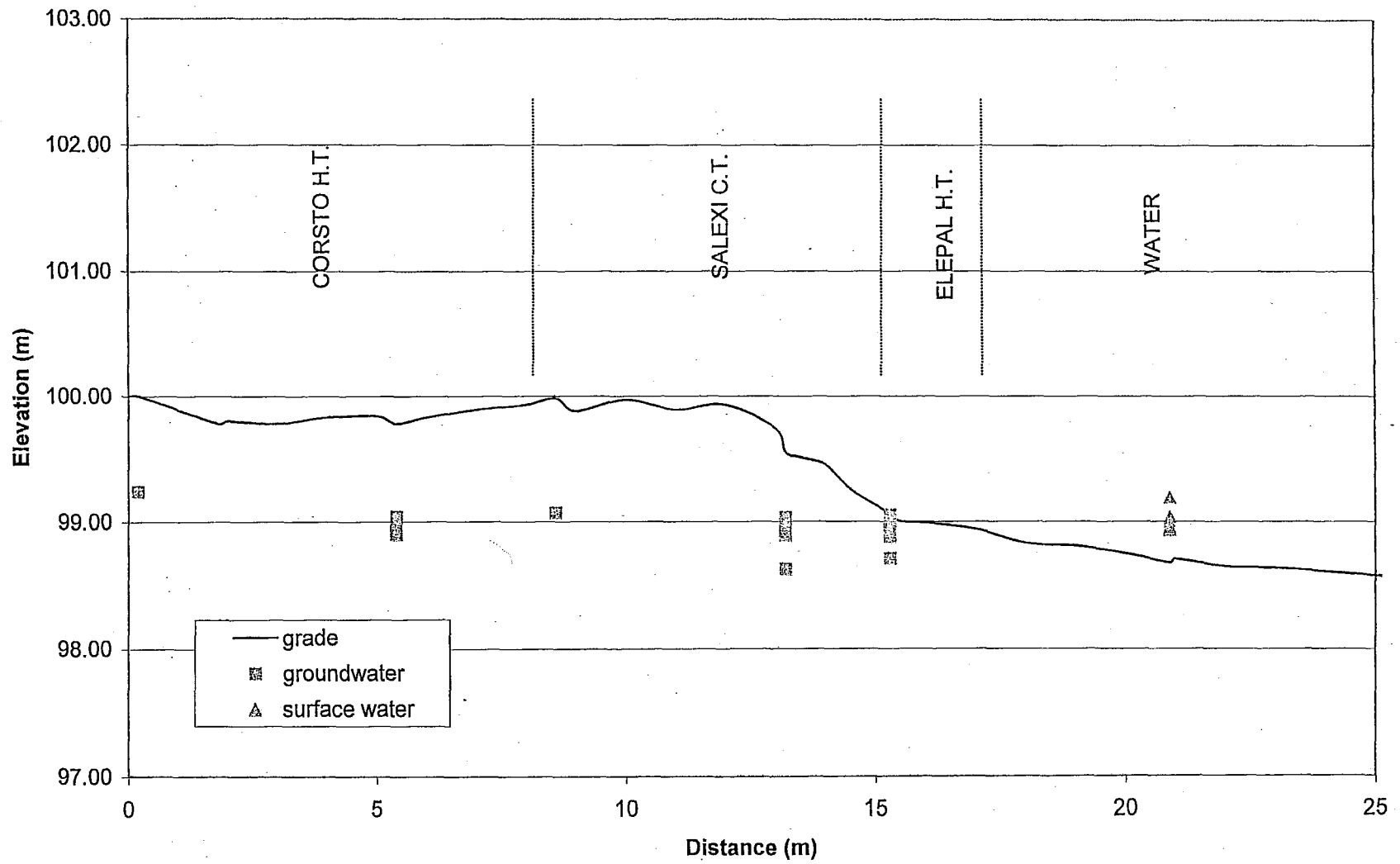
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Upper Smith River



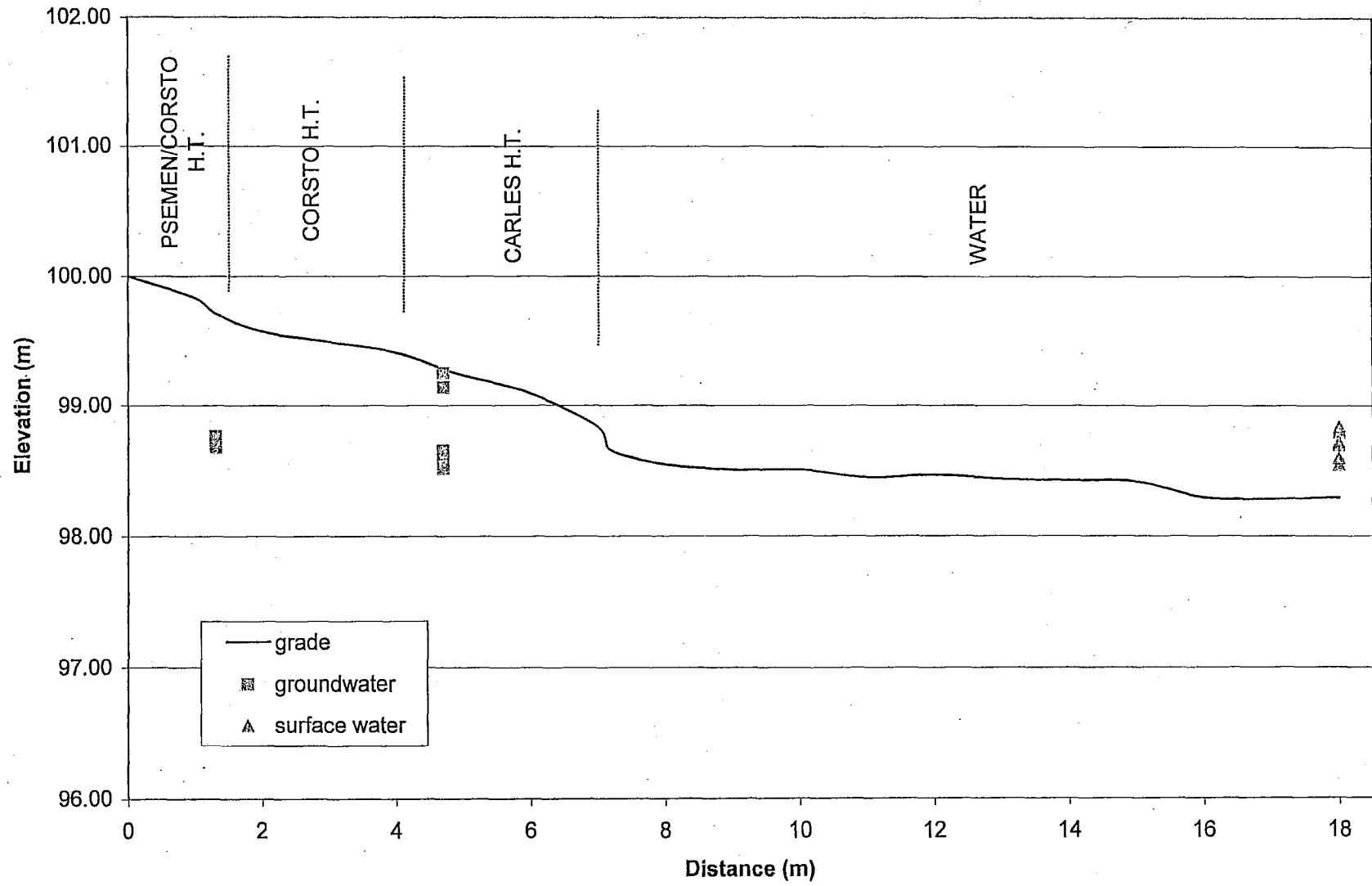
L3
Camp Baker, Smith River



L4
Camp Baker, Smith River

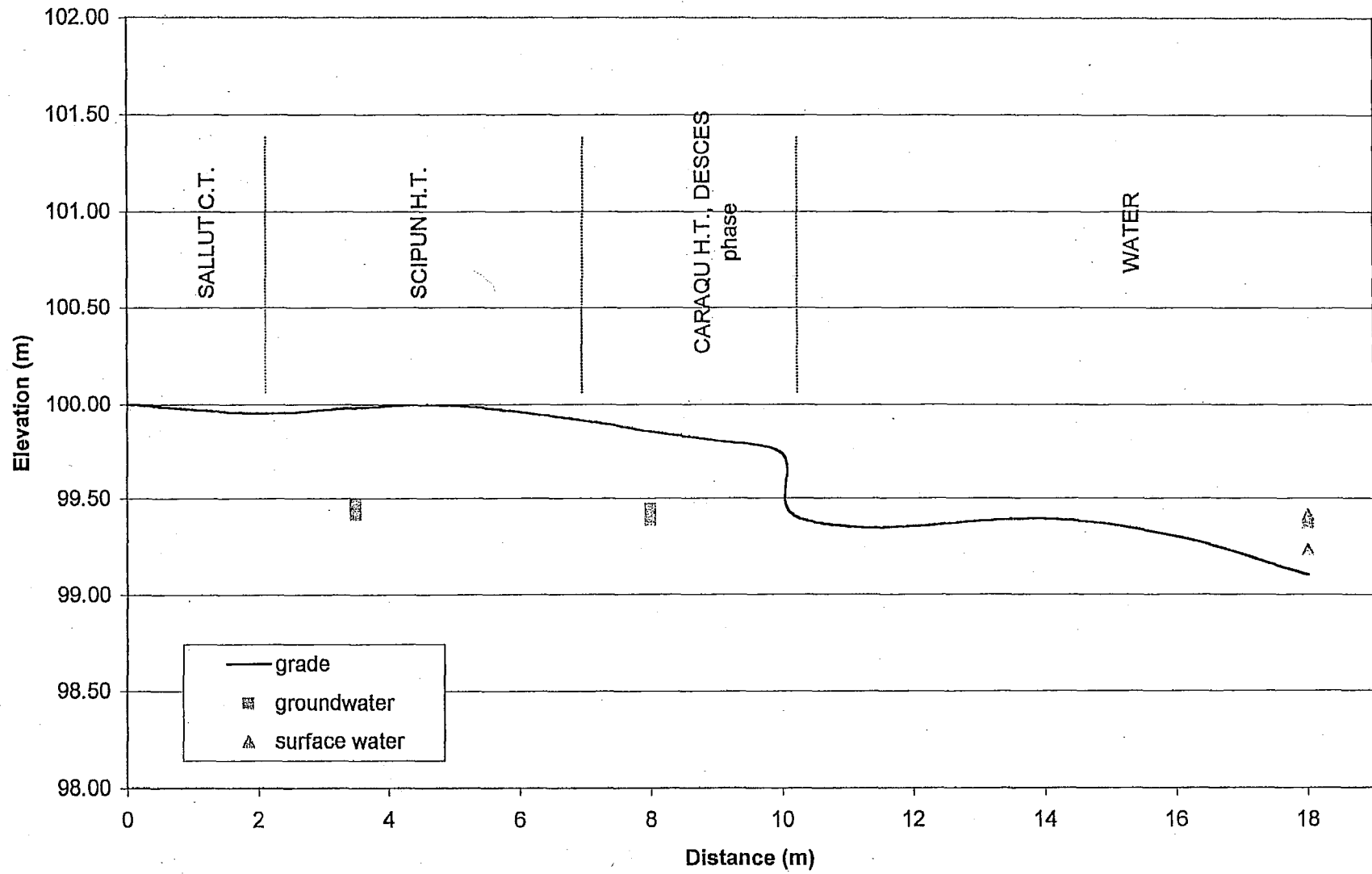


L6
Camp Baker, Smith River

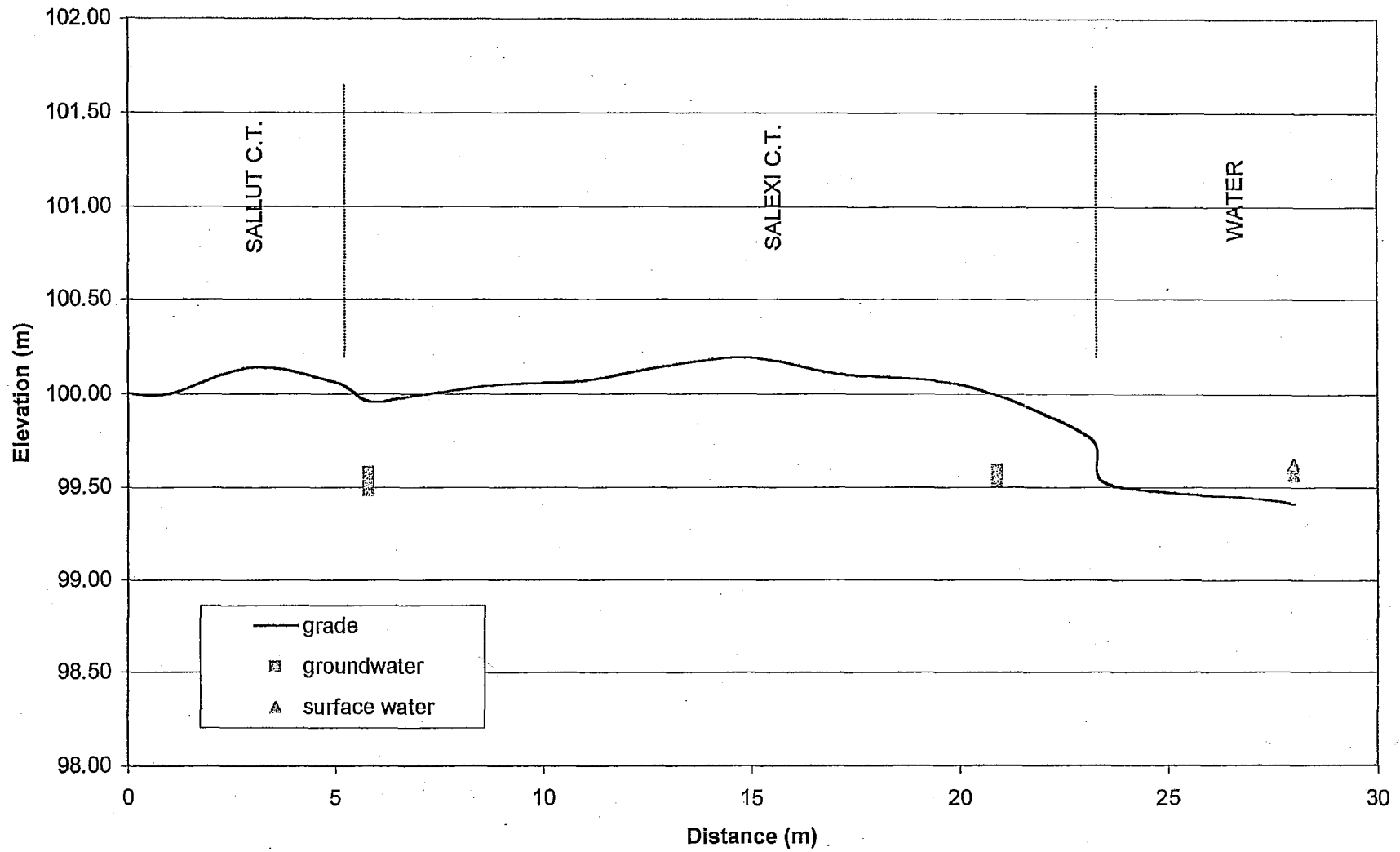


L7

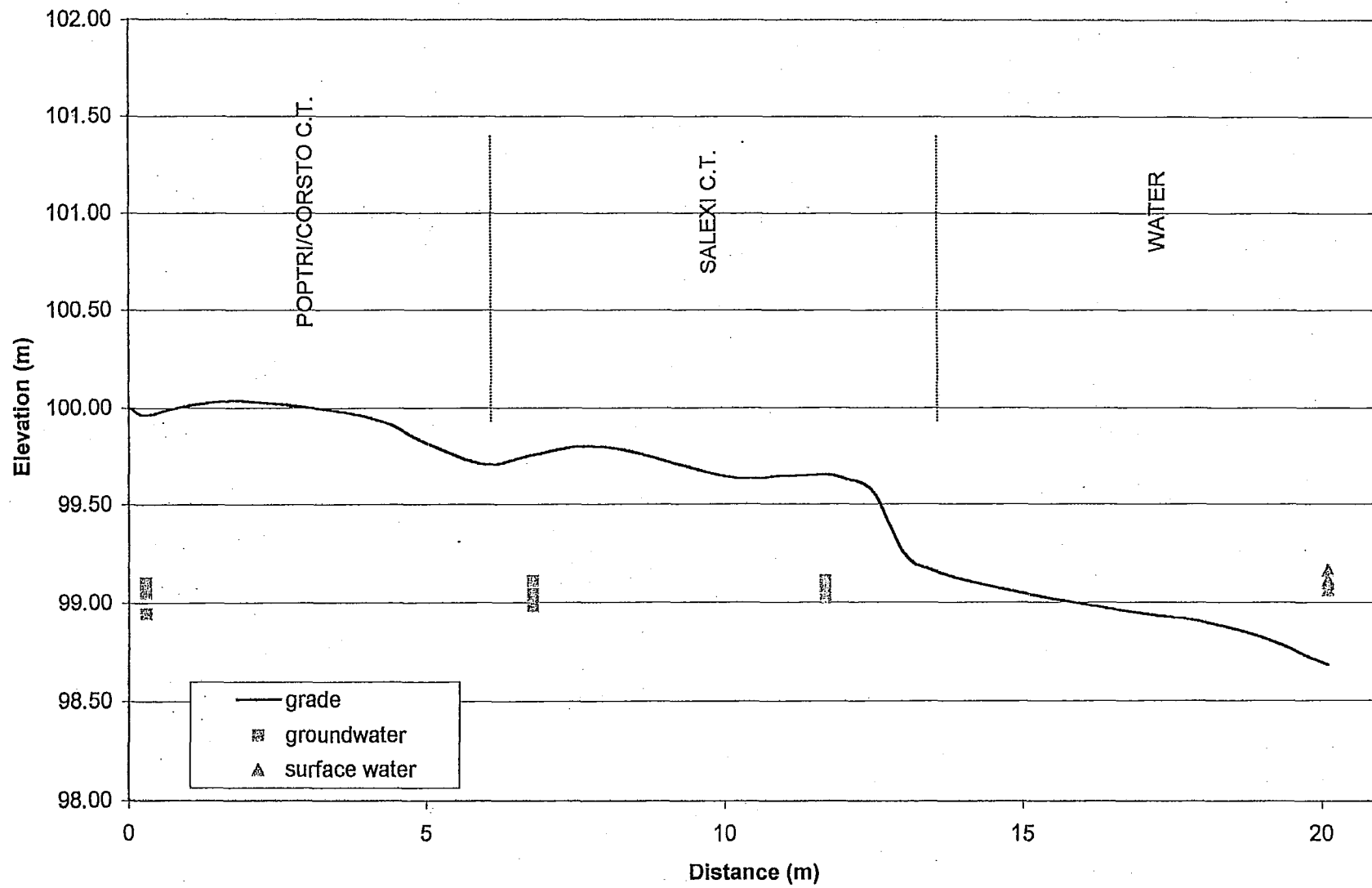
Bair Headquarters, Musselshell River



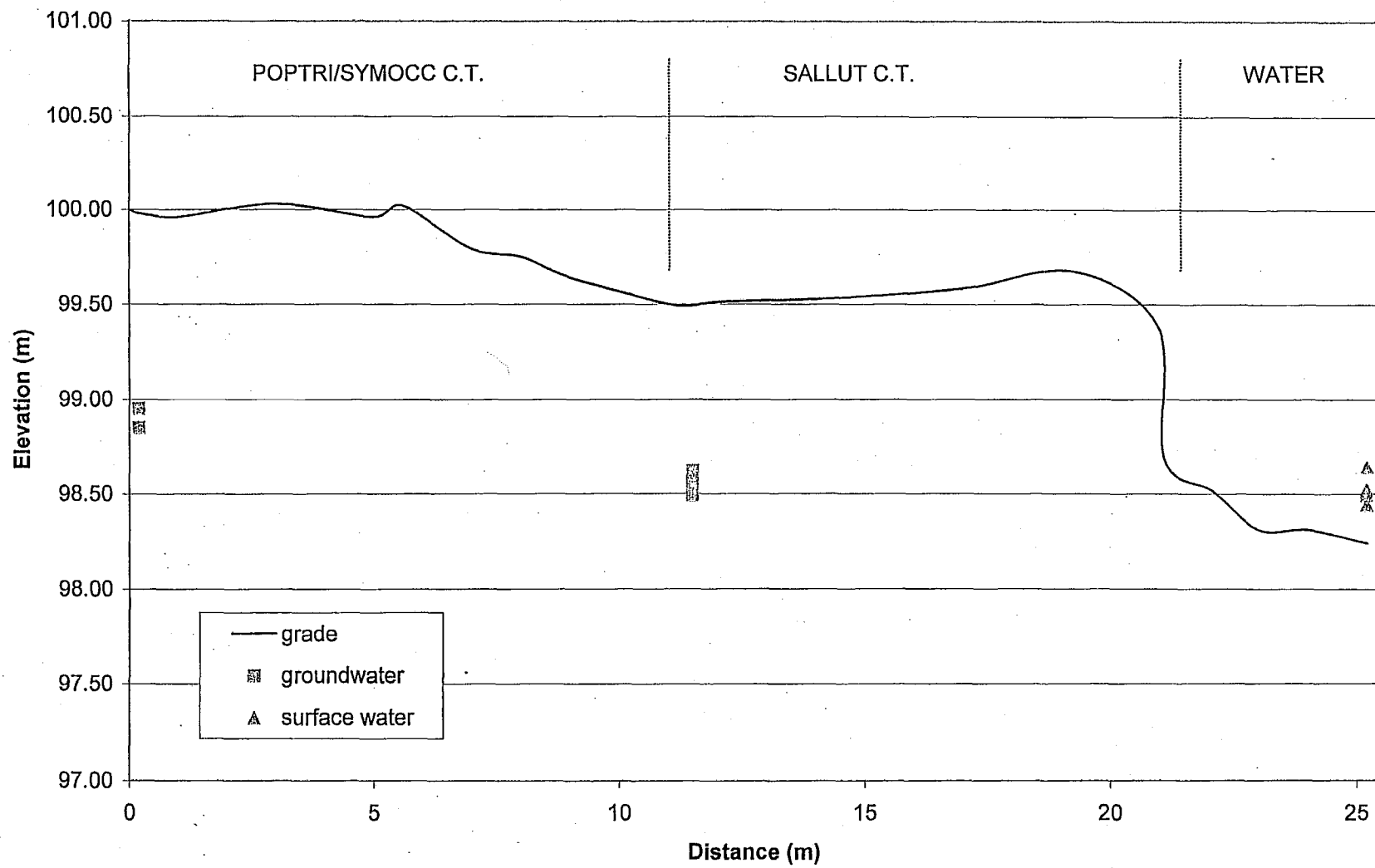
L8
Bair Headquarters, Musselshell River



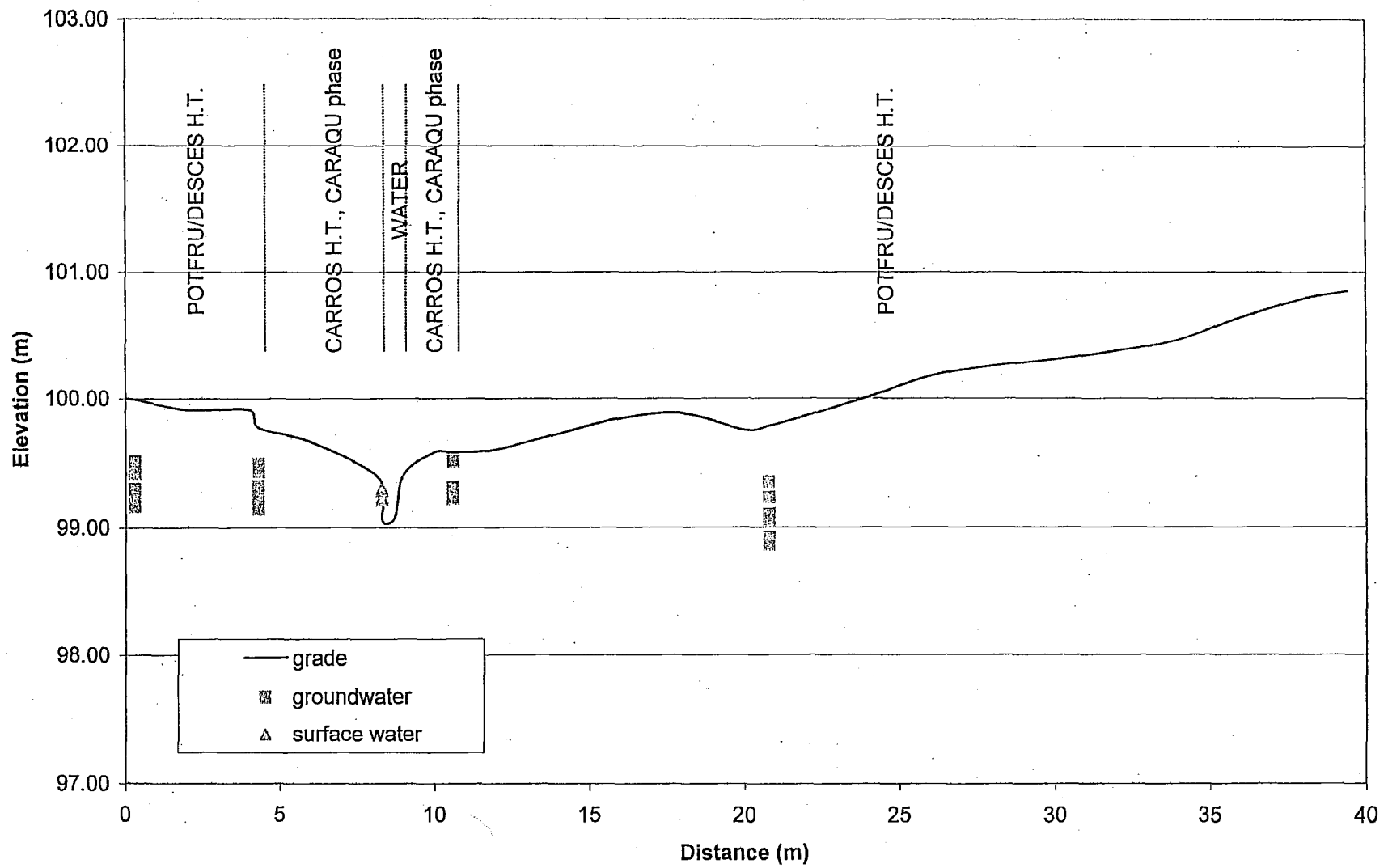
L9
Bair Headquarters, Musselshell River



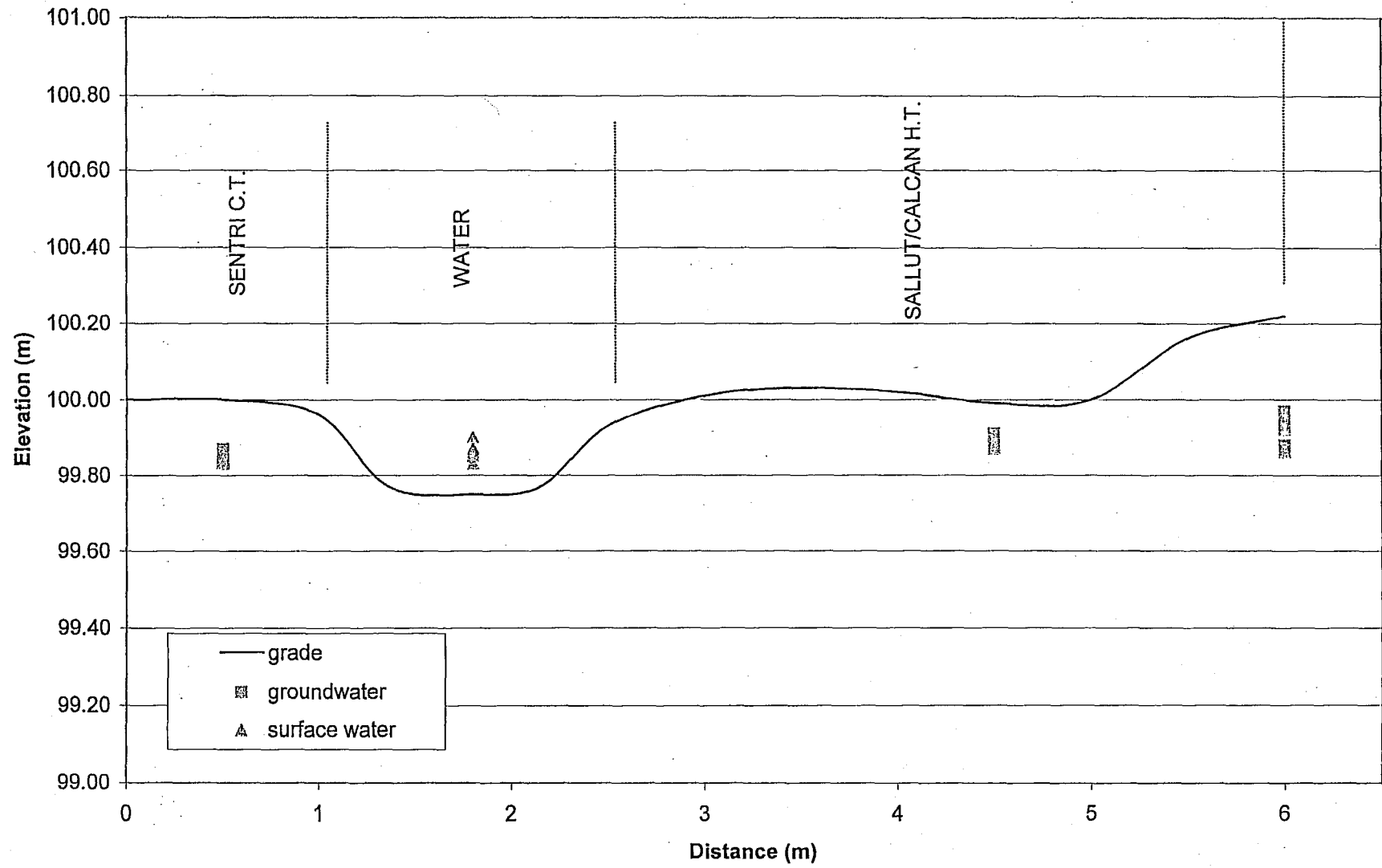
L10
Bair Headquarters, Musselshell River



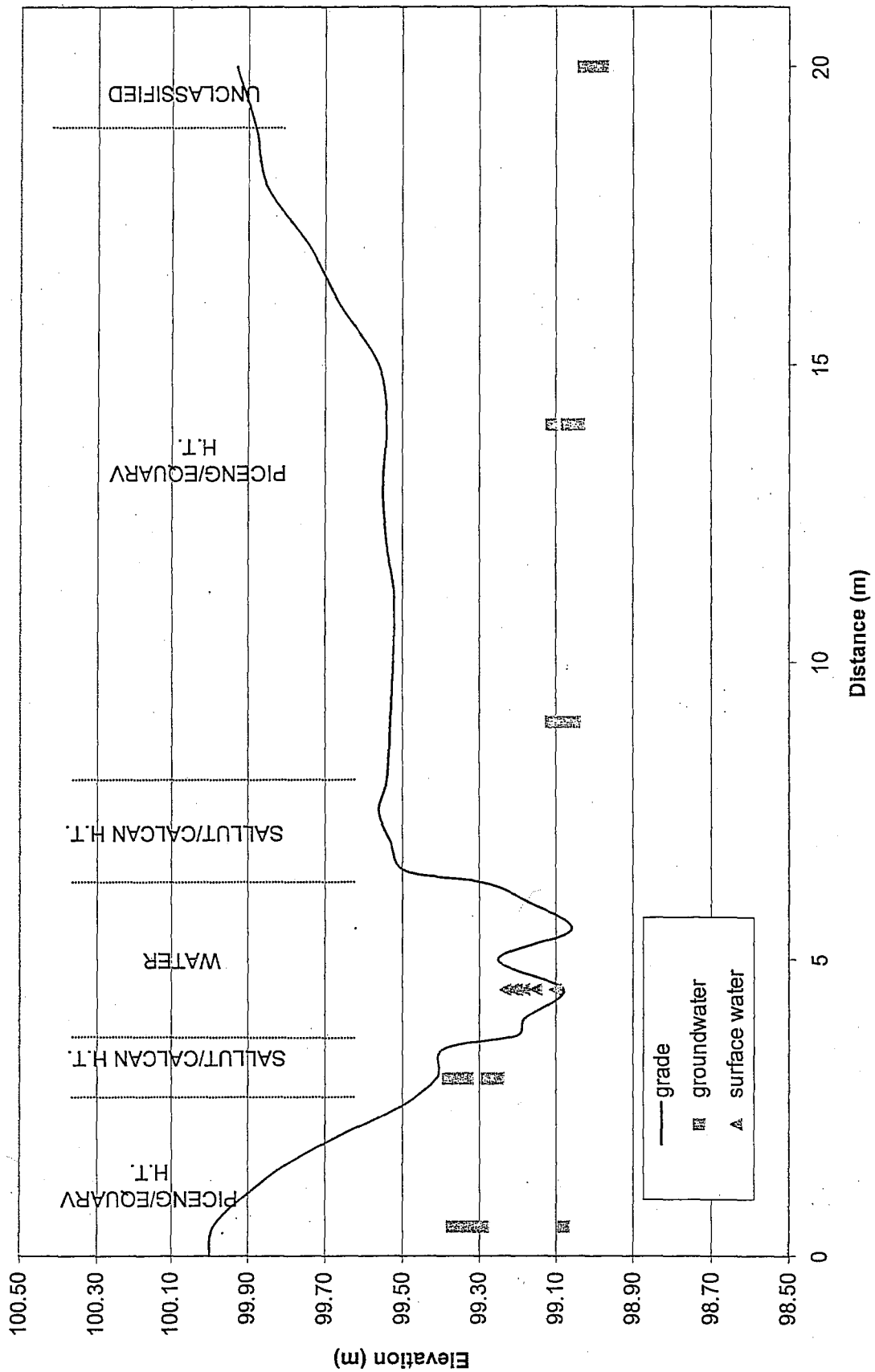
M2
Copper Creek



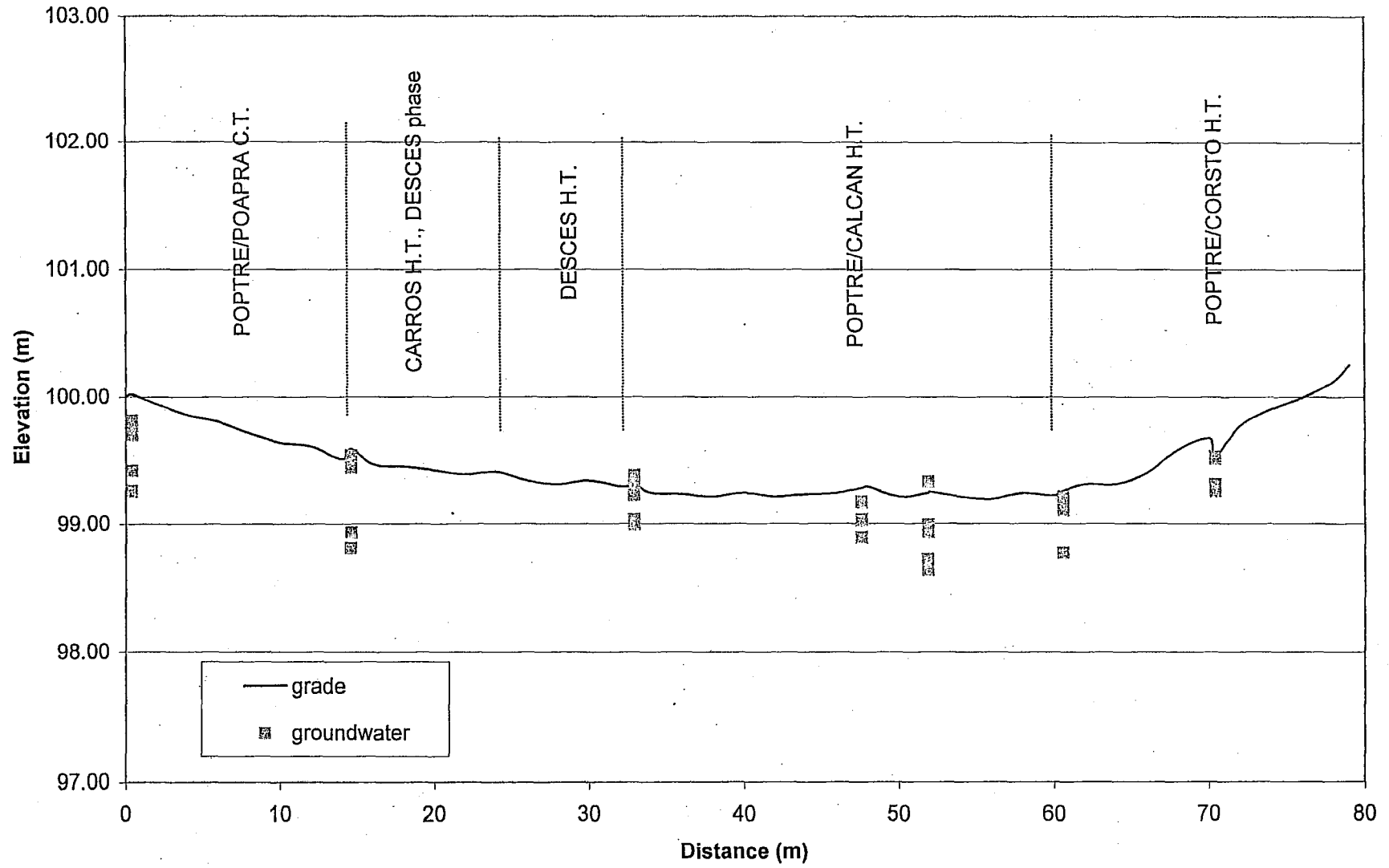
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Lion Creek



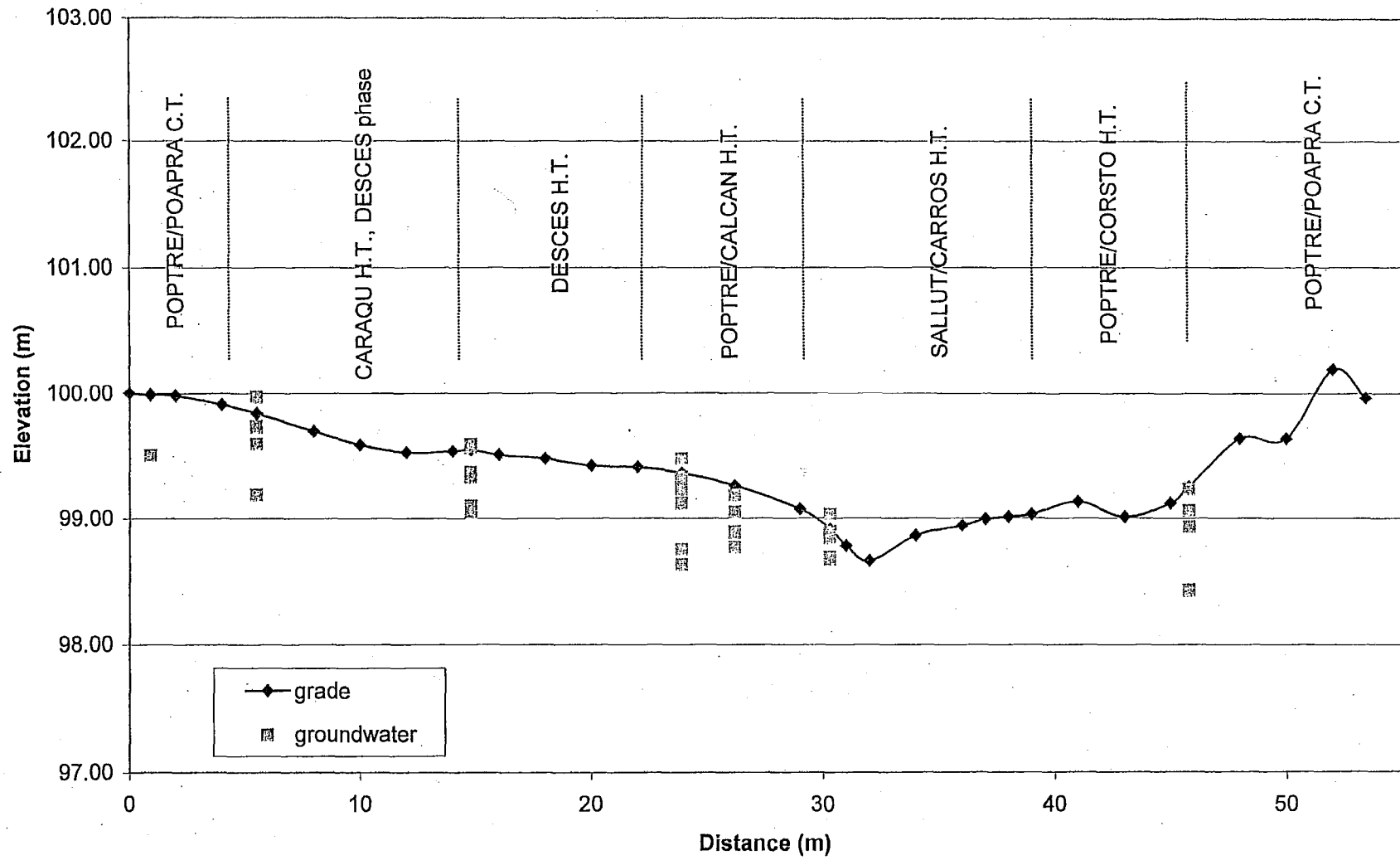
M4 Lion Creek



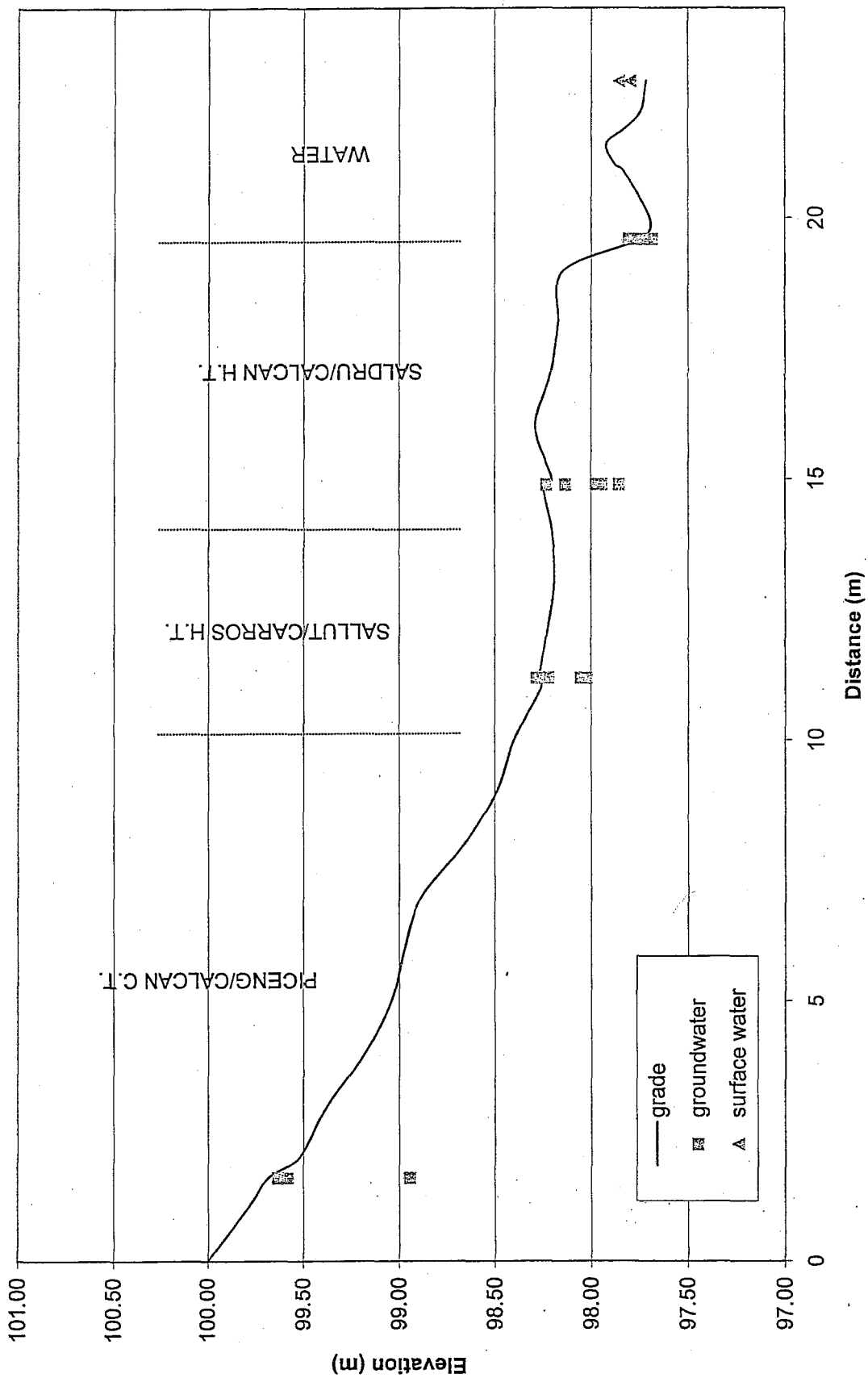
M5
Sheep Creek Road Wet Meadow



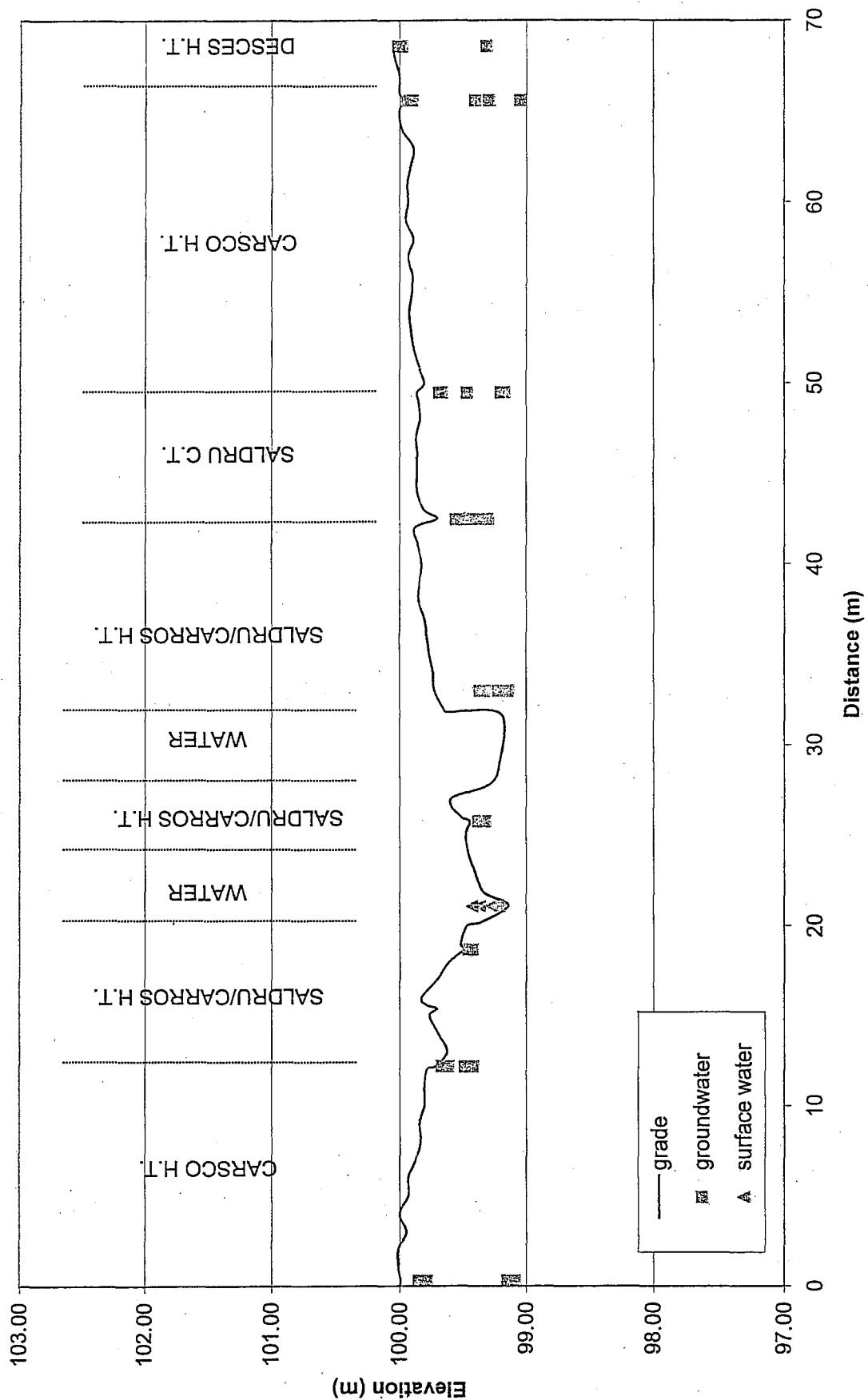
M6
Sheep Creek Road Wet Meadow



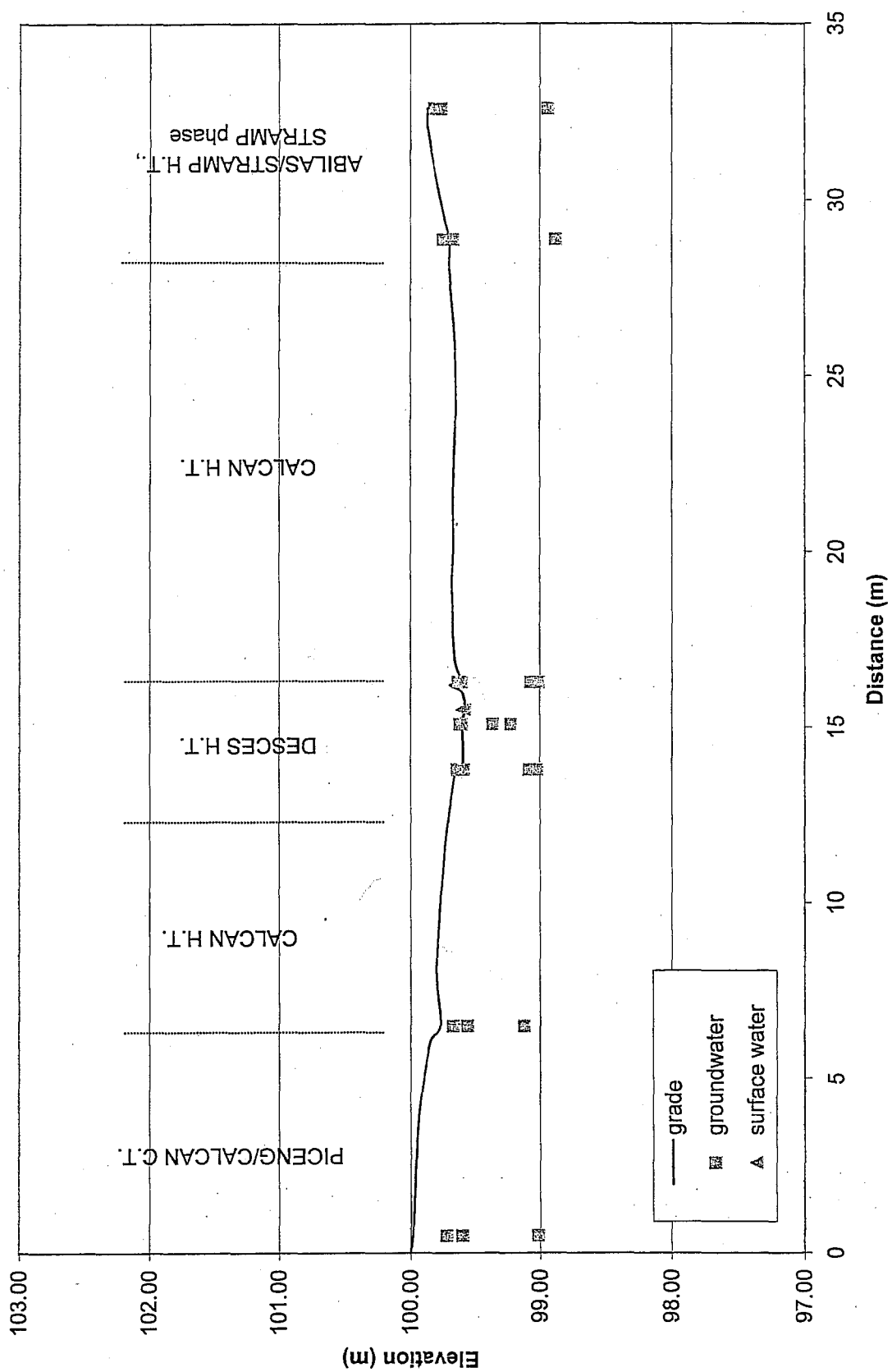
H1
TCEF



H2
TCEF



H3
TCEF



H4
TCEF

