OF 96-12.

Province of British Columbia
Ministry of Energy, Mines
and Petroleum Resources

Geological Survey Branch

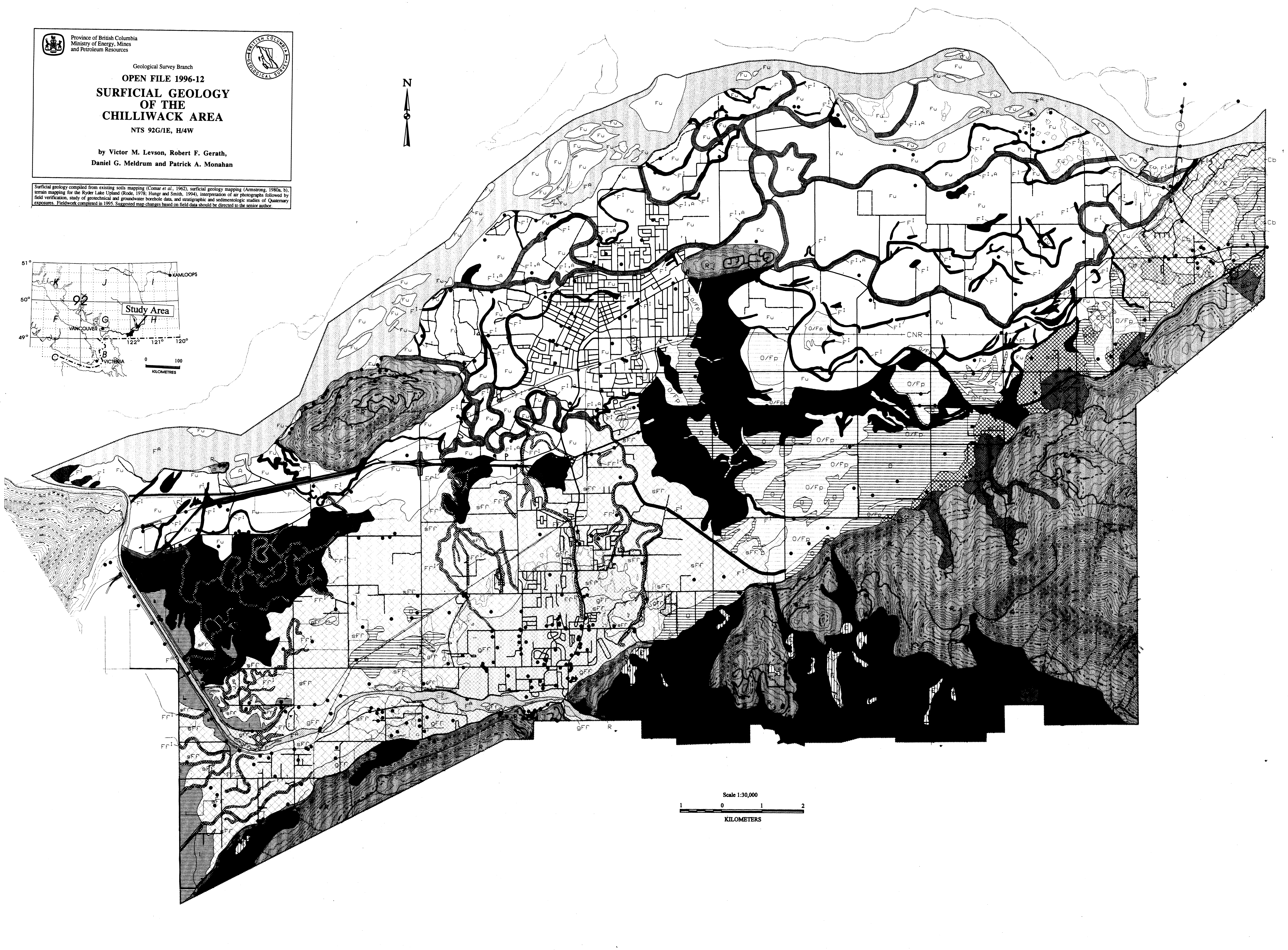
OPEN FILE 1996-12

SURFICIAL GEOLOGY OF THE CHILLIWACK AREA

NTS 92G/1E, H/4W

by Victor M. Levson, Robert F. Gerath,
Daniel G. Meldrum and Patrick A. Monahan

Surficial geology compiled from existing soils mapping (Comar *et al.*, 1962), surficial geology mapping (Armstrong, 1980a, b), terrain mapping for the Ryder Lake Upland (Rode, 1978; Hungr and Smith, 1994), interpretation of air photographs followed by field verification, study of geotechnical and groundwater borehole data, and stratigraphic and sedimentologic studies of Quaternary exposures. Fieldwork completed in 1995. Suggested map changes based on field data should be directed to the senior author.



SURFICIAL GEOLOGY MAP LEGEND

HOLOCENE

FLUVIAL DEPOSITS

F^A **Active river alluvium**
Sand and gravel bars and active channel deposits in the Fraser, Vedder and Chilliwack Rivers; active deposits are up to several metres thick; in the Fraser River fluvial sands and gravels are 15 to > 20 metres thick; some silt on bar tops and margins; largely unvegetated; water table at or very near the surface.

Fu **Fraser River alluvium with preserved channel and bar topography**
Sand and silt; minor clay; well stratified; meander scrolls, point bars, chute channels and sloughs common; relief on resulting ridges and swales about 1 metre; overbank fines typically 1 to 2 m thick, but up to several metres thick; fines overlie laterally-accreted sands in meander scrolls and bars; deposits coarsen down to sands and/or gravels >20 m thick; topography gently undulating to nearly level; imperfectly to well drained; water table typically within the upper few metres, fluctuates seasonally.

Fp **Fraser River alluvium with thick overbank fines**
Silt, clay and fine sand; often fining upwards; horizontally stratified; vertically-accreted overbank fines largely obscure underlying point bar and channel forms; fine sediments interbedded with organic-rich horizons, especially in low areas along the northern margins of the Vedder fan; overbank fines typically 2 to 3 metres thick but locally up to 13 m; overlie sands and gravels to >20 m depth; topography typically level or nearly level; drainage poor to very poor; water table typically within the upper few metres, often at the surface in wet seasons.

$F^{I,A}$ **Semi-active channels and large sloughs**
Sands and gravels, fining-upwards to silts and minor clays; sometimes with thin organic or peat layers near and at the surface; sedimentation is periodic and often associated with high water stages in the Fraser River; channels and sloughs typically are a few to several metres deep and about 25 to 75 metres wide but infilling sand, silt and organic sediments may be much thicker (e.g. > 10 m) and wider (extending beyond the present channel for > 200 m); unit is commonly mapped at a constant width, centered on stream channels, but may locally be wider, especially on the point bar side of meanders; water occurs at the surface most or all of the year.

F^I **Abandoned creek channels and small sloughs**
Silt, clay and organics, coarsening down to sands and gravels; mainly includes former meander and chute channels of the Fraser River system; locally includes ditches and small semi-active creeks; channel depth usually minor (< 3 m) at present but depth and width of channel-fill deposits may be similar to larger channels and sloughs ($F^{I,A}$); very poor drainage with the water table often at or near the surface; sedimentation periodic, usually associated with heavy winter rainfall.

ALLUVIAL FAN DEPOSITS

gFf **Proximal Vedder fan** -
Gravel and coarse sand; 20 to >30 m thick, thins down-fan; massive to well stratified; gravels mostly rounded to well rounded; sediment transported by the Chilliwack River; level to undulating topography; elevation of the proximal fan surface drops from about 30 m at the apex to 15 m at the boundary with the distal fan; generally well drained; water table typically several metres deep, up to 12 m, locally perched and seasonally shallow.

sFf **Distal Vedder fan**
Sand, silt and gravel; well stratified; sediment derived from the Chilliwack River drainage; fine sands and silt deposited mainly by suspension settling from flood waters that overtopped levees; gravels deposited by periodic floods; up to 20-30 metres thick, thins to negligible thickness on the distal fan margin; gradationally fines down-fan with increasing sand and silt and decreasing gravel; progrades over and interbedded with lacustrine deposits to the west and Fraser River alluvium to the north; level to undulating topography; elevation of the distal fan surface drops from about 15 m at the upper boundary, to 5-10 m at the distal fan margin; poorly to well drained; northward drainage to the Fraser River is restricted.

Ff^I **Vedder fan channels**
Sand, gravel and silt; channels draining the proximal fan to the north are incised up to a few metres and dominated by sand and gravel floodplain and levee deposits; distal fan channels are generally smaller and less well developed; in poorly drained areas on the northern periphery of the fan, they strongly meander and are incised into fine overbank sediments; many channels inactive due to Vedder River dykes; west of Vedder Canal, channels are abandoned and are now shallow sloughs.

gCf **Upper colluvial / alluvial fans**
Gravel, diamicton, sand and silty sand; massive to crudely stratified; coarse sediments typically several to >20 m thick; sandy surface sediments thicken down fan to about 1 m; gravels angular; unit includes fan-head channel areas underlain by sands and gravels, locally with loess-filled depressions; slopes up to about 20° at the fan apex, decreasing down fan; well to very well drained; water table variable, often 5 m or greater, varying with season.

sCf **Lower colluvial / alluvial fan and slope base deposits**
Silty sand, sand and gravel; crudely stratified; 2-10 m thick, thinning down fan; surface silts and fine sands up to 1 m thick; level to gently sloping topography, slopes decrease to 1-2° at the distal fan margin; generally poorly drained; water table typically 2-3 m but varying with season.

ORGANIC DEPOSITS

O **Swamp and bog organic deposits**
Decomposed organics and organic silts and clays; locally includes peat and, in the Cheam slide area, marl, lacustrine deposits and landslide sediments; widespread in the Fraser River floodplain where locally veneered by, or overlies, overbank silts and clays; organics typically less than 1 m but locally up to several metres thick; peats generally thickest close to the mountain front; level to gently undulating; unit confined to depressions and low areas; very poorly drained; water table usually at or near the surface.

O/Fp **Thin organic deposits and undifferentiated alluvium**
Organics in low areas, with silty and sandy overbank alluvium in slightly elevated areas; level to gently undulating; organics generally less than 0.5 m thick and overlie floodplain silts and clays; poorly drained.

HOLOCENE - LATE PLEISTOCENE DEPOSITS

LANDSLIDE DEPOSITS

Cb **Cheam Landslide deposits**
Diamicton; angular cobbles and boulders in a silt-sand matrix; commonly 3-10 m thick (but up to 30 m thick), interpreted as landslide deposits; locally thins to <0.5 m on the slide periphery; overlies outwash sand and gravel to >20-30 m depth; locally underlain by loess or gravelly sand alluvium; overlain in some places by ice-contact sand and gravel; gently undulating to rolling topography well to imperfectly drained; typically deep water table (10-30 m), shallows to <5 m to the west and north, locally perched.

F/C **Alluvial sand overlying slide debris**
Sand and gravelly sand derived from adjacent mountain slopes and locally reworked Cheam slide debris; up to several metres thick but much deeper in some areas; occurs in low areas around the margins of the Cheam slide; level to gently undulating topography; moderate to imperfect drainage.

LACUSTRINE SEDIMENTS

L **Lacustrine sediments**
Sands, silts and clays; well stratified; locally interbedded with alluvium from the Vedder and Fraser rivers; sediments 15 to >20 m thick; poorly drained; level topography; water table often above 2 m depth.

EOLIAN DEPOSITS

E **Loess**
Silt and fine sand; massive; generally 1-2 m thick; mainly in depressions; buried soil horizons common; poorly to very poorly drained, seasonally well drained; locally well drained where underlain by outwash sands and gravels; locally includes organics, as in the Ryder Lake area; subject to piping and caving and highly erodible when disturbed; veneers and small pockets of loess not mapped; common on Chilliwack, Shannon, Vedder and Cascade mountains and Ryder Lake-Promontory upland.

LATE PLEISTOCENE DEPOSITS

GLACIAL DEPOSITS

M/F^G **Till and undifferentiated gravels and sands**
Diamicton, gravel and sand; minor silts; diamicton is massive, matrix-supported, dense with a sand-silt-clay matrix, interpreted as till; till usually less than a few metres thick but up to several metres; gravel and sand typically glaciofluvial in origin, commonly >20 m thick, underlying till; gravels stratified and clast-supported; unit locally includes glaciolacustrine silts in Promontory area, colluvium and slide debris; undulating to rolling topography; bedrock locally near surface in hilly areas; thin veneer (<0.5 m) of silty to sandy loess common, especially in depressions and level areas; moderately well to well drained; water table often tens of metres deep, locally perched on fine-grained strata and as shallow as a few metres.

U_s **Steeply eroded Pleistocene sediments**
Undifferentiated gravel, sand, silt and diamicton; commonly 8 >20 m thick; mainly occurring on the Ryder Lake-Promontory upland; much of area considered to be a large kame terrace; includes Pleistocene glaciofluvial, glaciolacustrine and minor glaciomarine sediments and till; undulating to rolling topography; unit usually mantled by colluvium 1-2 m thick and locally includes thicker accumulations of landslide debris; loess locally present, especially in depressions and level areas; mainly well drained.

OTHER

BEDROCK

R Rock at or near the surface; colluvial veneers (< 1 m thick) common; thicker colluvium occurs locally at slope bases; undifferentiated landslide debris locally common in the Cascade Mountains; apparent landslide scarps shown as mapped by Rode (1978); veneer (< 1m) of silty to sandy loess and/or till also locally present; moderate to steep slopes common; includes Upper Paleozoic to Mesozoic sedimentary, volcanic, plutonic and metamorphic rocks; locally susceptible to rockfall and landslide hazards.

ANTHROPOGENIC DEPOSITS

A Rock, sediment and organic fill; composition variable; generally 1-5 m thick; assumed to be underlain by surrounding surficial materials; largest area of fill located along the Fraser River west of Chilliwack Mountain; areas of fill not shown occur under roads, buildings, dykes and other man-made structures.

Apparent landslide scarp

Subsurface data

20 meter contour

100 meter contour

SURFICIAL GEOLOGY NOTES

INTRODUCTION

This geological compilation map results from one part of a geological and geotechnical survey of the Chilliwack region that includes surficial geology and earthquake hazard mapping components. Summaries of the program have been provided by Levson *et al.* (1995, 1996). The project area includes the entire Chilliwack District and parts of the former Fraser-Cheam Regional District, now the Fraser Valley Regional District (contained within NTS mapsheets 92 G/1E and H/4W, south of the Fraser River and north of 49° 3' N lat.). The map area is located approximately 100 kilometres east of Vancouver via the Trans-Canada Highway.

PREVIOUS WORK

The surficial geology of the Chilliwack study area was described and mapped at a scale of 1:50 000 by Armstrong (1960, 1980a, b; 1984). Detailed (1:20,000) soil surveys of the region were conducted by Kelly and Spillsbury (1939), Comar *et al.* (1962) and Luttmerding (1981). Detailed (1:20 000 scale) terrain mapping in the Ryder Lake - Promontory Upland area was conducted by Rode (1978) and Hungr and Smith (1994). Information from all these sources was used in the compilation of this map. Groundwater studies in the region were conducted by Halstead (1961, 1986), Dakin and Holmes (1989) and Dakin (1994). Other relevant regional reports include a geological investigation of the Sumas Valley based on borehole data (Cameron, 1989), a geological investigation of the Cheam Plateau (Smith *et al.,* 1991) and a number of University of British Columbia theses on the Cheam slide area (Bayfield, 1947; Smith, 1971; Naumann, 1990).

METHODOLOGY AND DATABASE

Surficial geology data was compiled at a scale of 1:20 000 and focused on the Fraser River valley and Promontory - Ryder Lake upland. The mapping program involved several phases: 1) collection of existing geotechnical and water well borehole data (testhole sites shown on map); 2) compilation of existing soil survey data (Comar *et al.*, 1962; production date of accompanying map was 1958) and classification of soils into map units with similar parent materials; 3) review and modification of map units using existing 1:20 000 scale terrain maps for the Ryder Lake Upland (Rode, 1978; Hungr and Smith, 1994) and 1:50 000 scale surficial geology maps for the entire area (Armstrong, 1980a, b); 4) verification of map units by field checking and interpretation of recent (1993) aerial photographs; 5) study of geotechnical and groundwater borehole data; 6) stratigraphic and sedimentologic studies of Quaternary exposures; 7) collection of new geotechnical data at several sites selected to fill in gaps in the existing database by ConeTec Investigations Ltd. (methodology described in Levson et al., 1995, 1996); 8) input of surficial geology and geotechnical data into a Geographic Information System (GIS); 9) development of a three-dimensional geologic model for the area; and 10) final review, editing and map production. Data collected for each map unit included: type of sediment, age, genesis, grain-size characteristics, thickness, subsurface stratigraphy and hydrogeologic, geotechnical and geophysical properties. Geological analysis and interpretation of the surficial geology data included an assessment of data quality, description of the relationship of map units with the subsurface stratigraphy and geological interpretation. Large semi-active channels (see below) were mapped using a GIS function that provided a 50 metre buffer zone on either side of the channel centres.

On the Fraser River floodplain, numerous additions, deletions, groupings or other modifications of pre-existing map units (principally after Comar *et al.,* 1962) were made including: 1) recognition and mapping of four types of channels: those draining the Vedder alluvial fan, active Fraser and Vedder river channels, large semi-active channels like Hope Slough and small abandoned channels and sloughs; 2) distinction of the floodplain into areas where channel and bar morphology are well preserved, and areas where overbank deposits are thick and largely obscure the underling channel and bar landforms; 3) extensive modifications along the Fraser and Vedder rivers to accommodate changes in the river and island shorelines since soils mapping in the 1950's; 4) deletion of a number of soils units showing no air photo or field evidence for topographic or geologic distinction; 5) addition or extension of a number of units (including sloughs in the downtown Chilliwack area and along the Fraser River and an area of organics on the southeast margin of the Vedder fan) and; 6) subdivision of areas with organic soils (using soils and testhole data) into areas of undifferentiated alluvium/organics and units of mainly organics. Almost all terrain units in the Promontory - Ryder Lake Upland were modified from pre-existing maps (Rode, 1978; Hungr and Smith, 1994) to accommodate borehole data and field observations. Terrain data in this region was simplified into units dominated mainly by bedrock (at or near the surface), Pleistocene deposits (mainly till, locally with underlying glaciofluvial gravels and sands), steeply eroded Pleistocene units, loess and organics, and fan deposits. Slide deposits associated with mapped scarps in the Cascade Mountains (Rode, 1978) were not differentiated due to large uncertainties in the mappable extent of these deposits.

The testhole database for the map area includes over 1700 geotechnical boreholes and 700 water well logs. Information from this database was also used in the earthquake hazard mapping component of this study and will be released in a GIS format at a later date with the hazard map series. Geotechnical drill holes are concentrated along the Trans-Canada Highway, in the Chilliwack, Sardis and Vedder Crossing areas, along the Fraser River and Vedder Canal dykes, and along B.C. Hydro's Main Transmission Line. About 150 of the deeper water wells were selected to fill in gaps in the geotechnical data. Borehole data was compiled from private and public agencies including the District of Chilliwack, Regional District of Fraser Cheam, Chilliwack School Board, B.C. Ministry of Transportation and Highways, B.C. Hydro, Ministry of Environment, Lands and Parks, B.C. Building Corporation, Geological Survey of Canada, Department of National Defense, Public Works and Government Services Canada, Canadian National Railways and geotechnical consultants.

SURFICIAL GEOLOGY

The surficial geology of the map area is dominated by the Fraser River floodplain which is bounded to the north by active deposits of the Fraser River (**F^A**). Two broad units of fluvial deposits are distinguished on the Fraser River floodplain: sediments on the north side of the floodplain where channel and bar morphology are well preserved and overbank deposits are relatively thin (**Fu**) and areas on the southern side of the floodplain, away from the modern river, where overbank deposits are thicker and largely obscure the underlying channel and bar morphology (**Fp**). Soils are typically better drained in the Fu unit whereas to the south (Fp unit) they are more poorly drained, commonly with surface or buried organics. Large areas with thick surface accumulations of silt, clay and organics (Fu) include: an area between the Vedder Canal and Chilliwack Mountain, where a number of small meandering stream channels have incised into fine sediments and an area southeast of Chilliwack, interpreted as a relatively old part of the Fraser River floodplain, in part occupied by a large, inferred, paleochannel-fill sequence. Fraser River alluvium becomes progressively more sandy and less gravelly towards the west, with an approximate boundary between gravel and sand dominated areas at the east end of Chilliwack Mountain.

The Fraser River lowland is also characterized by numerous semi-active channels and abandoned sloughs (**$F^{I,A}$**). Prior to diking of the river along the northern boundary of the study area, many of these channels were periodically occupied by flood waters. These channels contain unconsolidated sands, silts, clays and organics, often have water at the surface and locally have steep banks, a few metres or more high. Numerous abandoned creek channels and sloughs (**F^I**), often completely infilled with fine sediments and organics, are also present on the Fraser lowland. Elsewhere, Fraser River alluvium is dominated by gravels and sands with up to a few metres of overbank silts.

A large alluvial fan (**Ff**) occurs in the southwestern part of the map area where the Chilliwack-Vedder River enters the Fraser River lowland. The alluvial fan deposits are gravelly and generally well-drained in the proximal parts of the fan (**gFf**) and they become more sandy, less gravelly and thinner in the distal parts of the fan (**sFf**). The Chilliwack-Vedder River system historically has been prone to large floods and has been extensively channelized and dyked, the lower canal dykes being the highest in British Columbia. Other than the Vedder River, channels on the fan (**Ff^I**) mainly drain relatively small areas and no longer carry significant amounts of surface water from the Chilliwack River. The old channels are more deeply incised and contain more gravel, where they drain the proximal parts of the fan, and less well developed around the fan margins. A number of smaller alluvial and colluvial fans extend out onto the Fraser Valley from the Cascade Mountains in the southeast part of the map area. These fans include channel gravels and some debris flow deposits in the proximal parts of the fans (**gCf**) and mainly alluvial silts, sands, gravels and organics in the more distal reaches (**sCf**).

Organic deposits (**O**) are widespread on the Fraser River lowland, especially on older parts of the floodplain such as in the area southeast of Chilliwack and along the Cascade Mountain front. They are also common in low areas between colluvial/alluvial fans and on the Cheam slide in the east part of the map area. Relatively thick peats are known to occur in the organic units mapped on the west-central part, and southeast margin, of the Vedder fan and along the Cascade Mountain front. Areas mapped as undifferentiated organics and alluvium (**O/Fp**) are most common on the Fraser River floodplain where topographically low, poorly drained areas contain organic deposits but are generally too small to map individually.

The east part of the map area is dominated by a large landslide deposit known as the Cheam slide (**Cb**). This large area of landslide debris, overlies glacigenic deposits and is locally capped by up to about 10 metres of soft silt, peat and marl (O). The landslide debris is typically 3 to 10 m thick and consists of diamicton with numerous angular cobbles and boulders. Margins of the slide are locally overlain by alluvial sands (**F/C**).

The western edge of the map area is dominated by lacustrine silts, sands and clays (**L**) deposited in the former Sumas Lake. The lake was drained in 1924. The lake sediments are interbedded with Vedder fan and with Fraser River alluvium to the east and northeast, respectively.

Pleistocene deposits (mainly till and underlying glaciolacustrine silts and glaciofluvial sands and gravels; **M/F^G**) are up to several tens of metres thick in the Ryder Lake - Promontory Upland area, southeast of Vedder Crossing. Glaciomarine silts and clays are also locally present, such as near the base of the northern flank of the upland in the Bailey landfill area. Till thicknesses on the upland are variable. In some areas, such as in the Promontory Heights area, the till has been completely removed by meltwater and post-glacial stream erosion, exposing the underlying Pleistocene deposits. Elsewhere the till is up to several metres thick. Steeply eroded slopes of the upland area are mapped separately as undifferentiated Pleistocene deposits (**Us**). Also mapped on the upland are accumulations of eolian silts up to a few metres thick (**E**) and local fan deposits (Cf). Areas where bedrock occurs at or near the surface (**R**) are confined mainly to steep mountain slopes such as on Chilliwack, Sumas and Vedder mountains and steep slopes on and above the Ryder Upland. Mantles of glacial deposits, colluvium, slide debris and local pockets of silty loess occur in these areas but they are not differentiated on the map. Maps showing the details of terrain units in these areas are available (Rode, 1978; Hungr and Smith, 1994).

QUATERNARY STRATIGRAPHY AND HISTORY

The oldest Quaternary deposits exposed in the map area consist of glaciomarine clays and silts exposed at the base of the Bailey landfill pit, located about 5 kilometres northeast of Vedder Crossing. These sediments are horizontally bedded with strata varying from about 1 to 10 centimetres in thickness. They contain rare dropstones, mainly granules to medium pebbles. Numerous shells occur in the upper metre, concentrated along bedding planes. A radiocarbon date of greater than 34 000 years BP (GSC-2230), obtained on shells in this unit, suggests that they were deposited during the Semiahmoo Glaciation (Armstrong, 1981).

The silts and clays are erosionally overlain by a unit of glaciofluvial sands and gravels (correlative with the Quadra Sand or Coquitlam Drift) from which several proboscidean (probably mammoth) tusks have been recovered (Armstrong, 1981; Armstrong *et al.*, 1985). A tusk from the basal part of the gravels at the Bailey pit yielded a radiocarbon date of 22 700 years ±320 years BP (GSC-2232; Lowden and Blake, 1979) and two other tusks, recovered from stratigraphically equivalent gravels in the Chilliwack River valley, yielded radiocarbon dates of 21 400 years ±240 years BP (SFU-65) and 21 600 years ±240 years BP (SFU-66; Hicock *et al.,* 1982). In the Chilliwack River valley, at least two units of glaciolacustrine silts and clays and interbedded outwash gravels overlie the lower sand and gravel sequence. The lowermost of these glaciolacustrine units is known to contain freshwater *Pediastrum* algae (Hicock *et al.,* 1982). The glacial lakes formed when ice in the Fraser River valley blocked the Chilliwack River drainage. Although glaciers reached their maximum extent in the Puget Lowland during the Vashon Stade about 14 500 to 14 000 years BP, ice free conditions existed locally in the Chilliwack region as late as 16, 000 years BP (Clague *et al.,* 1988).

The upper part of the sand and gravel sequence at the Bailey pit generally coarsens upwards and is capped by three to four metres of massive, compact, matrix-supported diamicton interpreted as a basal till. This till and gravels were probably deposited near the end of the Fraser Glaciation during the Sumas Stade (Armstrong, 1981; Armstrong *et al.*, 1985). Several radiocarbon dates on wood collected from exposures in the Chilliwack River valley, on the opposite side of the Ryder Upland, indicate that the last advances of glaciers in the area occurred about 11 500 and 11 200 years BP and the area was completely ice free by about 11 000 years BP (Saunders *et al.,* 1987).

Geomorphic and stratigraphic evidence in the Cheam Slide area, including interbedding of ice contact gravels and sands with slide debris, suggests that Late-Pleistocene landslide activity occurred in that area. Several radiocarbon dates on wood indicate that an event about 5000 BP also occurred. Although multiple Cheam landslide events are probable, the origin, distribution and stratigraphic context of these deposits remain enigmatic (studies in progress by J.C. Clague and R.F. Gerath).

Subsequent to the retreat of ice from the main part of the Fraser River valley, a prograding delta and overlying Holocene fluvial sequence developed into an early Holocene and/or earlier glaciomarine (?) basin in the valley. Borehole data in the valley indicate that about 50 metres of fluvial and deltaic sand and gravel, interbedded with silt and peat, overlie inferred glaciomarine silts, clays and sands that locally extend to depths of up to 500 metres. These deep sediments are undated. Holocene sedimentation in the valley bottom was probably characterized by deposition in braided river channels and bars, similar to those along the modern Fraser River, with gradual vertical accretion of silts and clays on the floodplain. The greater thickness and extent of surface organic and peaty soils and more subdued expression of point bar and channel forms, on the southern parts of the Fraser River floodplain compared to the north, suggest that the river last migrated across the floodplain from south to north and that alluvium in the south is older. In the Sumas Valley, Fraser River floodplain deposits pass laterally into Holocene lacustrine sands, silts and clays (Cameron, 1989). In the Vedder Crossing area, gravels and sands of the Chilliwack-Vedder River alluvial fan prograded out into the Sumas and Fraser River valleys. At the mountain front, the Chilliwack-Vedder fan gravels and sands are locally over 60 metres thick but towards the distal margins of the fan, such as in the Sardis and Yarrow areas, the fan sediments thin to less than several metres and become more sandy. Alluvial fan sediments at the west end of the Sumas Valley contain inferred Mazama tephra (~6800 years BP) and a radiocarbon date on peat of 8360±170 (GSC 225), suggests that fan progradation began shortly after deglaciation (Cameron, 1989). Holocene sedimentation in other parts of the area includes localized accumulation of loess in upland areas, organics on the Fraser River floodplain and colluvial deposits along the margin of the Cascade Mountains.

REFERENCES

Armstrong, J.E. (1960): Surficial Geology of the Sumas Map Area. *Geological Survey of Canada,* Paper 59-9.
Armstrong, J.E. (1980a): Surficial Geology, Mission, British Columbia. *Geological Survey of Canada,* Map 1485A, 1:50 000 scale.
Armstrong, J.E. (1980b): Surficial Geology, Chilliwack (West Half), British Columbia. *Geological Survey of Canada*, Map 1487A, 1:50 000 scale.
Armstrong, J.E. (1981): Post-Vashon Wisconsin Glaciation, Fraser Lowland, British Columbia; *Geological Survey of Canada,* Bulletin 322, 34 pages.
Armstrong, J.E. (1984): Environmental and Engineering Applications of the Surficial Geology of the Fraser Lowland, British Columbia; *Geological Survey of Canada,* Paper 83-23, 54 pages.
Armstrong, J.E., Clague, J.J. and Hebda, R.J. (1985): Late Quaternary Geology of the Fraser Lowland, Southwestern British Columbia. *in* Field Guides to Geology and Mineral Deposits in the Southern Canadian Cordillera, D. Tempelman-Kluit, Editor, *Geological Society of America,* Cordilleran Section Meeting, pages 15-1 to 15-25.Bayfield, J.T. (1947): A Study of the Nature and Character of Marl with Special reference to Cheam Lake Deposits. *University of British Columbia* , Unpublished B.Sc. thesis.
Cameron, V. J., 1989. The Late Quaternary Geomorphic History of the Sumas Valley. unpublished M.A. thesis, *Simon Fraser University*, 154 pages.
Clague, J.J., Saunders, I.R. and Roberts, M.C. (1988): Ice-free Conditions in Southwestern British Columbia at 16 000 Years BP. *Canadian Journal of Earth Sciences,* Volume 25, pages 938-941.
Comar, V.K., Sprout, P.N., and Kelley, C.C. (1962): Soil Survey of the Chilliwack Map Area, Lower Fraser Valley; *B.C. Department of Agriculture*, Preliminary Report 4.
Dakin, R.A. (1994): Section 9.1.1 Fraser Lowland; *in* Groundwater Resources of British Columbia, *British Columbia Ministry of Environment, Lands and Parks and Environment Canada,* pages 9.1-9.30.
Dakin, R.A., and Holmes, A.T. (1989): Hydrogeologic Evaluation of Options for Ground Water Disposal of Storm Water Runoff, Watson - Glen Phase II, Vedder Crossing, British Columbia. Prepared by *Piteau Associates* for Wedler and Associates Ltd. and District of Chilliwack.
Halstead, E.C. (1961): Ground Water Resources of Sumas, Chilliwack, and Kent Municipalities, British Columbia. *Geological Survey of Canada,* Paper 60-29.
Halstead, E.C. (1986): Ground Water Supply - Fraser Lowland, British Columbia; *Environment Canada, Inland Waters Directorate,* NHRI Paper 26, IWD Scientific Series 145.
Hicock, S.R., Hobson, K. and Armstrong, J.E. (1982): Late Pleistocene Proboscideans and early Fraser Glacial Sedimentation in Eastern Fraser Lowland, British Columbia. *Canadian Journal of Earth Sciences,* Volume 19, pages 899-906.
Hungr, O., and Smith, D. (1994): Ryder Lake Comprehensive Development Plan, Overview Geotechnical Assessment. Unpublished Report by *Thurber Engineering Ltd.* to Urban Systems Ltd. and District of Chilliwack.
Kelly, C.C. and Spillsbury, (1939): Soil Survey of the Lower Fraser Valley. *Canada Department of Agriculture,* Publication 650, 67 pages and 1:20,000 map.
Levson. V.M., Monahan, P.A., Meldrum, D.G., Matysek, P.F., Watts, B.D., Yan, L., Sy, A. and Gerath, R.F. (1995): Seismic Microzonation Mapping in Southwestern British Columbia: A Pilot Project. *Canadian Geotechnical Society,* Trends in Geotechnique, 48th Canadian Geotechnical Conference, Volume 2, pages 927-936.
Levson. V.M., Monahan, P.A., Meldrum, D.G., Matysek, P.F., Gerath, R.F., Watts, B.D., Sy, A. and Yan, L.(1996): Surficial Geology and Earthquake Hazard Mapping, Chilliwack, British Columbia (92G/1 and H/4). *in* Geological Fieldwork 1995, B.M. Grant and J.M. Newell, Editors, *British Columbia Ministry of Energy, Mines and Petroleum Resources,* Paper 1996-1.
Lowden, J.A. and Blake, W.Jr. (1979): Geological Survey of Canada Radiocarbon Dates XIX. *Geological Survey of Canada,* Paper 79-7, 58 pages.
Luttmerding, H.A. (1981): Soils of the Langley - Vancouver Map Area. *British Columbia Ministry of Environment, Lands and Parks,* RAB Bulletin 18.
Naumann, C.M. (1990): The Cheam Slide: A Study of the Interrelationship of Rock Avalanches and Seismicity. *University of British Columbia*, Unpublished M.Sc. thesis.
North, M.E.A. and Treversham, J.M. (1984): The Revegetation of the Floodplain of the Fraser, Serpentine and Nicomekl Rivers, 1859 to 1890. *Syesis, (British Columbia Provincial Museum)* Volume 17, pages 47-66.
Rode, M. (1978): Chilliwack - Ryder Lake Uplands, Terrain Analysis: Base Data. *British Columbia Ministry of Environment, Lands and Parks,* 1:20 000 scale map.
Saunders, I.R., Clague, J.J. and Roberts, M.C. (1987): Deglaciation of Chilliwack River Valley, British Columbia. *Canadian Journal of Earth Sciences,* Volume 24, pages 915-923.
Smith, H.R. (1971): A Study of a Prehistoric Landslide Surface at Cheam Lake, East of Chilliwack. *University of British Columbia* , Unpublished B.Sc. thesis.
Smith, D., Gerath, R. and Hungr, O. (1991): Cheam Landslide Review. Unpublished Report by *Thurber Engineering Ltd.* to Regional District of Fraser-Cheam, 23 pages.