WHARF RESOURCES

GROUNDWATER CHARACTERIZATION STUDY OF THE CLINTON EXTENSION PROJECT AREA

OCTOBER 1996

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SECTION 1

EXECUTIVE SUMMARY

The primary objectives of this report are: (1) characterize the hydrogeology of the project area, (2) characterize the baseline groundwater quality and hydrology, and (3) predict impacts to groundwater quality and hydrology resulting from development of the Clinton Project. The Clinton project will consist of two open pits extending east from the existing Foley Ridge / Annie Arm mine pits, and a 28-million ton waste rock depository which will be constructed on top of the existing Bald Mountain Mill tailings impoundment.

Geologic units within the project area include Tertiary intrusives, Ordovician and Cambrian sediments, and Precambrian metamorphics. The predominant rock types are the Precambrian metamorphics (phyllites, schists, and quartzites) and Tertiary intrusives (monzonite porphyry, phonolite porphyry, and porphyry breccia). The Cambrian Deadwood Formation is present in the southern portion of the project area and is the primary ore-bearing rock unit, with ore present primarily in three stratigraphic horizons, separated by monzonite porphyry sills. The three horizons were extensively developed by underground mine workings between 1878 and 1959.

Groundwater is found at depths typically in excess of 200 feet throughout most of the project area. Given the predominance of low permeability crystalline rock units in the project area, relatively few water supply wells are present and groundwater data is limited. Successful wells have been completed in the Deadwood Formation, sometimes tapping groundwater from deep flooded mine workings located south and west of the study area. Wells in the igneous or Precambrian metamorphic rocks typically produce a few gallons per minute (gpm) or less. Mine water supply is derived primarily from wells completed in limestone aquifers outside of the project area. Underground workings beneath the proposed pits are reported to be dry, and mining is anticipated to generally occur above the regional water table. As such, significant pit inflows are not anticipated.

Evaluation of hydrochemistry in the project areas shows two principal water types, calcium bicarbonate and calcium sulfate. The calcium bicarbonate water is typically found in the southern and western portions of the study area, reflecting the area underlain by the Deadwood Formation and felsic intrusives (dacite, rhyolite, and monzonite). The calcium-sulfate hydrochemical facies occurs within the northern and eastern portions of the project area where Precambrian rocks (mostly phyllites and schists) are present at the surface and at depth.

Water quality in the False Bottom Creek drainage may have been impacted by past mining activities, primarily tailings disposal. This is suggested by low levels of total cyanide that have been detected at False Bottom Spring, False Bottom Creek, and MW-22. Concentrations of TDS at False Bottom Spring and MW-22 are slightly elevated compared to other sample sites in the project area; however, it is not clear if TDS concentrations are related to past mining activities. The pH of samples from False Bottom Creek, False Bottom Spring, and MW-22 are relatively low due to natural oxidation of pyrite-bearing Precambrian bedrock within the drainage; low pH in the False Bottom Creek drainage does not appear to be related to the Bald Mountain tailings.

Significant mining related impacts to groundwater hydrology and quality are not anticipated as a result of the Clinton Project. Groundwater recharge rate may increase slightly in the pit and waste depository areas. Groundwater quality in the vicinity of the proposed waste depository could potentially to be impacted by nitrate, leached from residual ammonium nitrate blasting agent in the waste rock, but is not expected to exceed the groundwater standard.

SECTION 2

INTRODUCTION

This report describes hydrogeology and hydrochemistry in the vicinity of the proposed Wharf Resources Clinton Project. The report includes examinations of geology, hydrogeology, groundwater occurrence, groundwater quality, and projected impacts to groundwater quality and groundwater hydrology resulting from the proposed project.

OBJECTIVES

The primary objectives of this report are: (1) characterize the hydrogeology of the project area, (2) characterize the baseline groundwater quality and flow, and (3) determine impacts to groundwater quality and flow resulting from development of the Project. This report contains the groundwater related items necessary to meet the permit application completeness requirements under Chapter 74:29:02:07 and 74:29:02:11.

DESCRIPTION OF GROUNDWATER STUDY AREA

The Clinton Extension Project is an expansion of the existing Annie Creek Mine located approximately three miles west of the town of Lead in Lawrence County, South Dakota (Figure 2-1). The groundwater study area (Figure 2-2) encompasses approximately 5 square miles in the vicinity of Trojan, situated in portions of T.4N., R.2E., Sections 1, 2, and 3, T.5N., R.2E., Sections 25, 26, 27, 34, 35, and 36.

Surface Water

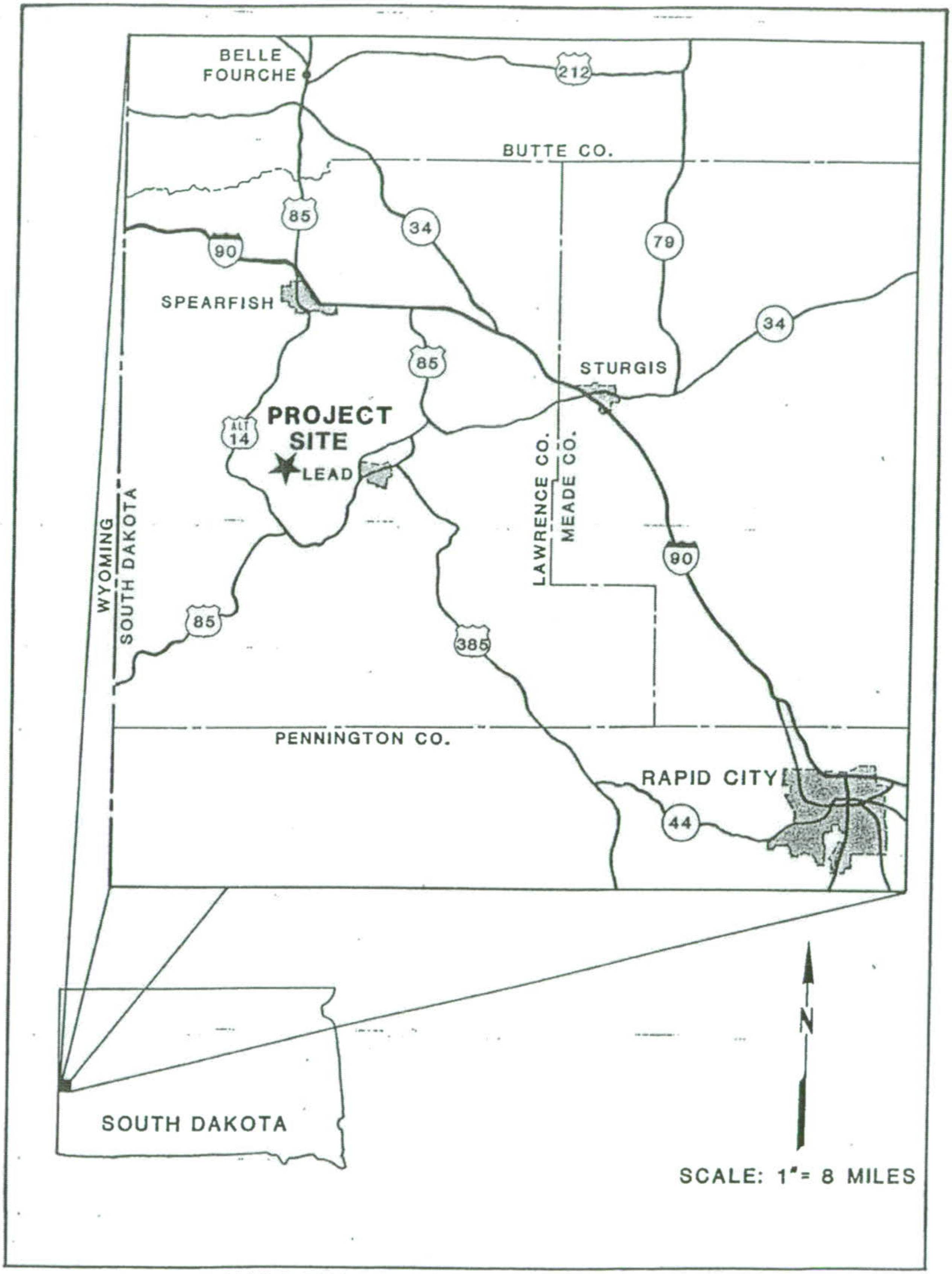
The groundwater study area includes portions of the Deadwood, False Bottom, and Squaw Creek drainages. These streams are intermittent within the project area. A small pond is located in the headwaters of Deadwood Creek. This pond is (or was) apparently connected to wastewater disposal systems for several homes in the Trojan area. As such, it is not representative of surface water or groundwater conditions in the study area and will not be considered further in this report. False Bottom Spring,. located in False Bottom Creek below the lower Bald Mountain tailing dam, was included in the characterization of baseline groundwater quality.

Topography

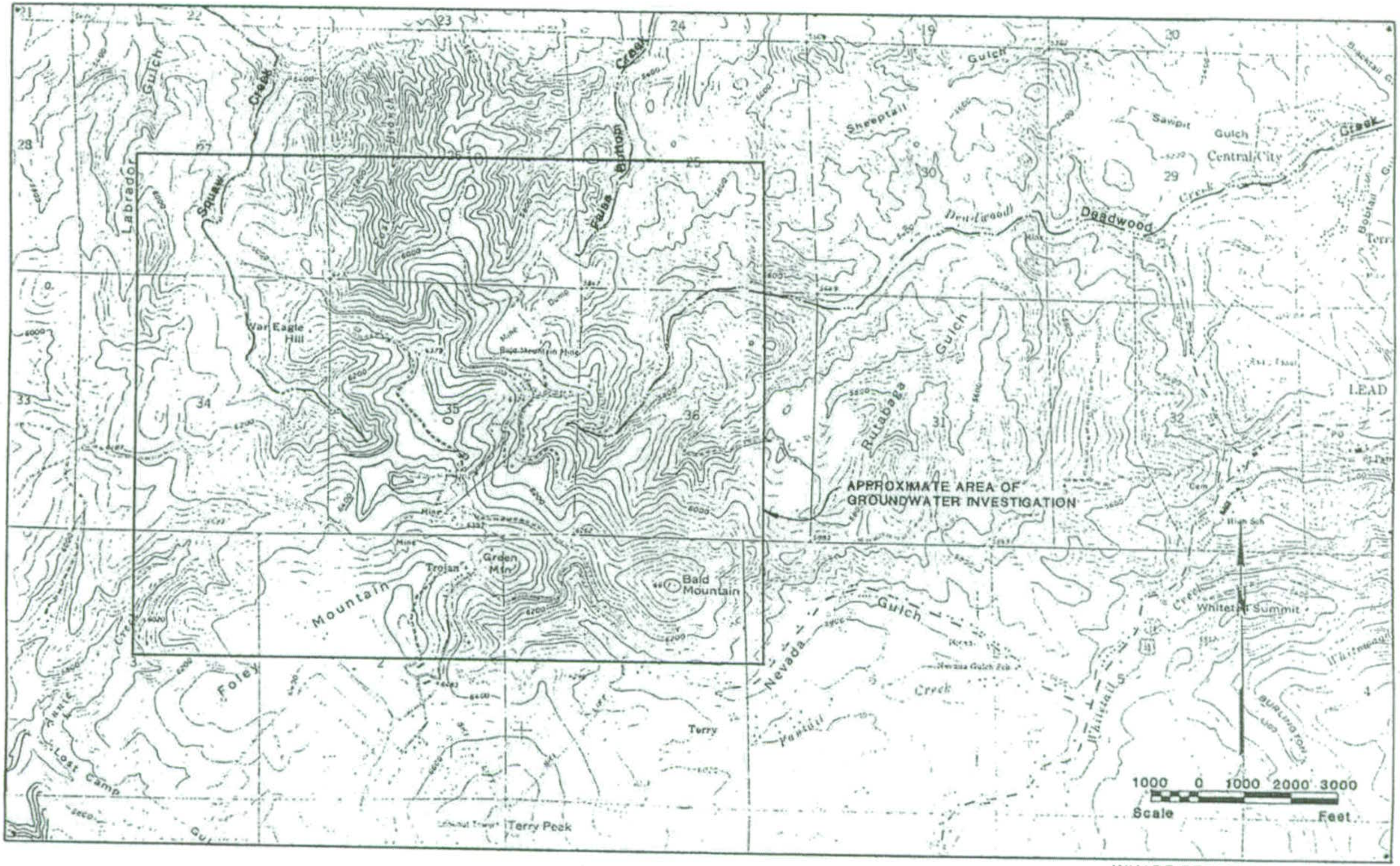
The topography of the project area is characterized by moderately steep mountainous terrain, with elevations ranging from 6650 feet at the summit of Foley Mountain to about 5500 feet in lower reaches of False Bottom and Deadwood Creeks.

Climate

Isohyetal maps showing annual precipitation rates for the State of South Dakota indicate that an average of 28 inches per year of precipitation may be expected for the study area. The closest



WHARF RESOURCES - CLINTON PROJECT
LOCATION MAP
FIGURE 2-1



WHARF RESOURCES - CLINTON PROJECT
GROUNDWATER INVESTIGATION AREA
FIGURE 2-2

certified precipitation recording station to the study area is located at Lead. The average annual for the NOAA weather station at Lead is 25 inches. May is typically the wettest month and February is the driest month.

Existing Mine Developments

The Project is located in a historic mining area known as the Portland District that has actively been mined since the 1880s. Included within the project area is extensive underground development from several mines including the Portland-Trojan, Bald Mountain, Dakota Group, Imperial, Clinton, Decorah, Ofer, and others. These mines were eventually consolidated by the Bald Mountain Mining Company and actively mined from about 1880 to 1959.

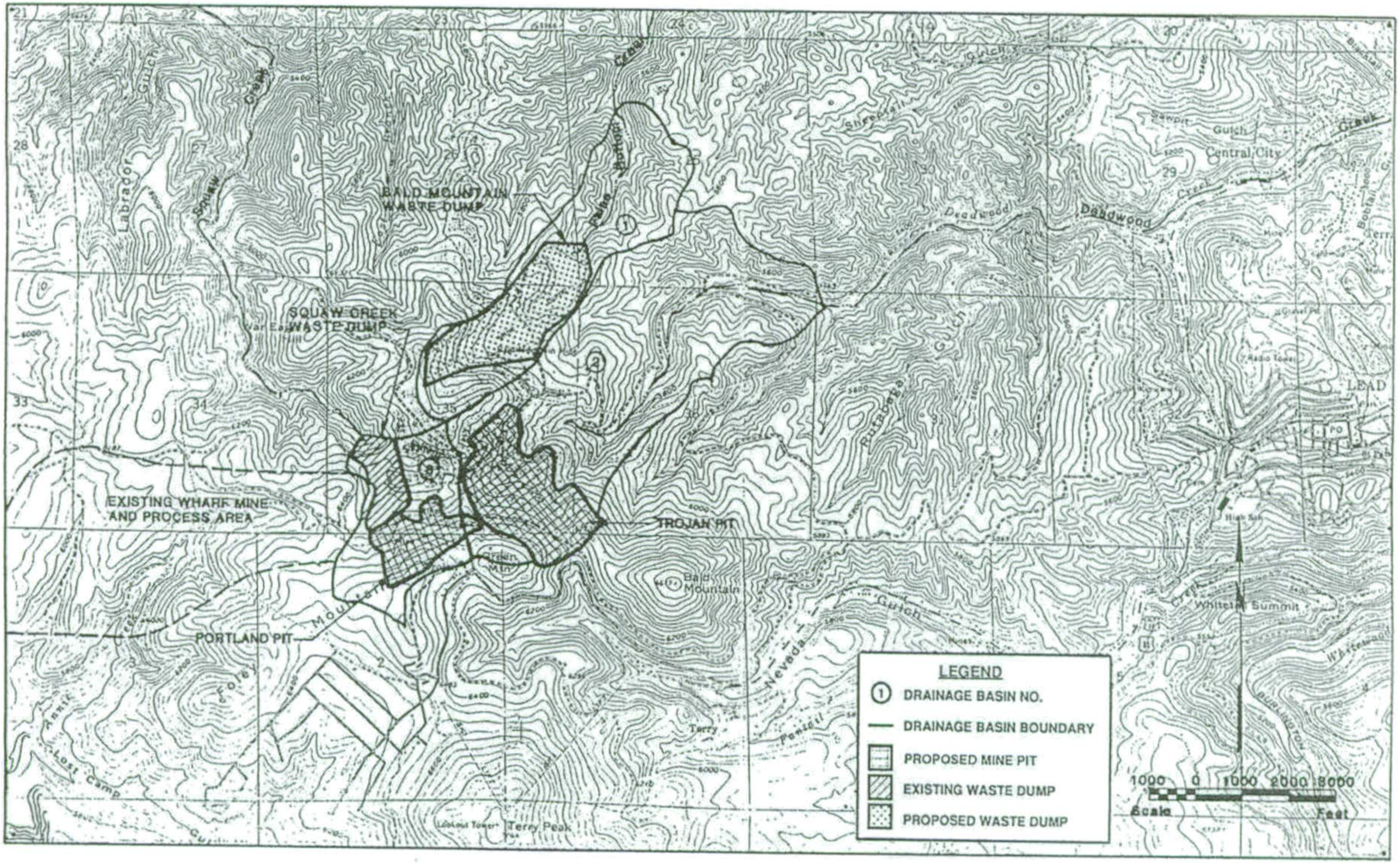
The most prominent surface features in the Clinton Project area associated with historic mining in the area are the Bald Mountain Mill and tailings impoundment and the Squaw Creek Waste Rock Facility. The Bald Mountain Mill tailings cover approximately 60 acres in the upper watershed of False Bottom Creek drainage. Approximately 3 million tons of tailings were deposited in the two-level impoundment between 1908 and 1959. The tailings were subsequently stabilized with a cover of rock, soil, and vegetation in about 1994. The Squaw Creek Waste Rock Disposal Facility is a permitted facility associated with the Wharf Mine operated by Wharf Resources. Wharf operates open pit mines located west of the proposed Clinton Extension Project. Waste from these open pits has been deposited in the Squaw Creek Waste Rock Facility and in other waste disposal areas in the Annie Creek drainage. The Squaw Creek Waste Rock Facility is currently in the reclamation stage.

PROPOSED CLINTON EXTENSION PROJECT

The proposed Clinton extension project will consist of two open pits as shown on Figure 2-3. The Portland Pit will be an extension of the existing Foley Ridge / Annie Arm Mine. The Trojan Pit will be located east of the Portland Pit and may be interconnected with the Portland Pit. The pits will mine oxidized gold ore which will be heap leached in the existing on-off heaps located at the Annie Creek Mine. Waste rock from these open pits will be disposed in a waste depository which will cover the existing Bald Mountain Mill tailings, contained within the False Bottom Creek drainage. Spent ore will be neutralized and disposed as backfill in the existing Foley Ridge pit. This report will address impacts associated with mining and waste rock disposal.

PREVIOUS INVESTIGATIONS

Previous work within the groundwater study area has generally been related to geology and mineralization. Notable reports include "Reconnaissance of Gold-Mining Districts in the Black Hills, South Dakota (USBM Bull 427, 1940), "Geology and Gold Mineralization of the Foley Ridge Deposits, Bald Mountain Mining District, Lawrence County South Dakota" (J.D. Taylor). Previous investigations of groundwater in the project vicinity are limited to studies of groundwater occurrence in the Annie Creek and Ross Valley areas (JMM 1988, Klohn Leonoff 1986, SRK 1986). A list of references for the project vicinity are included at the end of this report.



WHARF RESOURCES - CLINTON PROJECT
PROPOSED FACILITIES MAP

FIGURE 2-3

SECTION 3

GEOLOGY

Bedrock exposures are relatively rare within the project area and surface geology is inferred from drill hole data and outcrops. Cross-sections have been developed based primarily upon drill log information. Project area drill holes, wells, and piezometers are shown on Figure 3-1. Surface geology is shown on Figure 3-2, and cross-sections are shown on Figures 3-3 through 3-5.

GEOLOGIC UNITS

Geologic units within the project area include Tertiary intrusives, Ordovician and Cambrian sediments, and Precambrian metamorphics. These units are described briefly below.

Precambrian Units

As shown on Figure 3-2, Precambrian-age rock, consisting of phyllites, schists, and quartzites, is the dominant surficial rock unit in the north and northeastern portions of the project area, and underlies essentially the entire project area at depth. The Precambrian rock units are thought to be part of the Proterozoic-age Flag Rock and Ellison Formations. These highly foliated units strike north-northwest and dip steeply, generally to the northeast.

Paleozoic Units

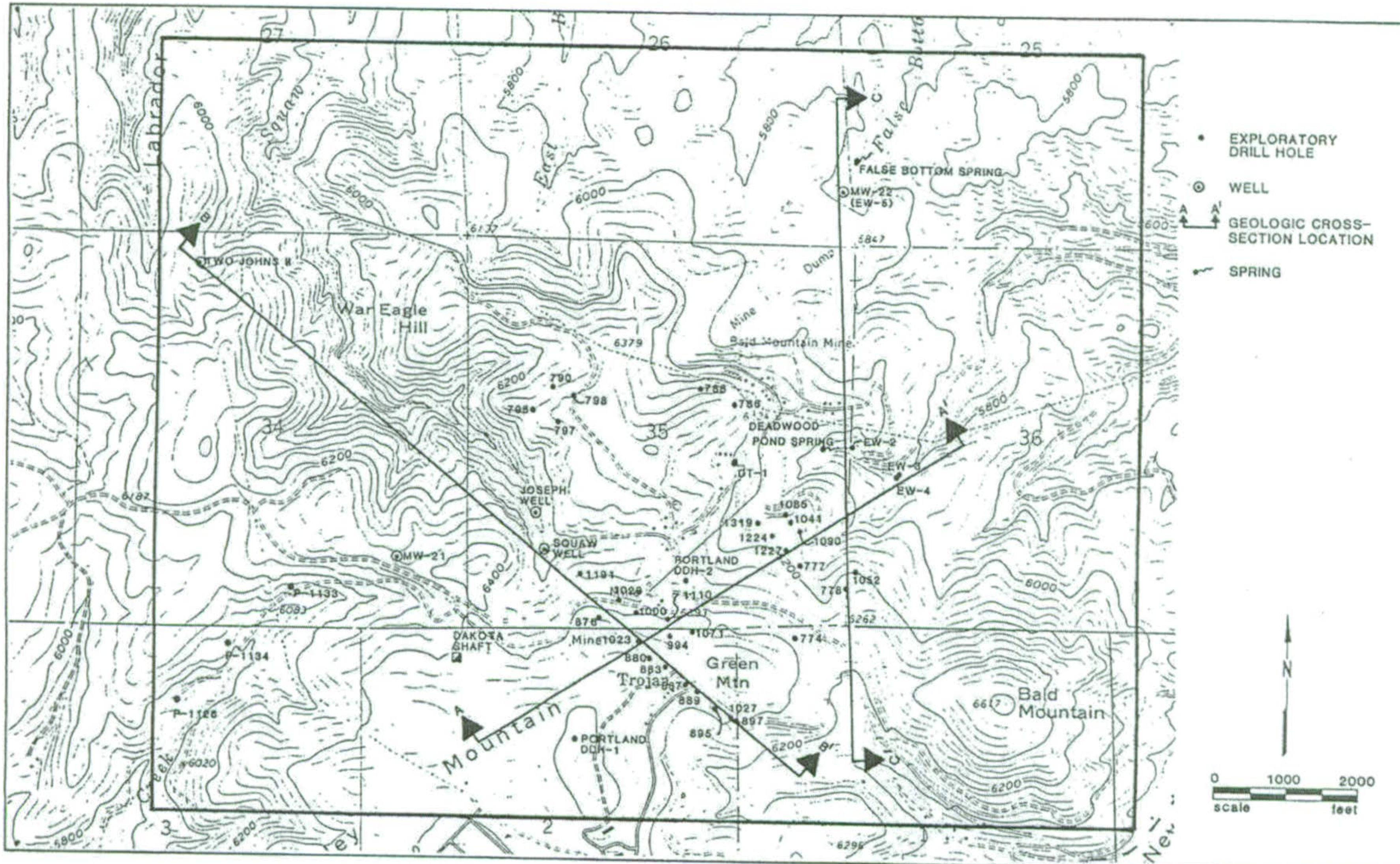
Deadwood Formation. The Cambrian-age Deadwood formation disconformably overlies the Precambrian units. The Deadwood Formation consists of a complex sequence of regressive-transgressive depositional deposits, including sandstone, siltstone, shale, intraformational limestone conglomerate, quartzite, dolomite, and basal conglomerate. These sediments dip southwesterly at 6 to 15 degrees and have a total thickness of about 400 feet in the project area. The contact with the underlying Precambrian units is irregular.

Winnipeg Shale. The Ordovician-age Winnipeg shale is present on Green Mountain and Foley Ridge. This unit consist of a dense, green, friable shale with isolated siltstone partings. The contact between Winnipeg shale and the Deadwood Formation is conformable.

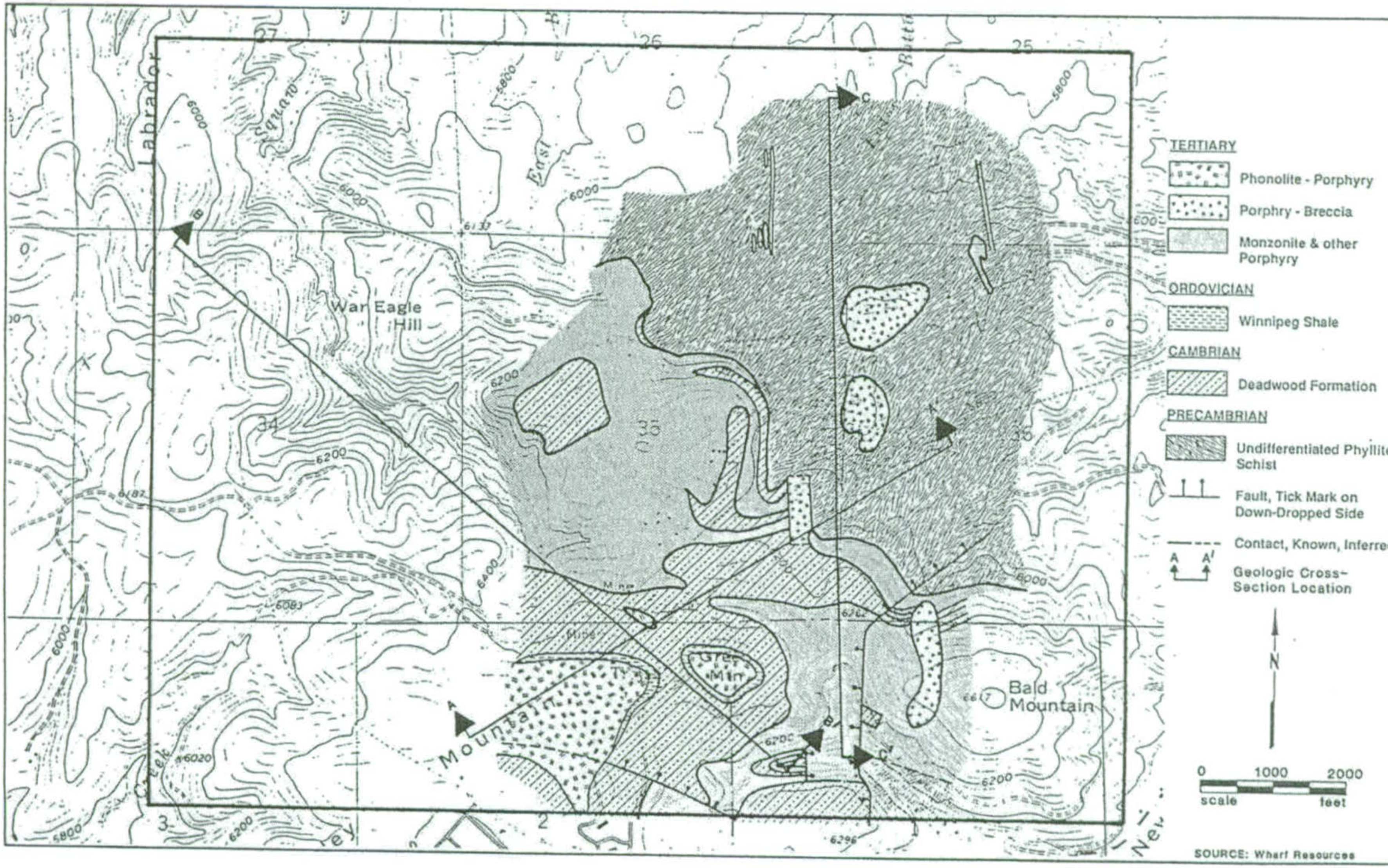
Cenozoic Units

Tertiary Igneous Intrusives. Tertiary-age igneous rock types are common throughout the project, and are typically found as planar intrusions along bedding planes, foliation, and fractures within the country rock. The igneous rocks are locally subdivided into monzonite porphyry, phonolite porphyry, and porphyry breccia.

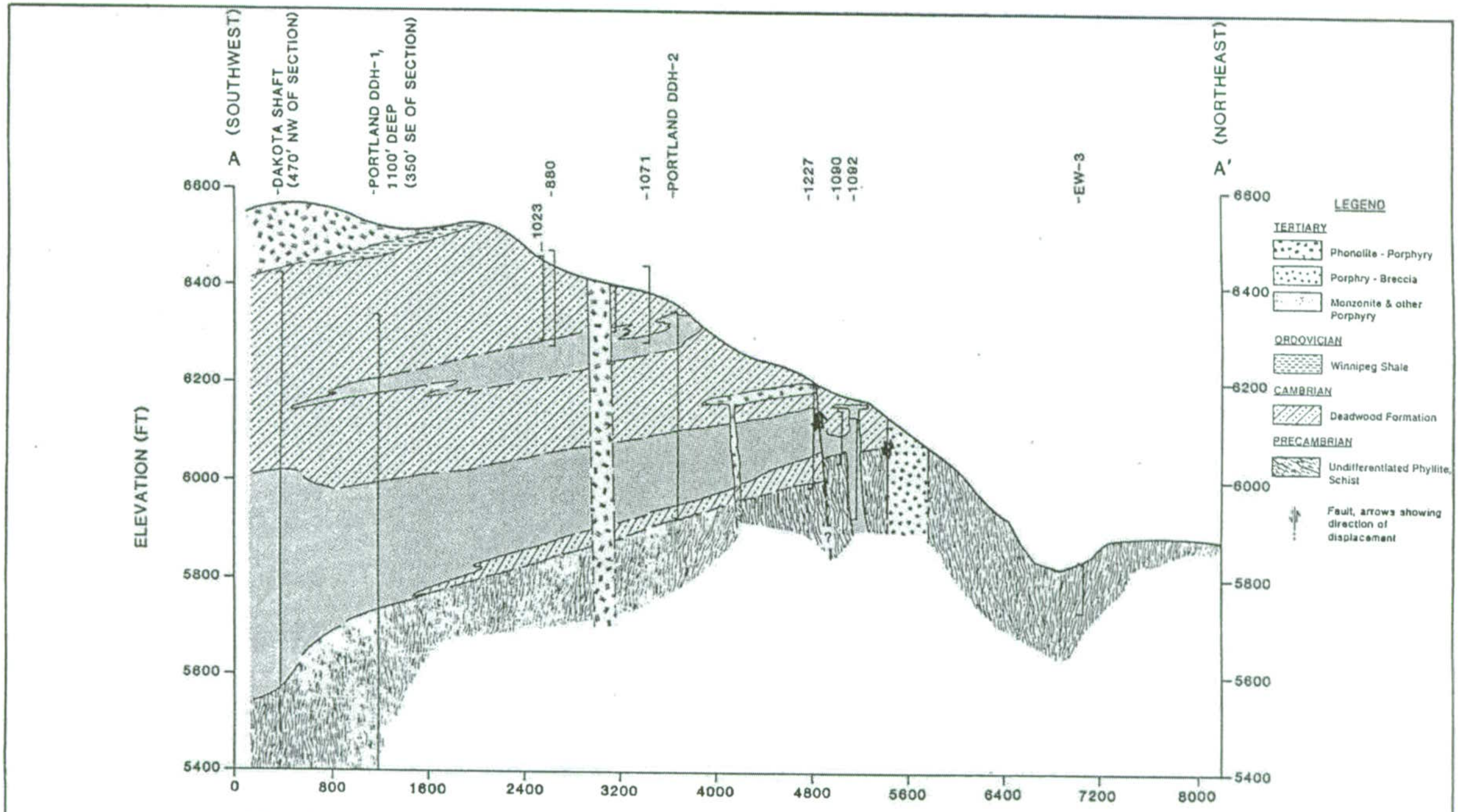
Numerous monzonite porphyry rocks intrude the Precambrian units, forming sills that are typically less than 20 feet thick and parallel the Precambrian foliation. Similarly, thin monzonite porphyry sills and dikes intrude the Deadwood Formation. A small monzonite porphyry stock



WHARF RESOURCES - CLINTON PROJECT
DRILL HOLE & WELL LOCATIONS
FIGURE 3-1

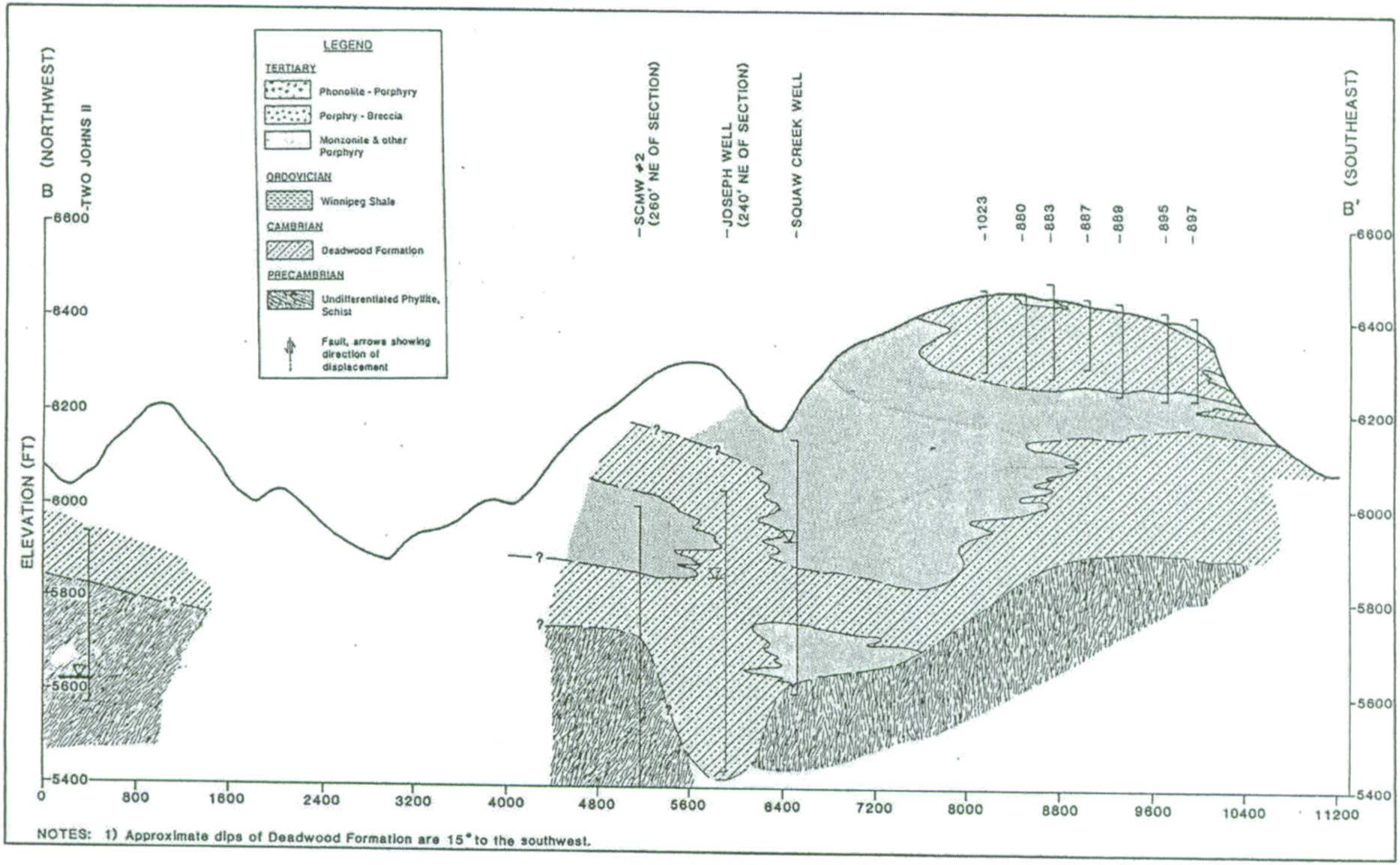


WHARF RESOURCES – CLINTON PROJECT
GEOLOGIC MAP OF
CLINTON PROJECT AREA
FIGURE 3-2

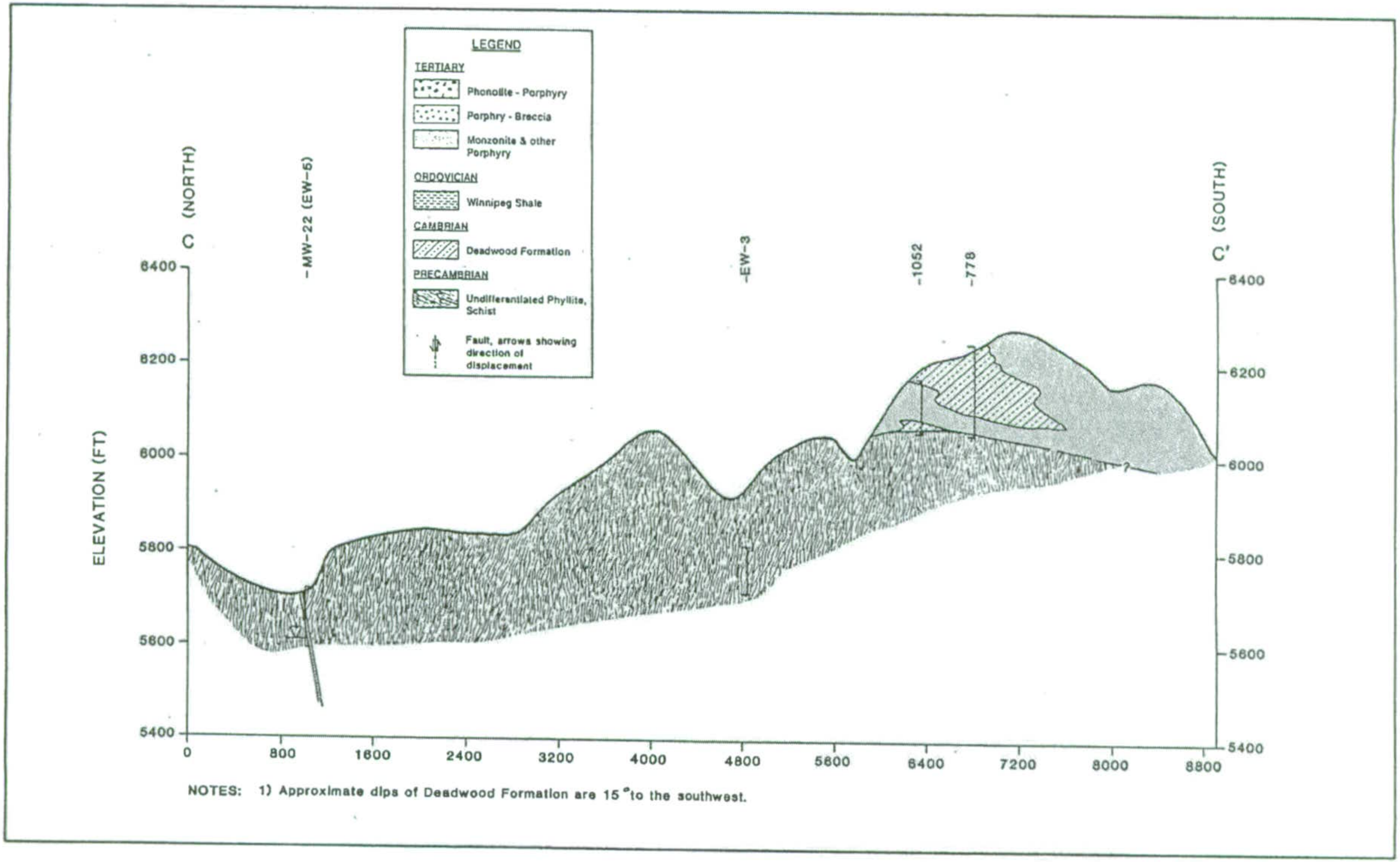


NOTES: 1) Approximate dips of Deadwood Formation are 15° to the southwest.

WHARF RESOURCES – CLINTON PROJECT
GEOLOGIC CROSS-SECTION A–A'
FIGURE 3–3



WHARF RESOURCES - CLINTON PROJECT
GEOLOGIC CROSS-SECTION B-B'
FIGURE 3-4



WHARF RESOURCES - CLINTON PROJECT
GEOLOGIC CROSS-SECTION C-C'
FIGURE 3-5

and dike swarm has been identified east of the lower Bald Mountain Tailing Dam. The lower portion of the Deadwood Formation is intruded by a 90 to 120-foot thick monzonite porphyry sill locally known as the Clinton sill. The numerous offsets or faults within the Deadwood result in the Clinton sill contacting the Precambrian to the east of the Decorah Mine, but rising to 80 feet above the Precambrian in the vicinity of the county road. Another locally significant monzonite porphyry sill is the 60 to 100-foot thick Portland or Green Mountain sill, which appears to be an extension of the Clinton sill. This sill intrudes the upper part of the Deadwood Formation in the southern portion of the project area.

Porphyry breccia contains highly variable amounts of Precambrian metamorphic and Tertiary igneous clasts, within a monzonite porphyry matrix. Two porphyry breccia stocks have been identified east of the Bald Mountain Mill. A large porphyry breccia dike crops out near the Decorah Mine, in the southeast quarter of section 35.

Emplacement of phonolite appears to post-date emplacement of the monzonite. A large phonolite porphyry sill overlies the Winnipeg shale on Foley Ridge and Green Mountain. This sill varies in thickness from 0 to 250 feet, with thickness generally increasing to the southwest.

Soils and Colluvium

The majority of the project area is covered by a thick veneer of soil and colluvium, with minor alluvium along stream channels. Information on soil classification for the project study area was obtained from the Soil Conservation Service (SCS) Soil Survey of Lawrence County, South Dakota. The areal distribution of the predominant soil groups is shown in Figure 3-6.

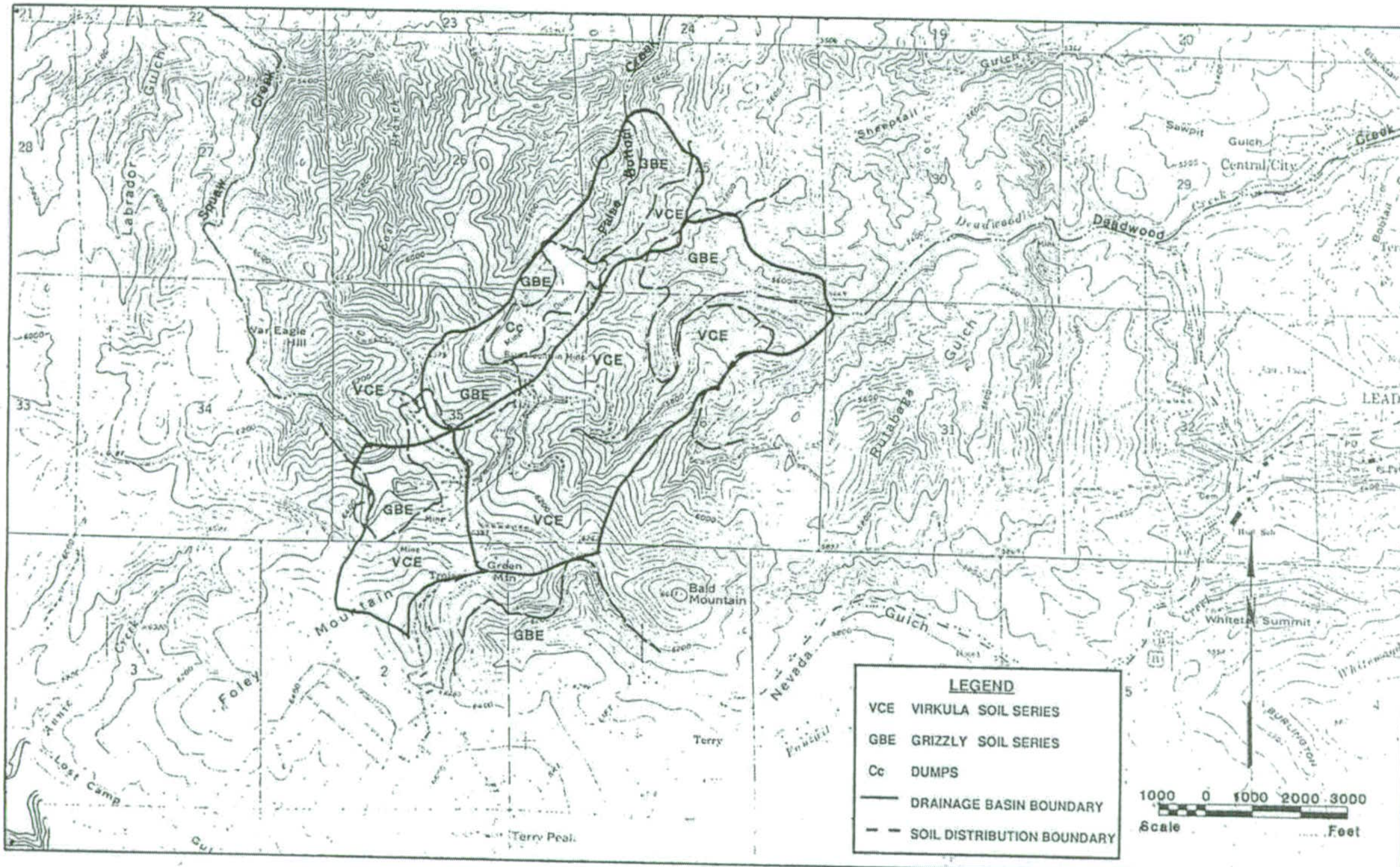
The predominant soils in the study area include the Grizzly-Virkula association and the Virkula soil series. The Grizzly series consist of deep, well drained soils that formed in igneous material. Permeability is moderately slow. Texturally, the soil is a gravely silt loam grading into a gravely clay loam below approximately 20 inches. Depth to bedrock is typically more than 60 inches. Fragments of igneous rock typically make up 35 to 80 percent of the soil mass at depths of less than 60 inches.

The Virkula series consists of deep, well drained soils that formed in material weathered from igneous and metamorphic parent materials. These soils are found on slopes typically ranging from 6 to 35 percent, permeability is moderately slow, available water capacity is moderate to high, and runoff is rapid. Texturally, the soil is a silt loam grading into a clay loam below about 12 inches. Depth to bedrock is typically greater than 40 inches.

The Grizzly-Virkula association represents soils with properties common to both soil series present in the watershed. Grizzly soils are generally deeper than the Virkula series and have a higher gravel and rock content.

GEOLOGIC STRUCTURES

Known geologic structures are shown on Figure 3-2. These structure include normal faults west of Bald Mountain and south of Green Mountain. Bald Mountain is contained with a horst block,



WHARF RESOURCES – CLINTON PROJEC
SOIL DISTRIBUTION MAP
FIGURE 3-6

bordered on the west by the fault shown on Figure 3-2 and bordered on the east by the Tornado Fault, located outside the geologic map area of Figure 3-2. Other smaller faults are undoubtedly present, many of which have controlled emplacement of dikes.

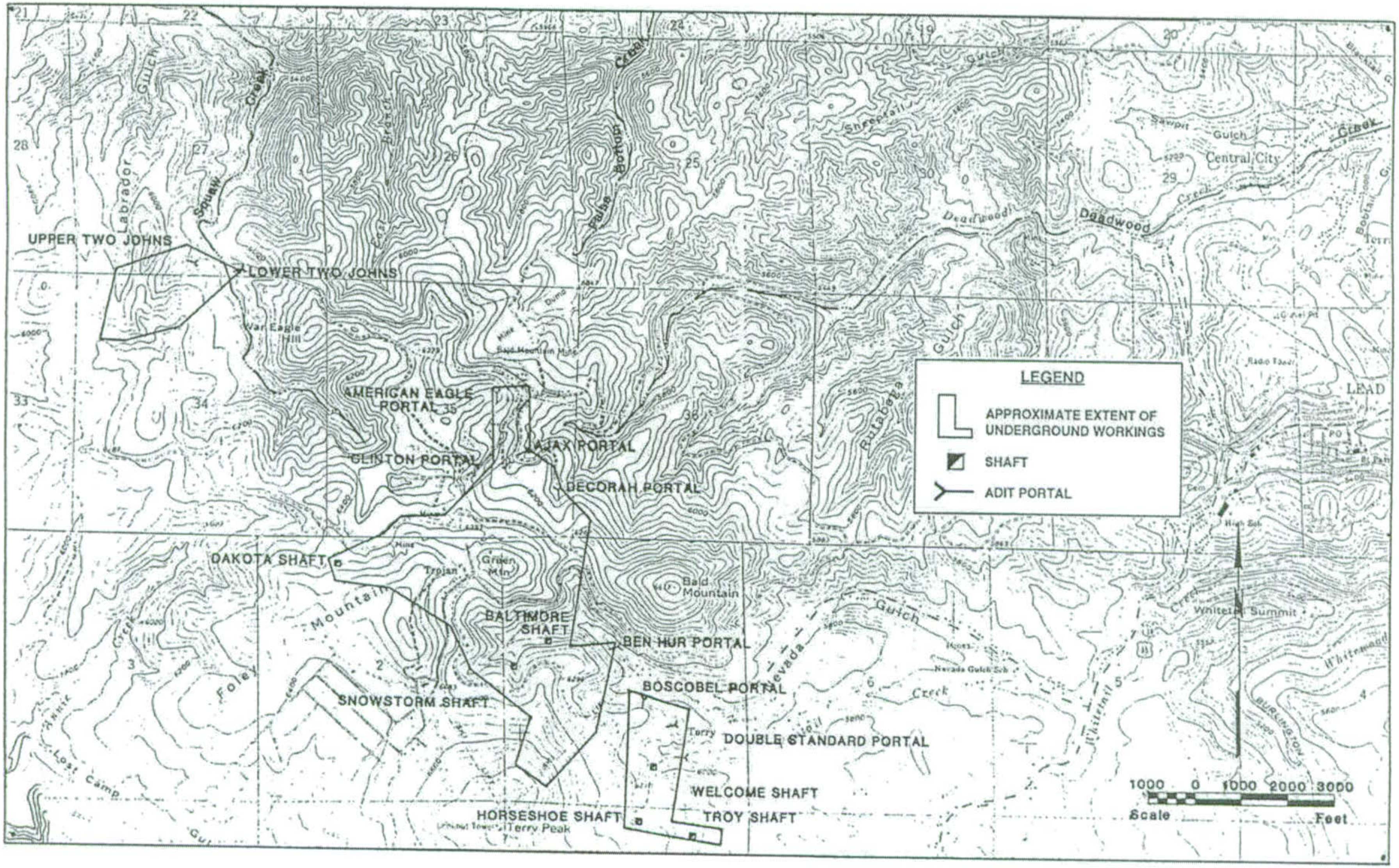
MINERALIZATION

Mineralization within the project area occurs primarily within the Deadwood Formation, with lesser amounts of mineralization within the Precambrian and Tertiary rocks. The mineralization is associated with the emplacement of the Tertiary igneous intrusions and resulted from the migration of hot metal-bearing fluids into the ore zones. Mineralization occurred primarily by replacement (decarbonization) in the Deadwood Formation, with additional mineralization by silicification in the Deadwood, Precambrian or igneous units.

The Deadwood Formation was preferentially mineralized due to its higher permeability in comparison to the Precambrian or Tertiary rock. As a result, high grade ore zones do not extend significantly into the Precambrian or the Tertiary igneous intrusions. Thus, potential pit depths are generally limited by the depth to the contact with the Precambrian basement or Tertiary sills.

Most of the higher grade ore is located in three stratigraphic horizons within the Deadwood. The lower horizon (generally referred to as the lower contact zone) is above a basal quartzite, near the contact with the Precambrian. This horizon has been mined by underground workings (Clinton, Decorah, American Eagle, Ajax, Alaska, and Dividend mines) below and east of the proposed Portland Pit, at the Two Johns Mine west of Squaw Creek, and at the workings beneath Nevada Gulch (Snowstorm, Boscobel, Ben Hur, and Double Standard mines). Lower contact zone mining areas are identified in Figure 3-7. The upper horizon (upper contact zone) is 300 to 600 feet above the lower horizon, and has been more extensively developed by underground workings. Underground workings within the upper horizon (upper contact zone) include the Portland, Trojan, Elder, Folger, Alameda, Empire State, and Dakota Mines. These workings are present primarily in the northern half of Section 2, beneath Green and Foley Mountains. The middle horizon (intermediate contact zone) was developed by underground workings from both the upper contact zone and lower contact zone mines. The intermediate contact horizon is separated from the lower and upper horizon by monzonite porphyry sills. The proposed Portland Pit will mine the upper contact zone. The proposed Trojan Pit will mine the upper and the lower contact zones, along with some of the intermediate contact zone.

Ore within the Clinton project area is found in an oxidized condition, typical of ores near or above a regional water table. These "brown" ores were the predominant ores of past production from the Portland District mines. Unoxidized ore in Portland District was mined from the Two Johns Mine and from mines below Nevada Gulch. This "blue" ore was mined in areas below the regional water table and made up a lesser fraction of the Portland District production. Significant amounts of unoxidized ore are not anticipated in the proposed Portland and Trojan Pits.



WHARF RESOURCES - CLINTON PROJECT
LOWER CONTACT ZONE WORKINGS
FIGURE 3-7

SECTION 4

HYDROGEOLOGY

Local hydrogeology is characterized by a relative lack of permeable water-bearing rock beneath the project area. In general, depth to groundwater typically exceeds 200 feet and where present, is found primarily in low permeability metamorphic and igneous rocks. Some areas of saturated sediments of the Deadwood Formation are present, primarily in the southern half of the study area.

HYDROGEOLOGIC UNITS

Precambrian

The Precambrian rock units in the project area are not significant aquifers due to low porosity and low permeability. Where fractured, these rocks will yield only small flows of groundwater to wells. According to Rahn (1981), lithostatic pressure keeps most water-transmitting voids closed in the Precambrian units below a depth of about 500 feet. This is confirmed by deep drilling in the project area, as exploration holes 700 to 1100 feet deep in the Foley pit failed to encounter water, and deep drill holes one mile north of the Bald Mountain tailing dam did not encounter meaningful water at depths in excess of 2000-feet (Lessard, 1990). Similarly, the Homestake mine penetrates 8000 feet into Precambrian rock and is essentially dry. As a result, groundwater stored in deep Precambrian rocks can be considered as insignificant, and storage and transport of groundwater in the upper 500 feet of the Precambrian is minor. Rahn (1981) estimated that the effective porosity of the Precambrian is one percent. Hence, the Precambrian is not considered a regional aquifer of any importance.

Deadwood Formation

Groundwater is found within Deadwood Formation sediments in the western portion of the project area in the vicinity of the Joseph Well. Saturated Deadwood sediments are found at the Two Johns Mine northwest of the project area and at mines in Nevada Gulch, south of the project area. We also anticipate that groundwater may be encountered in the Deadwood at the contact with the Precambrian below the proposed Portland pit. Within the remainder of the project area, much of the Deadwood is dry as it is located above the regional water table. Sporadic perched zones of limited areal extent are believed to exist above the regional water table.

Winnipeg Formation

The Winnipeg formation is above the water table within the project area. As such, it is not considered as a hydrogeologic unit within the groundwater study area.

Tertiary Intrusives

Hydrogeologic characteristics of the Tertiary igneous units within the project area are similar to the Precambrian units. That is, these intrusive rocks have very low primary porosity and permeability, with essentially all water transmission through joints and fractures. As such, the Tertiary intrusives are not considered an important aquifer. Where penetrated by wells, the intrusive rocks occasionally produce sufficient yield for domestic purposes.

Colluvium/Alluvium

Few areas of saturated colluvium or alluvium exist within the project area. These areas are limited to springs and saturated creek bottoms, which cover less than one percent of the project area. The area covered by colluvium and alluvium is relatively insignificant; thus, hydrogeology of the colluvium and alluvium will not be addressed further.

GROUNDWATER USE

Surface water flows in the False Bottom Creek and Deadwood Creek drainages were insufficient to provide a water supply for the Bald Mountain Mill and the town of Trojan. Water was obtained by pumping from Ross Springs and the Two Johns Mine. Groundwater supply for homes in the project area is derived from the Two Johns Well. Groundwater supply for the Wharf Mine is obtained primarily from wells completed in the Pahasapa limestone, approximately two miles southeast of the Clinton project area. Some additional supply for Wharf is obtained from the Joseph well within the Clinton Project area.

Water Rights

The State of South Dakota lists eight water rights (Table 4-1) for groundwater within T.4N., R.2E., Sections 1, 2, and 3, T.5N., R.2E., Sections 25, 26, 35, and 36.

TABLE 4-1

WATER RIGHTS IN THE CLINTON GROUNDWATER STUDY AREA

Number	Owner	Source	Amount	Location
301A-1	Black Hills Chairlift Co.	Ben Hur Mine	2.13 cfs	T.4N., R.2E., Sec.1 NE
301-1	Black Hills Chairlift Co.	Well 53' deep	0.02 cfs	T.4N., R.2E., Sec.1 SW
1346-1	Wharf Resources	Madison Fm.	0.22	T.4N., R.2E., Sec.3
1406-1	Wharf Resources	Two Johns Well	0.56	T.5N., R.2E., Sec.34
1406A-1	Wharf Resources	Two Johns Well		T.5N., R.2E., Sec.34
1365-1	Wharf Resources	Joseph Well	0.25	T.5N., R.2E., Sec.35
1174-1	Wharf Resources	Squaw Shaft	0.67	T.5N., R.2E., Sec.35
1460-1	Wharf Resources	Squaw Well	0.10	T.5N., R.2E., Sec.35

The first three water-rights above are for points of diversion outside the groundwater study area. The other water-rights are for points of diversion within the study area, and total 1.8 cfs. Assuming that these wells were pumped year around at 1.8 cfs, approximately 1300 acre feet would be produced. In reality, the wells are probably pumped at a much lower rate and annual groundwater production is probably on the order of several hundred acre feet.

Study Area Wells

Wells within the project area are listed and described in Table 4-2. A survey of well logs on file with the State of South Dakota Division of Water Rights includes four wells listed as being located within the project area. One additional well log (George Dunning) is listed as being located within the project area in the NE 1/4 Section 34, T.5N., R.2E. However, Wharf personnel report that this well is actually located outside of the project area in the NW 1/4 of Section 27, T.5N., R.2E. The log of a well owned by Dempsey and Francis Perkins, with a stated location of SE 1/4 Section 34, T.5N., R.2E., is actually located in the SE 1/4, SE 1/4, Section 26, T.5N., R.2E. The remaining well logs on file with the State are for the Squaw Well, Two Johns I Well, and Two Johns II Well.

TABLE 4-2

WELLS AND WATER LEVELS IN THE CLINTON PROJECT AREA

			Water Level Information		
	Total Depth	Well Head Elevation	Static DTW	Static Elevation	Date
Joseph Well	605	6022.41	179.75	5842.66	1990 avg
Squaw Well	550	6154.77	220	5934.77	7/1/83
MW-22	138	5684	15	5669	12/90
Two Johns II	370	5935.73	292	5643.73	1988
Two Johns I	830		400		1987
Piezometer 1126	100	5914.4	43.2	5871.2	1988
Piezometer 1133	70	6069.3	40.7	6028.6	1988
Piezometer 1134	45	5996.8	15.8	5981	1988
DT-1	520	6166.64	173.2	5993.44	11/5/91
MW-21	145	6201.35	>145	<6056	1989
MW-40	300	6071.2	125	5946	8/96
Foley Shaft	793	6403	335	6068	1996
EW-6 (Clinton Pit Bottom)	520	6240	240	6000	8/96
Perkins	189		120		10/87
False Bottom Spring				5650±	

GROUNDWATER OCCURRENCE

Groundwater Associated with Previous Underground Mining Operations

Historic records indicate that the underground workings in and adjacent to the project area are essentially dry. This has been confirmed during underground tours by Wharf personnel of the Clinton and Decorah Mines, beneath the east Foley pit area and Green Mountain. An extensive underground tour by Wharf personnel in June 1988 found that all workings were dry with the exception of approximately 1 gpm of seepage in an isolated drift in the Decorah Mine. The estimated elevation of the workings toured was between 5970 and 6070.

Lower Contact Workings. Paul Miller (a former Bald Mountain Mining Company employee and now a consulting geological and mining engineer in Lead) reported in a letter dated August 5, 1992, that the lower contact workings of the Bald Mountain Mine (including workings of the Clinton, Decorah, Ajax, Alaska, and Dividend Mines) were extensive in size and essentially dry. Inflows were occasionally encountered during the spring (wet season), but were rarely measurable and never sufficient in size to require pumping.

Lower contact zone workings in the Clinton and Decorah area mines dip southerly, from about 6050 in vicinity of the Ajax, Clinton, and Decorah portals to about 5870 in the southern portions of these workings (northwest of the Baltimore Shaft). The workings follow the dip of the Deadwood-Precambrian contact; the dip in this area is estimated at 8 degrees by Wharf geologists. These working elevations suggest that the water table is below 5900 feet in the Clinton Mine (Trojan Pit) area.

Miller reports that water was encountered in Bald Mountain Mining Company lower contact underground workings below the Nevada Gulch drainage. These workings joined workings of the Snowstorm and Ben Hur Mines. Groundwater is presently appropriated from these workings for snowmaking at Terry Peak ski area.

The flooded mine workings south of the project area are interconnected with the workings beneath the proposed Trojan Pit. However, there are no reports that the workings within the Clinton project area serve as drains for groundwater flow to the south. Instead, it appears that the lower contact workings within the Clinton project area are typically above the regional water table.

Upper and Intermediate Contact Zones. Clinton Mine workings at the Portland Sill (intermediate) contact are reported to be at an elevation of about 6260 and are dry. The workings in the Portland Mine encountered the Portland Sill at approximately 6204 feet elevation, and encountered the Upper Deadwood contact at 6330. These workings were essentially dry, suggesting that the water table is below 6200 feet in the Portland Mine area.

The Bald Mountain Decline, located in Nevada Gulch with a portal elevation of 6050 encountered water at the intermediate contact zone at an elevation of 5900 feet, approximately 1200 feet south of Green Mountain. The contact produced 50 to 90 gpm over time. Above this contact, seepage flows were encountered, suggesting a water table elevation near 5900 in this area. It is not clear if this water table is perched or regional. A four-inch diameter pipe draining the Elder workings was reported to be carrying 10 to 20 gpm in the mid 1970s. This water was assumed to be from a perched water body in the upper contact zone, at an elevation above 6300 feet. The Wharf Exploration Department reports that there has been no flow from these workings in recent times.

Groundwater in Exploration Drill Holes

Extensive exploration drilling in the project area has not encountered groundwater except in isolated perched zones, predominantly in the localized area south of the Decorah Mine. These perched water-bearing zones appear to be seasonal, and are typically located at contacts between sedimentary and igneous units. Only one exploration boring (DT-1, also known as Hole 1806) penetrated a water-bearing structure that resulted in appreciable groundwater production. This hole is located approximately midway between the Clinton and American Eagle portals. A confined water-bearing zone was encountered at 450 feet below ground surface (elevation 5716) in Precambrian rock, and 20 to 40 gpm was produced by air-lift pumping prior to abandonment of the boring. Mineral exploration drilling outside the Decorah Mine area has not encountered water bearing structures.

Groundwater boreholes drilled near the Deadwood Creek pond did not encounter significant water. Three holes (EW-2, EW-3, and EW-4) were drilled (two angle and one vertical). EW-2, an east-west bearing angle hole, hit a "wet zone" from 50 to 70 feet, but did not encounter any measurable production. The vertical hole (EW-3) was a colluvium hole, which produced no water. EW-4 was an angle hole with a bearing of S.35W. No water quality or water level data is available from these holes.

Groundwater drilling in the False Bottom Gulch vicinity did encounter water. Two holes, one vertical and one angle, were drilled. The angle hole (EW-1) was drilled due east at 45 degrees and hit water at 155 feet (approximate elevation 5600 feet). The vertical hole (EW-5) attempted to intersect the same zone but instead encountered water (16 gpm) at 116 to 122 feet. The vertical hole was later reamed and completed as a monitor well (MW-22).

Two holes were drilled in 1996 in the Trojan Pit area for groundwater characterization. EW-6 (Trojan Pit Bottom Hole) was drilled through the Trojan Pit to a total depth of 520 feet (bottom hole elevation of 5720). The hole encountered a broken zone between 255 and 280 feet that yielded 1 gpm. Since the hole was drilled in an area of dry underground workings, it is possible that the water-bearing zone was perched. MW-40 was drilled outside the proposed northeast edge of the Trojan Pit to a total depth of 460 feet. Water bearing zones producing 2 gpm and 12 gpm were encountered at depths of 150-160 feet and 240-260 feet respectively. The hole was backfilled to 300 feet and completed as a monitor well tapping the 240 to 260-foot zone.

Existing Wharf Resources Mine Pits West of the Clinton Project Area

The existing Annie Creek pit penetrates to elevation 6020 feet. Groundwater contours suggest that the Annie Creek pit bottom is at or below the regional water table, yet significant groundwater inflow has not been detected. The Foley Pit currently extends to below 6100 feet elevation with no inflow, and exploration drill holes extending to elevation 5980 feet suggest no groundwater above elevation 5980 feet.

Springs

False Bottom Spring is located approximately 500 feet north of the lower Bald Mountain tailing dam, and issues from the contact of Precambrian phyllite, quartzite, and schist and a Tertiary monzonite porphyry dike. Measured flow ranges from 1 to 30 gpm, with an average of 14.8 gpm for five measurements. The higher flows occur during spring, with low flow in late summer and fall. Given that groundwater exploration drilling encountered groundwater in this same area, it is possible that False Bottom Spring is an expression of the regional water table rather than an isolated perched groundwater zone.

HYDRAULIC CHARACTERISTICS OF HYDROGEOLOGIC UNITS

Given the lack of significant water-bearing zones beneath the project area, significant testing of "aquifers" has not been conducted. However, some inferences can be made related to hydraulic parameters based upon well tests within and adjacent to the project area.

Precambrian and Tertiary Intrusives

As previously mentioned, the porosity of the Precambrian rock is estimated to average only about 1 percent. Similarly, the permeability of the unfractured Precambrian is probably extremely low, probably on the order of 1×10^{-8} cm/sec. As such, successful wells are not completed in unfractured Precambrian rock within the project area because they do not yield water.

Fractures within the Precambrian may yield sufficient water for domestic water supplies. For instance the log of the Perkins well states that it produced 3 gpm by air lifting with a total depth of 186 feet and a static water level of 120 feet. Assuming a pumping drawdown of 60 feet results in a specific capacity of 0.05 gpm/ft. Similarly, the George Dunning well completed just north of the groundwater study area had a specific capacity of 0.01 while air-lift pumping from a 165-foot thick saturated section of Precambrian and Tertiary porphyry. Exploration borehole No. 1806 produced approximately 30 gpm from a fracture in Precambrian rock at a depth of 450 feet. This results in a specific capacity of approximately 0.07 gpm/ft. These production rates suggest effective transmissivities in the range of 1 to 20 ft^2/day and average effective permeabilities in the range of 1×10^{-5} cm/sec for the sections penetrated by these wells. Note that the average effective permeability takes into account the fracture permeability within a section penetrated by a well. For instance, the actual permeability in 99.9 feet out of a 100-foot section of rock may be 1×10^{-8} cm/sec, but a single fracture can raise the average effective transmissivity to 1×10^{-5} cm/sec.

Hydrogeologic characteristics of the Tertiary igneous units within the project area are similar to the Precambrian units. That is, the intrusive rocks have very low porosity and permeability, with essentially all water transmission through joints and fractures. Average effective hydraulic conductivities of monzonite porphyry in the Annie Creek and Ross Valley drainages, measured by JMM (1989) and Klohn Leonoff (1986), averaged 4×10^{-5} cm/sec. Again, fractures raise the average effective permeability of otherwise relatively impermeable rock. Drilling within and adjacent to the project area and experience at other sites suggest that 4×10^{-5} cm/sec may overestimate actual average effective hydraulic conductivity for the Tertiary units, particularly for unfractured portions.

Deadwood Formation

The hydraulic characteristics of the Deadwood Formation are extremely variable, depending on the nature of the sedimentary rocks at any particular location within the section. For instance, shale will have very low permeability while sandstone will have moderate permeability. As a result of the variable hydraulic conductivity, vertical anisotropy occurs where the overall vertical hydraulic conductivity through the section in much lower than the average horizontal hydraulic conductivity. Average measured hydraulic conductivity of Deadwood Formation sandstone within the Annie Creek valley was 7×10^{-4} cm/sec (JMM, 1989). Klohn Leonoff (1986) estimated hydraulic conductivity of Deadwood Formation quartzite at 1.6×10^{-4} cm/sec in Ross Valley. These averages are for horizontal hydraulic conductivity.

Yields from wells completed within the Deadwood Formation in the Clinton project area suggest similar hydraulic conductivities. For instance, according to the drill log, the Squaw Well produced approximately 24 gpm by air-lifting. Assuming that 20 gpm was from the 100-foot section of saturated Deadwood penetrated, the well had an approximate specific capacity of 0.2, which would result in a hydraulic conductivity of about 1×10^{-4} cm/sec.

PIEZOMETRIC SURFACE AND GROUNDWATER GRADIENTS

Groundwater level data from wells within the Clinton project area is sporadic at best. In addition, ore zones are generally above the water table so that exploration drilling and underground mining operations have not commonly extended into groundwater in the project area.

Documentation of water levels from deep exploration drilling is difficult, as groundwater production zones are generally noted when encountered, but static water levels are not measured. As a result, elevations of confined groundwater producing zones are not applicable for piezometric contours. This is demonstrated by exploration well DT-1 (1809) which intersected a water producing zone at elevation 5716, but reportedly had a measured static water level of 5993, a confined water-level rise of 277 feet.

The geology of the area complicates preparation of piezometric contour maps, because of the permeability differences between the different rock types. These permeability differences result in the establishment of vertical gradients (which vary by location) and perched water zones. Downward vertical gradients have been documented in the nearby Annie Creek drainage (Klohn Leonoff 1986, JMM 1989) and would be expected in an upland recharge area such as the Clinton project area. Perched and seasonal water zones of limited extent are also anticipated in the area, given the vertical anisotropy expected in layered sediments, particularly when associated with igneous sills. For instance, a perched water zone tapped by underground workings is suggested by approximately 20 gpm of drainage reported at the Elder adit during the mid 1970s. The Elder adit drainage appears to have been an isolated phenomena, suggesting that extensive perched zones are not common within the project area.

The underground workings also influence groundwater levels beneath the project area. For instance, the lower contact workings appear to penetrate the regional water table in Section 1. These workings are interconnected and may act as a drain. As a result, the water table may be relatively flat in this area. Existing data suggests a water table elevation of approximately 5850 to 5950 feet in this area.

Groundwater levels in the area south of Green Mountain may also be influenced partially by water supply pumping by the Black Hills Chairlift Company. For instance, Wharf Resources reported encountering dry workings at elevation 5870 beneath Green Mountain during exploration drilling. However, the Bald Mountain Decline reportedly encountered considerable water approximately 1000 feet to the south at elevation 5900 and above in the mid 1970s. The Bald Mountain Decline water is either perched, or water supply pumping has lowered the water table in this area.

Known piezometric levels in the project vicinity are listed in Table 4-2 . Based upon this data and reports of water conditions in the underground workings, water-table elevations have been estimated on cross sections (Figures 4-1 through 4-3), and water-table contours are estimated on Figure 4-4. The contours shown are based upon limited water-level data and should be considered conceptual. The water-table is assumed to mirror the topography to a certain extent, particularly in the northern portion of the project area where the geology consists of low-permeability metamorphic and igneous rocks. Water-table contours probably do not mirror topography as well in the southern half of the project area, where the moderate permeability Deadwood Formation is mixed with the low permeability metamorphic and igneous rocks and the hydrogeology is further complicated by underground workings.

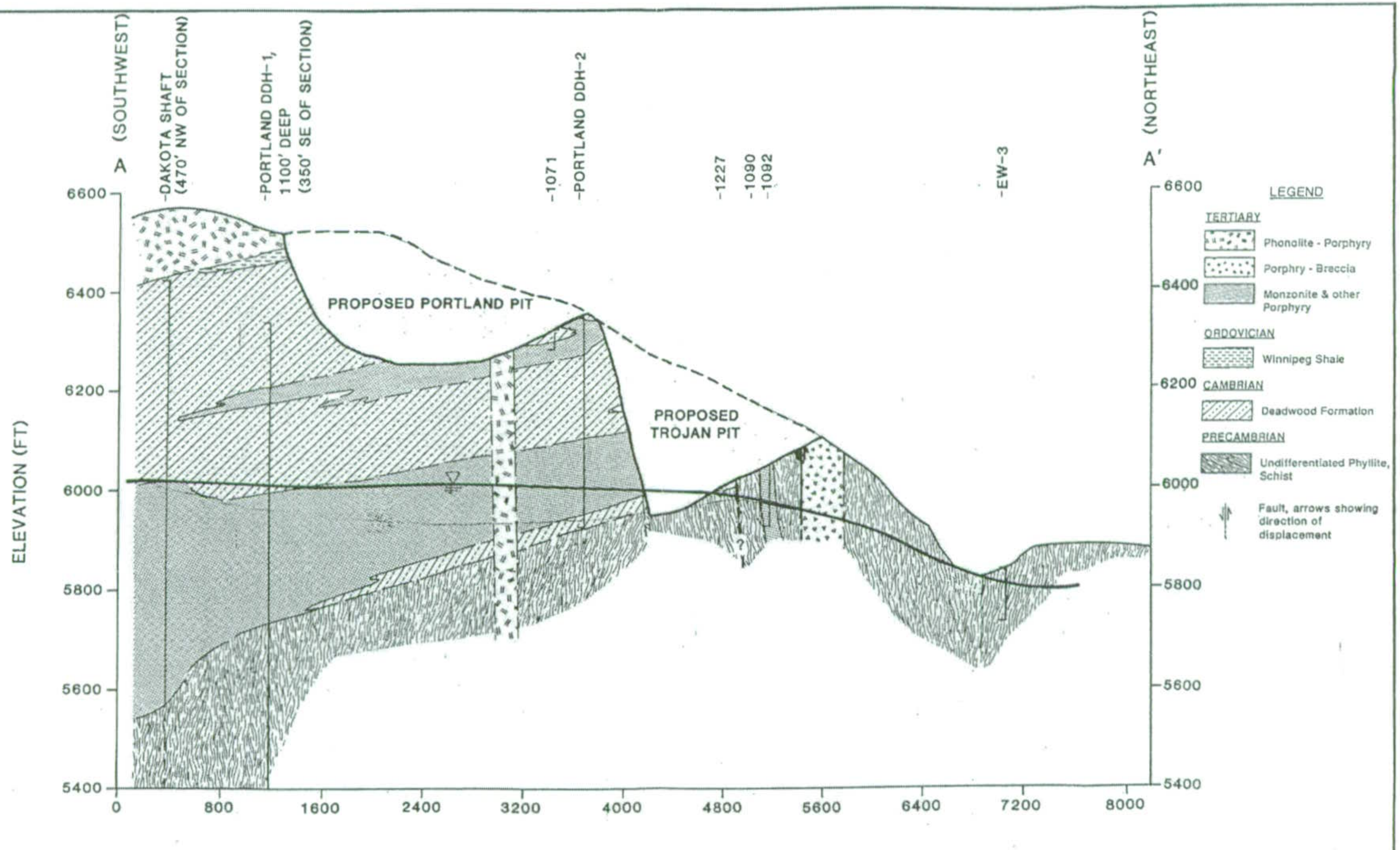
All static water levels in Table 4-2 are considered to reflect the regional water table. Deep wells (Squaw, Two Johns No. 2, Joseph, DT-1), are probably representative of the regional water table. Springs and shallow wells (False Bottom Spring, MW-22 and piezometers 1126, 1133 and 1134) may tap perched groundwater water bodies, but are assumed to reflect the regional water table. This assumption is conservative, as it may overestimate the elevation of the regional water table.

Evaluation of Figure 4-4 suggests that groundwater flow follows the topographic contours (i.e., downhill) with average hydraulic gradients in the range of 5 to 15 percent.

Groundwater Velocities

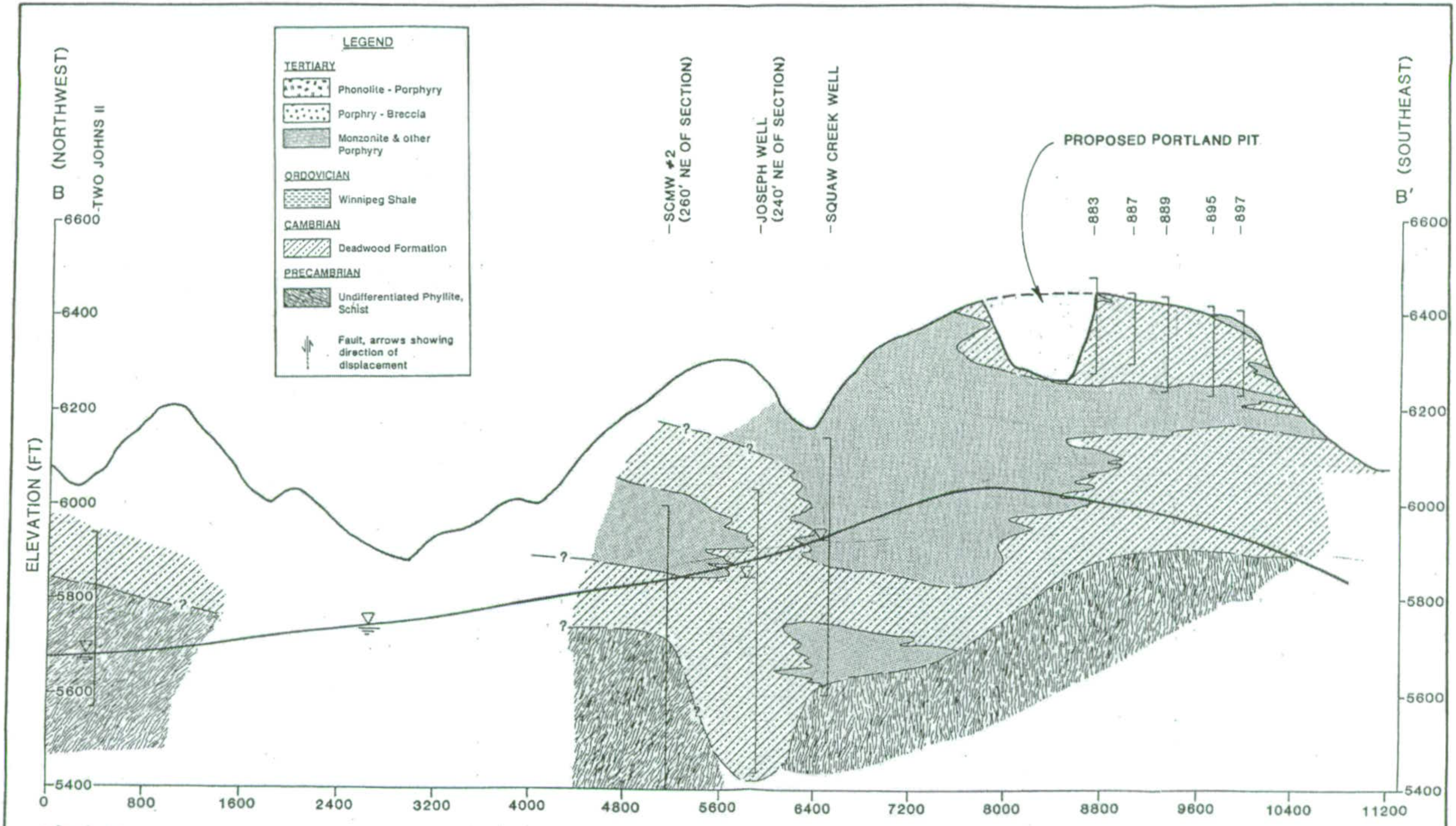
Horizontal groundwater velocity in the Deadwood Formation sediments was estimated at about 1.3 feet per day in the Annie Creek Valley by JMM (1989). This estimate was calculated using Darcy's law ($v=Ki/n$), with hydraulic conductivity (K) of 7×10^{-4} cm/sec, effective porosity (n) of 15 percent, and hydraulic gradient (i) of 0.10. This 1.3 feet per day value is probably conservatively high, as the average hydraulic conductivity of the Deadwood Formation is probably less than 7×10^{-4} cm/sec in the Clinton Project area. Thus, groundwater velocities through Deadwood sediments are anticipated to be less than one foot per day in the Clinton Project area.

As previously stated, permeability and porosity of the Precambrian and igneous rock mass in the project area is low. However, the low effective porosity of the rock will tend to increase the velocity of groundwater movement through fractures. For instance, assuming that (1) the effective



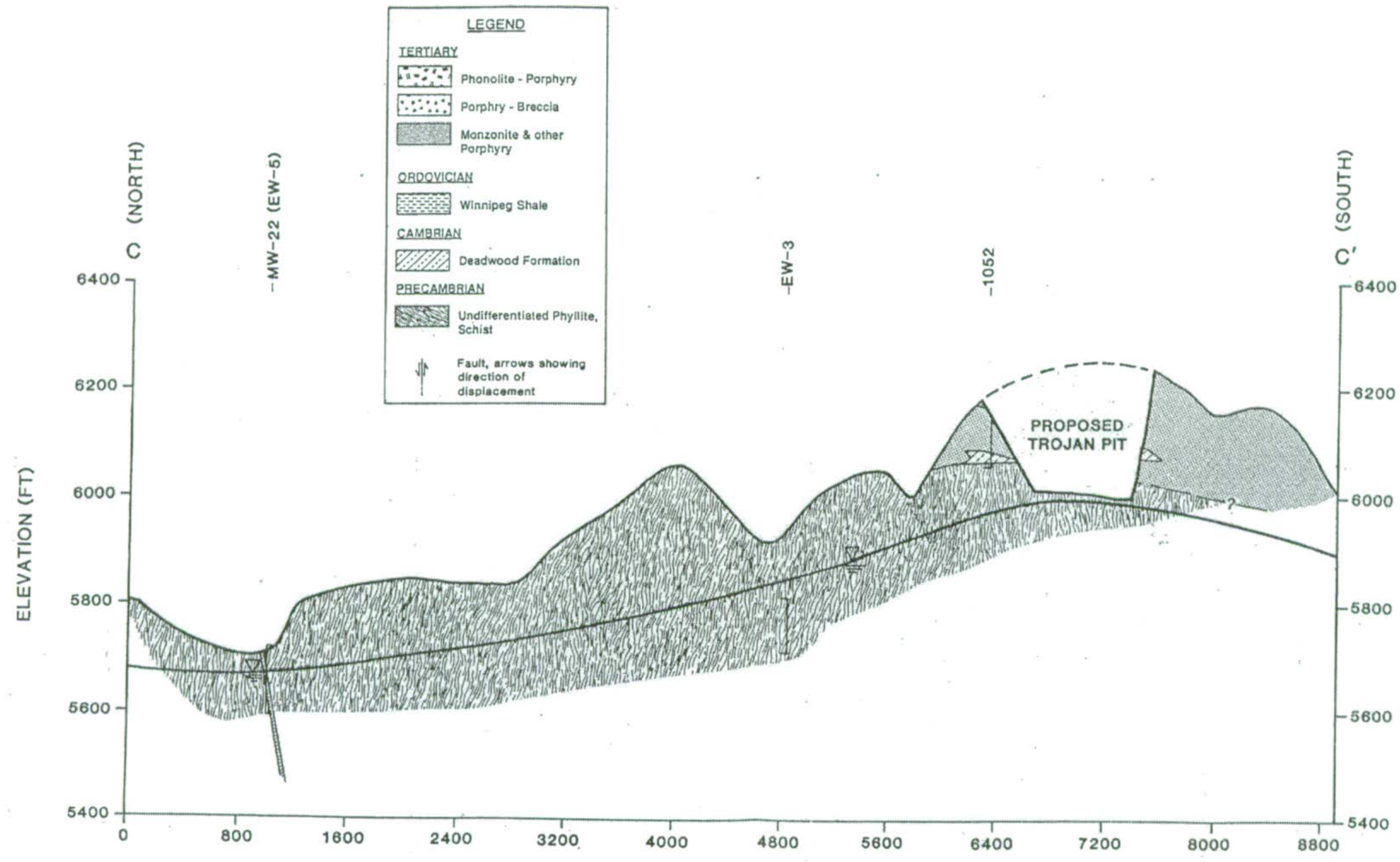
NOTES: 1) Approximate dips of Deadwood Formation are 15 to the southwest.

WHARF RESOURCES – CLINTON PROJECT
HYDROGEOLOGIC CROSS-SECTION A-A'
FIGURE 4-1



NOTES: 1) Approximate dips of Deadwood Formation are 15 to the southwest.

WHARF RESOURCES - CLINTON PROJECT
HYDROGEOLOGIC CROSS-SECTION B-B'
FIGURE 4-2



NOTES: 1) Approximate dips of Deadwood Formation are 15 to the southwest.

WHARF RESOURCES - CLINTON PROJECT
HYDROGEOLOGIC CROSS-SECTION C-C'
FIGURE 4-3

permeability of the Precambrian and igneous rock is 1×10^{-5} cm/sec, (2) the effective porosity is 2 percent, and (3) the hydraulic gradient is 0.10, Darcy's law (v=Ki/n) suggests a groundwater velocity of 0.15 feet per day. Darcy's law is not strictly applicable for fracture flow, but provides a reasonable approximation. Velocities will be higher if the effective porosity is less than 2 percent, or less if porosity is greater than 2 percent.

RECHARGE/DISCHARGE

Groundwater recharge and discharge relationships are not well documented within the project area. The project area can be considered a groundwater recharge area, given its high topographic position relative to other areas of the region. As suggested by piezometric contours, Foley Mountain, Bald Mountain, and Green Mountain probably form a regional groundwater divide, with flow north of the ridge draining north and east to Deadwood, False Bottom, and Squaw creeks, and flow south of the divide drained by Annie Creek and Nevada Gulch.

Groundwater recharge within the Clinton project area occurs from the infiltration of precipitation. Groundwater flow into the project area is probably not significant, as the project area is located on a regional groundwater divide. Groundwater discharge occurs to wells, springs, and seeps within the project area. Additional groundwater discharge occurs as groundwater outflow beyond project boundaries and as evapotranspiration.

Studies of the Annie Creek valley (SRK 1986, JMM, 1989) suggest that between 2 and 3 inches (5 to 10 percent of the annual precipitation) is available for infiltration to the Annie Creek groundwater system. Topography and vegetation in the Clinton project area is similar to Annie Creek. Geology is also similar, except that low-porosity Precambrian rocks are more common in the Clinton project area, and the more porous Deadwood Formation sediments are more common in the Annie Creek valley. As a result, the groundwater recharge rate for the Clinton project area is probably slightly less than that for the Annie Creek Valley, and is estimated at 2 inches per year. The project study area covers approximately five square miles, resulting in an average recharge of approximately 500 acre-feet per year.

Groundwater discharge to False Bottom Spring probably averages about 10 gpm on an annual basis. Groundwater discharge as baseflow to Deadwood, Squaw, and False Bottom creeks at the groundwater study area boundaries is considerably more, and might average between 100 and 150 gpm. This 100 to 150 gpm flow would total 160 to 240 acre feet per year, or about one-third to one-half of the estimated annual recharge. Wharf personnel estimate that the production from the wells within the project area averages no more than 20 gpm, or less than 30 acre-feet annually (6 percent of the estimated annual recharge). The remaining groundwater recharge is probably discharged as groundwater flow beyond the study area boundaries or as evapotranspiration within the project area.

SECTION 5

HYDROCHEMISTRY

The following is a discussion of water quality data from the Clinton Project area and surrounding areas. This discussion summarizes the water quality and a description of the chemical characteristics of water in the area, including trilinear diagrams and Stiff plots.

EVALUATION OF WATER QUALITY

Water Quality

The average concentrations of indicator parameters and inorganic constituents in samples of surface water, spring discharge, and groundwater were evaluated to characterize local groundwater chemistry and to determine if any water quality impacts have occurred as a result of past mining operations within the study area. Groundwater chemistry data for the Clinton project area are lacking, therefore many of the sample points examined are located outside the project boundary. However, data from outside areas are useful for comparative purposes. Sample sources that were analyzed are listed below.

- Surface Water: False Bottom Creek No. 1 (east fork)
  False Bottom Creek No. 2 (west fork)
  Deadwood No. 1
  Bald Mountain No. 1

- Springs: Annie Spring
  False Bottom Spring
  Beaver Spring

- Groundwater: Squaw Well
  Squaw Well Shaft
  Two Johns No. 2 Well
  EW-1 (angle hole near MW-22)
  EW-5 (MW-22 borehole prior to well completion)
  Joseph Well, deep
  MW-22
  DT-1
  MW-40
  EW-6 (Clinton Pit Bottom borehole)

Water chemistry data for each group of samples are summarized in Tables 5-1, 5-2, and 5-3. The summarized data represent average values of periodically collected analytical results. The majority of the listed sample points have been analyzed a minimum of eight times. Exceptions include Beaver Spring (5 samples), Squaw Shaft (2 samples), EW-1 (1 sample), EW-5 (1 sample), DT-1 (1 sample), MW-40 (1 sample), and EW-6 (1 sample). Beaver Springs data

TABLE 5-1

AVERAGE SURFACE WATER CHEMISTRY
(Concentrations are mg/l unless otherwise noted)

SITE NAME: PARAMETER	False Bottom Creek No. 1	False Bottom Creek No. 2	Deadwood No. 1	Bald Mountain No. 1
pH	7.11	5.89	6.56	7.08
Temperature (°C)	9.2	8.3	8.1	8.9
Conductance (umhos/cm)	435	144	203	202
Total Dissolved Solids	288	95	144	134
Total Suspended Solids	1	4.1	3.1	5.4
Fluoride	0.48	0.29	0.93	0.27
Nitrate as N	0.67	0.01	0.01	0.01
Total alkalinity as $CaCO_3$	28	4	22	35
Total hardness as $CaCO_3$	179	51	87	90
Calcium	54.8	11.2	22.26	24.45
Magnesium	10	4.0	6.52	5.58
Potassium	6.7	3.2	2.89	3.01
Sodium	11	2.7	3.24	2.07
Bicarbonate as HCO_3	36.8	4.4	27.48	42.81
Carbonate as CO_3	0.0	0.0	0.0	0.0
Chloride	6.3	9.2	3.2	0.6
Sulfate	169.4	38.2	63	58.6
Total Metals				
Arsenic	0.006	0.002	0.001	0.001
Barium	0.097	0.119	0.107	0.08
Cadmium	0.0023	0.0002	0.0004	0.0001
Chromium	0.001	0.001	0.001	0.002
Copper	0.012	0.006	0.007	0.008
Iron	0.78	0.886	1.38	1.09
Manganese	0.09	0.03	0.1	0.01
Zinc	0.058	0.132	0.094	0.078

TABLE 5-2

AVERAGE SPRING WATER CHEMISTRY
(Concentration are mg/l unless otherwise noted)

SITE NAME: PARAMETER	Annie Springs	False Bottom Spring	Beaver Springs	Deadwood Pond
pH	7.3	6.27	7.5	6.25
Temperature (°C)	6	8.5	4.4	8.4
Conductance (umhos/cm)	151	599	360	113
Total Dissolved solids	99	374	204	63
Total Suspended Solids	6.3	3.9	2.4	39.8
Fluoride		0.22	0.15	0.11
Nitrate as N	1.32	1.53	0.8	0.35
Total alkalinity as $CaCO_3$	66	44	203	17
Total hardness as $CaCO_3$		230	204	38
Calcium	22.0	78.3	47.8	10.3
Magnesium	3.0	11.7	21.0	2.8
Potassium	1.5	7.1	0.6	1.1
Sodium	2.5	14.7	2.2	3.3
Bicarbonate as HCO_3	80.0	52.2	247.0	22.0
Carbonate as CO_3	0.0	0.0	0.0	0.0
Chloride	2.5	8.0	1.4	18.1
Sulfate	4.9	225.8	4.7	3.5
<u>Dissolved Metals</u>				
Arsenic	0.059	0.006	0.006	0.012
Barium		0.103	0.088	0.300
Cadmium		0.002	< 0.0005	0.0006
Chromium		0.001	0.002	0.003
Copper	0.014	0.011	0.001	0.012
Iron		0.280	<0.3	1.40
Manganese		0.010		0.06
Zinc	0.022	0.076	0.018	0.082

TABLE 5-3

AVERAGE GROUNDWATER CHEMISTRY
(Concentrations are mg/l unless otherwise noted)

WELL NO.: / PARAMETER	Squaw Well	Squaw Well Shaft	Two Johns No. 2	EW-1 (Deep)	EW-5 (prior to completion as MW-22)	MW-22	Joseph Deep	Joseph Shallow	DT-1	MW-40	EW-6
pH (S.U., field)			7.34	6.49		5.07					
pH (S.U., lab)	7.15	7.44		6.9	4.4		7.34	6.59	6.91	6.62	7.67
Temperature, °C	7.3	8	11.8	11.8		7.3	9	14			
Conductance (umhos/cm, field)			262	249		499					
Conductance (umhos/cm @25°C, lab)	186	200		370	367		253	381	202	106	252
Total dissolved solids (180)	113	124	151	252	278	333	151	237	134	51	121
Fluoride	0.84	1.00	0.8	0.28	0.18	0.15	3.17	0.07	0.813	0.247	1.02
Nitrate as N	1.61	0.79	0.26	0.10	0.13	0.843	0.31	21.76	<0.05	0.583	<0.05
Total alkalinity as $CaCO_3$	83	98	126	44	< 1	19	119	59	46	33.3	115
Total hardness as $CaCO_3$			135	180	143	79.2	125	164		57.4	138
Calcium	25.6	29	42	55	35	58.1	35.6	45.4	17.8	11.3	38
Magnesium	5.05		7.4	10	13	10	9.3	9.4	6.49	3.65	10.1
Potassium	0.85	< 1.00	1	4	6	7.61	1.7	2.4	2.97	1.68	9.92
Sodium	3.2	3.6	2.1	8	9	12.47	4.4	6.4	2.03	10.4	3.5
Bicarbonate as HCO_3	100	120	153	54	0	23.1	143.8	71.6	56.1	40.7	140
Carbonate as CO_3	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0	0	
Chloride	2.4	< 1.0	1.8	4.0	5.0	7.1	0.5	12.3	1	0.5	2.5
Sulfate	2.4	4.1	8.1	149.0	156.0	222.0	16.1	9.9	35	<10	21.2
Dissolved Metals											
Arsenic	0.025	0.019	0.018		< 0.002	0.001	0.010	0.028	0.002	0.005	<0.005
Barium	0.207		0.08		0.111	0.052	0.17	0.32	0.06	0.08	0.145
Cadmium	0.0004	< 0.0005	< 0.0005		< 0.0005	0.001	< 0.0005	< 0.0005	0.001	<0.001	<0.001
Chromium	0.001		< 0.001		< 0.001	0.001	0.002	0.008	<0.001	<0.001	<0.001
Copper	0.01	0.008	0.003		1.279	0.146	0.004	0.014	0.005	0.009	0.05
Iron	0.03	< 0.05	< 0.03			3.63	0.32	0.10	3.38	0.419	0.056
Manganese	0.03	< 0.03	0.02			0.062	0.12		2.35	0.08	1.16
Zinc	0.303	0.155	0.036			0.143	0.054	0.03	0.301	<0.05	<0.05
Total Metals											
Arsenic				0.326		0.002					
Barium				2.2							
Cadmium				0.235							
Chromium				0.235							
Copper				3.355							

after April 1989 was not analyzed because of effects on water quality from mine waste disposal activities in Annie Creek.

Water quality data, averaged over the period of record, are summarized in Tables 5-1 through 5-3. The water quality data are discussed below. For the purpose of this discussion, the sample points have been divided into three groups: (1) sample points west of the study area, (2) sample points within the northern half of the study area, and (3) sample points located within and adjacent to the eastern portion of the study area.

Water Quality West of the Study Area (Annie Creek and Squaw Creek Drainage Basins)

Sample points located west of the study area include two springs (Annie Springs and Beaver Springs) and three deep wells (Squaw Well, Two John No. 2 Well, and Joseph Well, deep. Of these, Annie Springs and Beaver Springs are located within the Annie Creek drainage basin, and the remaining sites are located in the Squaw Creek drainage basin.

Data from these sample points indicate neutral pH. Conductance at Beaver Springs is slightly elevated with average values of 360 μmhos/cm, when compared to the other points which are below 260 μmhos/cm.

Samples obtained from the Squaw Well show an increasing nitrate trend, from an average of less than 1 mg/l nitrate-nitrogen prior to 1989 to a peak of 8 mg/l in 1994. This increasing nitrate trend is attributed to impacts from the Squaw Creek waste rock disposal. In addition to increased nitrate, TDS concentrations at the Squaw Well increased by 25 percent after 1989.

The concentrations of dissolved metals show elevated levels of arsenic at Annie Springs, Squaw Well, and Two Johns No. 2 Well; however, Annie Springs is the only sample location where the average arsenic concentration (0.059 mg/l) exceeds the drinking water standard of 0.050 mg/l. Average arsenic concentrations in groundwater west of the study area ranges from 0.010 mg/l in the deep Joseph Well to 0.028 mg/l at Squaw Well. The average concentrations of arsenic within the northern portion of the Clinton project area and east of the study area are lower than 0.010 mg/l (see Tables 5-1 through 5-3). It is probable that arsenic occurs naturally in groundwater, probably associated with mineralization or with chemistries of the stratigraphic units that exist west of the study area. The remaining average dissolved metal concentrations for sample points west of the study area do not differ significantly and no particular trend can be described with certainty.

Water Quality in the Northern Half of Study Area (False Bottom Creek Drainage Basin)

Sample points located within the northern half of the Clinton project area include two surface water stations (False Bottom Creek No. 1 and False Bottom Creek No. 2), one spring (False Bottom Spring), two boreholes (angle hole EW-1 and vertical borehole EW-5), and one well (MW-22). EW-5 was eventually completed as well MW-22. These sample points are all located within the False Bottom Creek drainage basin.

Averaged data from these sample points indicates relatively neutral pH at False Bottom Creek No. 1 and in EW-1, with values of 7.1 and 6.5, respectively. The pH at False Bottom Creek No. 2, False Bottom Spring, and MW-22 are lower, with average values of 5.9, 6.3, and 5.1, respectively. (A single sample from EW-5 had a laboratory pH of 4.4, but actual pH at this location is probably more correctly reflected by field measurements at MW-22.)

Except for the conductance at False Bottom Creek No. 2 (144 µmhos/cm), conductance is elevated relative to the average for the project area, at all of these sample points (ranging from 367 µmhos/cm at EW-5 to 599 µmhos/cm at False Bottom Spring). Average TDS and sulfate concentrations exceed 250 and 145 mg/l, respectively, at False Bottom Creek No. 1, False Bottom Spring, EW-1, EW-5, and MW-22. The highest average TDS and sulfate concentrations occur at False Bottom Spring and MW-22, with TDS concentrations of 374 and 333 mg/l and sulfate concentrations of 226 and 22 mg/l, respectively.

Generally, the dissolved metal concentrations in the north half of the study area are not significantly different from those west of the study area (described above), except the average arsenic concentrations are much lower. However, the dissolved copper concentration at EW-5 (1.28 mg/l) is two to three orders of magnitude higher than copper concentrations reported for most of the other sample points that are examined herein. Again, this is a single EW-5 sample and may not be indicative of actual conditions as MW-22 average concentration for dissolved copper is 0.146 mg/l, which is elevated by about one order of magnitude compared to the other sample points. The sample from EW-1 was analyzed for total recoverable metals rather than dissolved metals. Although total and dissolved metals cannot be directly correlated, data from EW-1 suggest that copper is also elevated at this site. This result is consistent with the finding at EW-5 / MW-22.

Total cyanide has been detected in samples from False Bottom No. 1, False Bottom Spring, and MW-22, with average concentrations of 0.004, 0.019, and 0.014 mg/l, respectively. Two of sixteen samples from False Bottom Spring had detectable (0.02 mg/l) WAD cyanide. The source of cyanide is suspected to be the Bald Mountain mill tailings. No WAD cyanide was detected at the other sample sites in the area.

Water Quality in the Eastern Portion of the Study Area (Deadwood Creek Drainage Basin)

Sample points located within and adjacent to the eastern portion of the study area include groundwater from monitor well MW-40 and borings DT-1 and EW-6, and surface water sample sites Deadwood No. 2 and Bald Mountain No. 1. These sample points are located within the Deadwood Creek drainage basin.

Data from these sample points indicate pH values between 6.5 and 7.7 and conductance at each site is less than 260 µmhos/cm. The average TDS concentrations at Deadwood No. 1 and Bald Mountain No. 1 are 144 and 134 mg/l. The single samples from MW-40, DT-1, and EW-6 had a TDS concentrations of 51, 134, and 121 mg/l, respectively.

In general, the average dissolved metals concentrations from these sites do not differ significantly from those west of the study area, except arsenic concentrations which are less than

0.005 mg/l. An exception to this is elevated levels of iron and manganese at some sites. In particular, the single sample from DT-1 had 3.38 mg/l iron and 2.35 mg/l manganese and the single sample from EW-6 had 1.16 mg/l manganese.

EVALUATION OF HYDROCHEMISTRY

The average concentrations of major inorganic cations and anions in water samples from the study area were evaluated to compare the chemical composition of water at all of the sample points listed previously, except Squaw Well Shaft. Data from Squaw Well Shaft could not be examined in this analysis because the sample was not analyzed for magnesium, a major cation used for characterizing and comparing water chemistries.

The major-ion chemistry of the selected sample points was evaluated by the following methods:

- Ionic charge balances,
- Trilinear diagrams, including identification of hydrochemical facies
- Stiff diagrams.

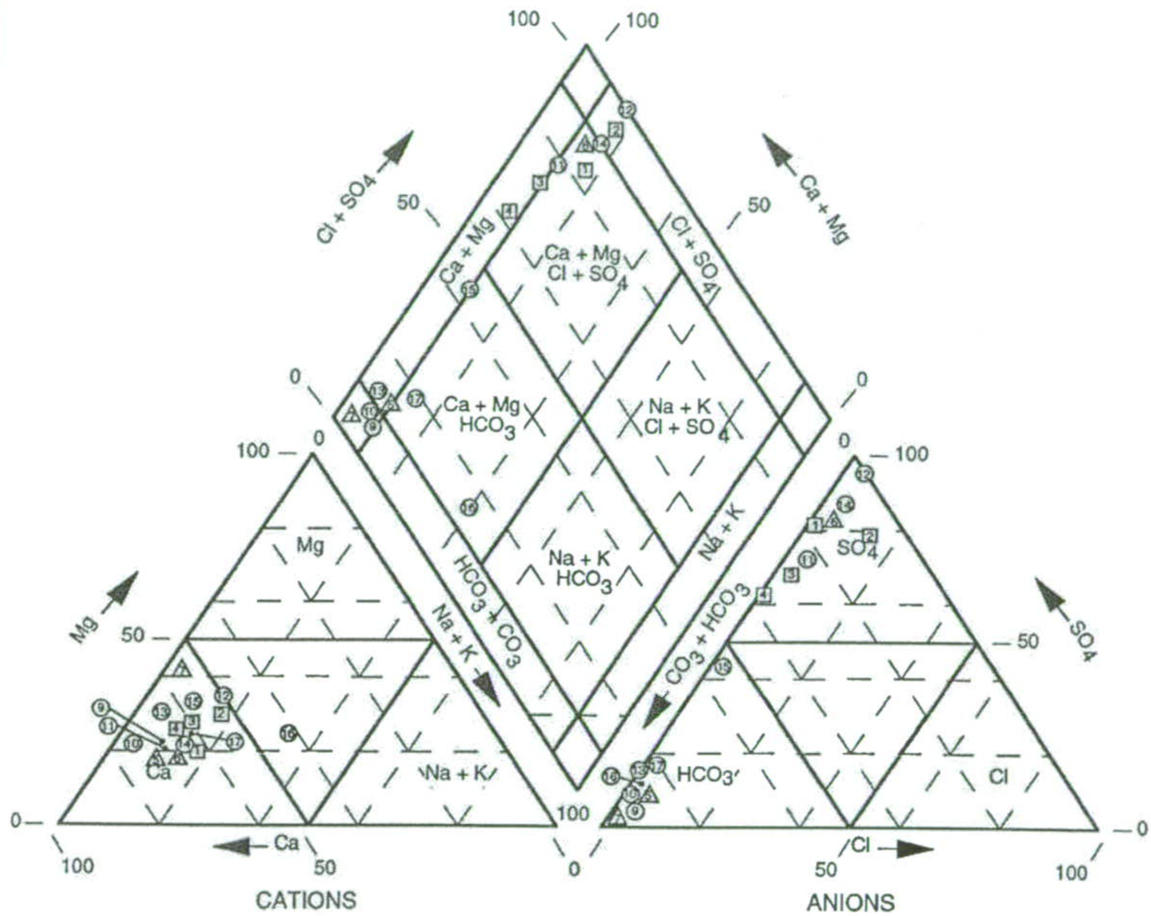
These methods are useful for determining the geochemical water type present at each sampling point, and provide a basis for grouping various waters according to chemical composition.

Ionic Charge Balances

The ionic charge balance calculations are summarized in Table 5-4. The goal of a major-ion analysis is to categorize waters from various sources based on cation/anion distributions. Generally, ionic charge balance differences within about 10 percent are adequate for this purpose. Sample results with differences greater than 10 percent, however, must be interpreted carefully; differences greater than 20 percent can lead to significant error or uncertainty in the interpretation of geochemical data. The ionic charge balance calculations for the selected sample points are summarized on Table 5-4. All sample points show differences between cation and anion composition that are less than 14 percent (Table 5-4), except for MW-40 and EW-6. Differences between cation and anion composition for the single sample from MW-40 was 25 percent. As a result, the single sample from MW-40 is not suitable for significant geochemical interpretation.

Identification of Hydrochemical Facies

The geochemical data for the sample sources listed above were plotted on a trilinear diagram and on Stiff diagrams. These plots are presented in Figures 5-1 and 5-2. Trilinear diagrams and Stiff plots illustrate differences in major-ion chemistry in groundwater flow systems and can be used to correlate water compositions to identifiable groups, or hydrochemical facies.

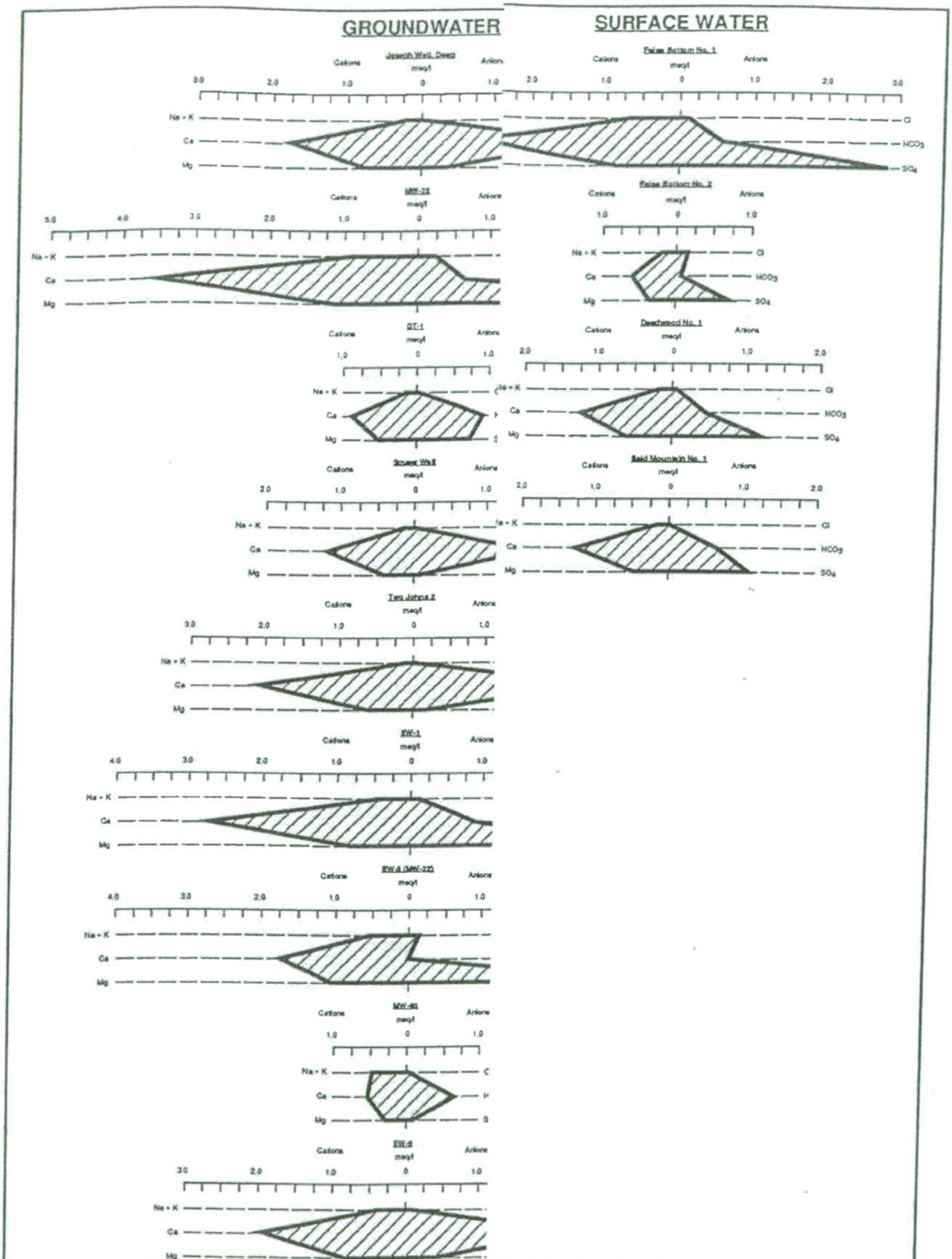


LEGEND

SPRINGS	SURFACE WATER	GROUNDWATER	
5 Annie Springs	1 False Bottom No. 1	9 Squaw Well	13 Joseph Well, Deep
6 False Bottom Spring	2 False Bottom No. 2	10 Two Johns 2	14 MW-22
7 Beaver Springs	3 Deadwood No. 1	11 EW-1	15 DT-1
	4 Bald Mountain No. 1	12 EW-5 (MW-22)	16 MW-40
			17 EW-6

TRILINEAR ION DISTRIBUTON

FIGURE 5-1



VHARF RESOURCES - CLINTON PROJECT
STIFF DIAGRAMS
FIGURE 5-2

TABLE 5-4

IONIC CHARGE BALANCES

Data Source	Total Cations (meq/l)	Total Anions (meq/l)	Percent Difference[a]
Surface Water			
False Bottom Creek No. 1	4.34	3..49	9.6
False Bottom Creek No. 2	1.18	0.85	13.7
Deadwood No. 1	1.91	1.54	10.9
Bald Mountain No. 1	1.89	1.67	6.0
Springs			
Annie Springs	1.49	1.51	0.5
False Bottom Spring	5.70	5.82	1.0
Beaver Springs	4.22	4.21	0.2
Groundwater			
Squaw Well	1.86	1.83	0.6
Two Johns No. 2	2.82	2.77	0.9
EW-1	4.02	4.12	1.2
EW-5 (MW-22)	3.36	3.40	0.6
Joseph Well, deep	2.79	2.88	1.6
MW-22	4.59	5.22	6.5
DT-1	1.71	1.72	0.4
MW-40	1.37	0.81	26.0
EW-6	3.13	2.86	4.6

[a] Percent different = [(C-A/(C+A)] x 100 where C = sum of cations in meq/l and A = sum of anions in meq/l.

The data presented in Figures 5-1 and 5-2 show two dominant chemical groups: (1) calcium bicarbonate water, and (2) calcium sulfate water. Table 5-5 summarizes these chemical categories, grouping water from each sample point. The categories shown on Table 5-5 are based on information shown on Figures 5-1 and 5-2. Calcium-bicarbonate chemistry is shown by samples from sources west of the Clinton project area. Calcium-sulfate chemistry is shown by samples from sample points near the east boundary of the Clinton project area and within the northern half of the area. Exploration boring DT-1 and Bald Mountain No. 1 surface water site both show characteristics of a mixture of both water types, with similar amounts of sulfate and bicarbonate.

TABLE 5-5

HYDROCHEMICAL FACIES IDENTIFIED
IN STUDY AREA

Hydrochemical Facies	Surface Water	Springs	Groundwater
Calcium-bicarbonate	None	Annie Springs Beaver Springs	Squaw Well Two Johns No. 2 Well Joseph Well, deep DT-1, EW-6, MW-40
Calcium-sulfate	False Bottom Creek No. 1 False Bottom Creek No. 2 Deadwood No. 1 Bald Mountain No. 1	False Bottom Spring	EW-1 EW-5 MW-22

The calcium-bicarbonate hydrochemical facies generally occurs within the area underlain by the Deadwood Formation and felsic intrusives (dacite, rhyolite, and monzonite). The calcium-sulfate hydrochemical facies occurs within the area where Precambrian rocks (mostly phyllites and schists) are present at the surface and at depth. Groundwater and surface water in the Squaw Creek drainage basin are of the calcium-bicarbonate hydrochemical facies, reflecting flow of these waters within the Deadwood Formation and igneous intrusives. Groundwater and surface water within the False Bottom Creek and the Deadwood Creek drainage basins are of the calcium-sulfate hydrochemical facies, possibly reflecting flow of these waters through the Precambrian rocks. Thus, two principal geochemistries exist beneath the project area.

SUMMARY OF EXISTING IMPACTS TO GROUNDWATER QUALITY

False Bottom Creek Drainage

Sample points located within the False Bottom Creek drainage show some indications of minor impacts to the natural water quality. Impacts to water quality are indicated by relatively high TDS and detections of total cyanide at False Bottom Spring, MW-22, EW-1, and False Bottom No. 1. The elevated TDS impacts are suggestive, and cannot be described with certainty.

The most visible source of potential groundwater chemistry impacts in the False Bottom Creek drainage is the Bald Mountain tailing impoundment. The tails were investigated by Wharf in 1990 and 1996 Analysis of tailing samples from test borings showed a relatively low potential for generation of metal bearing leachate, as average concentrations of metals (As, Ba, Cd, Cr, Pb, Hg, Se, and Ag) in TCLP extract samples were less than maximum allowable levels. Elevated concentrations of these parameters were not detected in the down-gradient monitor well MW-22, suggesting that there is not a significant plume of degraded groundwater immediately down-gradient of the tails at MW-22. Furthermore, investigation of the tails in 1996 found that the average pH of the materials at the bottom of the tailing impoundments is 9.5. This high pH suggests little potential for the generation of acidic leachate that might tend to mobilize metals.

Low pH at some of the sample sites in the False Bottom drainage are believed to be the result of natural weathering of pyrite-bearing Precambrian rock, rather than mining related impacts. False Bottom Creek No. 2, False Bottom Spring, and MW-22 have average pH values of 5.89, 6.27, and 5.07, respectively. Most noticeable is the low pH at MW-22. MW-22 was drilled adjacent to a zone of pyritic Precambrian phyllite. The pyritic rock was encountered in nearby exploration angle hole EW-1. The pH at MW-22 dropped from an average of 5.9 in 1991-92 to an average of 4.0 in 1996. At the same time, alkalinity decreased from an average of 34 mg/l to zero, TDS decreased from an average of 462 mg/l to an average of 173 mg/l. Iron, aluminum, and copper increased erratically during the same period. This change in chemistry is believed to be the result of fresh oxygen-bearing surface water infiltrating to the unoxidized Precambrian rock. The contact of the fresh water results in the rapid weathering of exposed pyrite minerals, and the subsequent release of acidity and metals. It is not clear if the pathway for the fresh water is along naturally occurring fractures in the rock or along the borehole walls of MW-22 (EW-5) or EW-1.

Squaw Creek Drainage

Impacts to groundwater quality are apparent at the Squaw Well, where nitrate-nitrogen increased from less than 1 mg/l prior to 1990 to 8 mg/l in 1994. These impacts are attributed to waste rock disposal at the Squaw Creek Waste Rock Disposal Facility.

SECTION 6

PROJECTED IMPACTS TO GROUNDWATER RESULTING FROM THE CLINTON PROJECT

POTENTIAL IMPACTS TO GROUNDWATER HYDROLOGY

Pit Inflow

Significant groundwater inflows are not anticipated at proposed mine pits because of (1) the relative absence of groundwater in exploration drill holes, (2) the measured static water levels in local wells, (3) the low permeability of the rock underlying the pit areas, and (4) the upland location of the pits. The pit bottom elevations for the Portland and Trojan pits are anticipated to be approximately 6280 and 5920, respectively. As such, the Portland Pit will certainly be well above the level of the regional water-table. Portions of the Trojan pit may penetrate the water table. However, inflows are anticipated to be limited because (1) no water producing zones were encountered during exploration drilling, (2) underground workings at elevations ranging from about 5900 to 6000 feet in the same area are reportedly dry, and (3) low-permeability igneous and metamorphic rocks inhibit upward movement of groundwater from deep confined zones. In addition, the Trojan Pit is not surrounded by a significant area of high permeability saturated rock which would contribute large, sustained inflows to a pit. In other words, the Trojan Pit may penetrate into the top of a groundwater recharge area that peaks near Green and Foley Mountains, but local experience suggests that pit inflow will be limited.

Recharge

The proposed project is not likely to have a substantial impact on groundwater recharge and discharge in the project area. Potential impact areas consist of the Bald Mountain Mill tailings and the two mine pits. The remainder of the study area will be unchanged by the project.

The recharge characteristics of the waste disposal facility / Bald Mountain tailings are not anticipated to change significantly. Any change will probably result in a slight increase in recharge rate, because the waste rock materials will tend to allow a faster rate of infiltration during storm events; thus, waste disposal facility runoff will decrease and recharge rate may increase. However, the overall change in recharge rate is not anticipated to be significant.

The recharge characteristics of the pit areas will change. The pits will contain all runoff. Evapotranspiration is anticipated to decrease due to reduction of vegetative cover. As a result, net recharge may increase after the end of mining (provided that runoff will infiltrate rather than pool and evaporate). During mining, any pooled runoff will probably be pumped out and land applied or utilized for dust abatement or process water.

Discharge

Groundwater discharge rates are not anticipated to increase as a result of mining activities. This assumes that significant pit inflows do not occur and that additional water supply wells are not constructed. Additional water supply wells completed in the project area are not anticipated because (1) difficulty in constructing high capacity wells in the project area (due to low aquifer permeabilities) and (2) sufficient water supply is present from wells at the existing mine site.

POTENTIAL IMPACTS TO GROUNDWATER QUALITY

Pits

Groundwater quality impacts related to the pits would result if incident precipitation (snow and rain) leaches metals and other ions into solution from exposed rock surfaces in the pit prior to infiltrating to the groundwater system. The most common mechanisms for mine pit related groundwater quality impacts is acid rock drainage, resulting from oxidation of sulfide minerals by aerated surface waters. These oxidation mechanisms typically result in low pH and alkalinity, and high concentrations of sulfate, metals, and other ions. Acid rock drainage mechanisms are not anticipated to result in significant water quality impacts in the Clinton Project area because of the oxidized nature of the ore being mined. These oxide ores have very low concentrations of sulfide minerals and relatively high neutralization potentials. As a result, mineral oxidation processes associated with mine pits will probably not significantly impact water quality. Any areas of the pits that encounter unoxidized pyritic rock will be backfilled or covered with waste material that has a high neutralization potential.

Waste Rock Disposal

Impacts to groundwater quality resulting from waste rock disposal may be similar to the groundwater impacts detected from the existing waste rock facilities at the Wharf Mine. Examples of these impacts are demonstrated by groundwater monitoring at Beaver Spring (Reliance Waste Disposal Facility) and the Squaw Well (Squaw Creek Waste Disposal Facility). Nitrate-nitrogen levels in groundwater discharging to Beaver Spring increased from an average of about 0.8 mg/l prior to Reliance waste disposal activities to a peak of 26.2 mg/l in 1996. Nitrate concentrations in samples from the Squaw Well increased from less than 1 mg/l to a peak of 8.3 mg/l in 1994. The source of this nitrate is attributed to residual ammonium nitrate blasting agent contained in the waste rock. In addition to nitrate increases, Beaver Spring and the Squaw Well experienced minor increases in TDS.

Given these experiences, it is possible that an increase in nitrate may occur below the proposed waste rock depository at False Bottom Creek due to groundwater recharge by precipitation that has leached through the waste rock. The magnitude of increase in nitrate will likely be less than experienced at Beaver Spring and Squaw Well because of changes in blasting practices used at the Wharf mine. These changes have resulted in greater blasting efficiency and significantly less residual ammonium nitrate in the waste rock. Greater increases are expected in the shallow groundwater discharging at False Bottom Spring than are expected in the deeper groundwater at well MW-22. Groundwater and surface water standards are not expected to be exceeded.

A significant increase in groundwater TDS below the waste facility is not anticipated because the ambient TDS at MW-22 and False Bottom Spring is already relatively high, averaging about 400 mg/l.

As with the pit surfaces, acid rock drainage problems are not anticipated from the waste rock because of low sulfide concentrations and high neutralization potential.

Bald Mountain Mill Tailings

Additional groundwater impacts, not presently occurring, resulting from the existing Bald Mountain Mill tailings are not anticipated because the pH of the water infiltrating through the waste rock and tailings is anticipated to be basic. As such, the infiltrating water will tend to be less likely than normal precipitation (generally neutral to slightly acidic) to leach residual metals from the tails.

POTENTIAL IMPACTS TO LOCAL WATER SUPPLIES

Based on the analyses presented above, the project is not anticipated to adversely effect water supply or water quality for Terry Peak snowmaking or local drinking water wells. No impacts to water supplies of Lead or Deadwood nor residential or commercial wells near the project area are anticipated.

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WHARF RESOURCES, LEAD SD, ANNIE CREEK/FOLEY RIDGE MINE
GROUNDWATER DATA

SAMPLE STATION: MW-22

DATE	pH	Temp (C)	EC umho cm	STATIC H2O LEVEL ft	TDS mg/l	TSS mg/l	Hardness mg/l	ALKAL CACO3	HCO3 mg/l	CO3 mg/l	Cl mg/l	TOT CN mg/l	WAD CN mg/l	F mg/l	NH4 mg/l	NO3 mg/l	NO2 mg/l	SO4 mg/l	MAJOR ANIONS %	MAJOR CATION %	CATION ANIONS DIFF %
08/26/91	6.02	7.00	574	14.01	410				41.5	0.0	6.5	<0.010		0.153	0.681	0.944	<0.050	220	5.52	5.25	-2.49
02/04/92	5.75	6.00	589	15.94	403			30	36.6	0.0	9.5	0.023	<0.010	0.138	<0.050	1.780	<0.050	247	6.14	5.93	-1.74
04/30/92	5.94	10.00	640	9.17	454			28	34.2	0.0	7.5	0.020	<0.010	0.151	<0.050	2.300	<0.050	254	6.23	6.56	2.61
05/29/92	6.03	8.00	754	9.35	576			40	48.8	0.0	15.0	<0.010	<0.010	0.178	<0.050	1.750	<0.050	331	8.24	7.76	-3.04
08/24/92	5.90	6.70	650	14.40	466			38	46.4	0.0	8.5	0.023		0.155	<0.050	0.814	<0.050	272	6.72	6.83	0.76
06/28/96	3.86	7.00	351	2.20	188	716.0	80.3		0.0	0.0	4.5	0.024	<0.010	0.081	0.076	<0.050	<0.050	284			
07/24/96	4.03	7.00	344	5.40	180	109.0	76.0	0	0.0	0.0	4.0	0.017	<0.010	0.167	0.057	<0.050	<0.050	126			
08/19/96	4.27	7.00	230	6.89	152	89.0	78.0	0	0.0	0.0	4.5	<0.010		0.169	0.053	<0.050	<0.050	128	2.80	3.10	5.08
09/18/96	3.84	7.00	357	7.94	171	48.0	82.4	0	0.0	0.0	4.0	0.017	<0.010	0.157	0.062	<0.050	<0.050	138	2.99	2.99	0.00
10/07/96	3.69	7.00	352	8.52	171	82.0	83.7	0	0.0	0.0	5.5	0.019	<0.010	0.120	<0.050	<0.050	<0.050	131	2.89	2.63	-4.68
MAX	6.03	10.00	754	15.94	576	716.0	83.7	40	48.8	0.0	15.0	0.024	0.000	0.178	0.681	2.300	0.000	331	8.24	7.76	5.08
MIN	3.69	6.00	230	2.20	152	48.0	76.0	0	0.0	0.0	4.0	0.000	0.000	0.081	0.000	0.000	0.000	126	2.80	2.63	-4.68
AVE	4.93	7.27	484	9.38	317	208.8	80.1	17	20.8	0.0	7.0	0.014	0.000	0.147	0.093	0.759	0.000	213	5.19	5.13	-0.44
GW Stand	6.5-8.5				1000						250		0.75	2.4		10	1	500			

DATE	Diss. Al mg/l	Diss. As mg/l	Diss. Ba mg/l	Diss. Be mg/l	Total B mg/l	Diss. Cd mg/l	Diss. Ca mg/l	Diss. Cr mg/l	Diss. Cu mg/l	Diss. Au mg/l	Diss. Fe mg/l	Diss. Pb mg/l	Diss. Mg mg/l	Diss. Mn mg/l	TOT Hg mg/l	Diss. Mo mg/l	Diss. Ni mg/l	Diss. K mg/l	Diss. Se mg/l	Diss. Si mg/l	Diss. Ag mg/l	Diss. Na mg/l	Diss. V mg/l	Diss. Zn mg/l
08/26/91	0.077	<0.010	0.058	<0.001	0.045	0.001	67.3	<0.001	0.079	0.002	1.79	<0.001	12.9	0.047	0.0002	<0.001	0.006	7.50	<0.005	8.38	<0.001	14.60	0.011	0.051
02/04/92	0.019		0.042	<0.001	0.108	<0.001	75.0	<0.001	0.077	<0.001	1.18	<0.001	14.3	0.024	0.0002	0.007	<0.001	7.90	<0.005	8.45	<0.001	18.60	0.019	0.157
04/30/92	0.017	<0.010	0.049	<0.001	0.115	0.001	90.0	<0.001	0.026	<0.001	0.09	0.004	13.3	0.043	<0.0002	<0.001	0.003	7.19	0.005	5.05	0.002	18.20	0.014	<0.050
05/29/92	0.012	0.009	0.053	<0.001	0.050	<0.001	107.0	0.009	0.013	<0.001	0.27	0.008	14.2	0.025	<0.0002	<0.001	<0.001	16.00	<0.005	6.13	0.001	19.30	0.019	0.050
08/24/92	0.032	<0.010	0.068	<0.001	0.142	<0.001	96.1	<0.001	0.014	0.002	0.24	<0.001	11.6	<0.050		0.004	0.002	8.31	<0.005	6.35	0.001	19.90	0.025	<0.050
06/28/96	2.140	<0.005		<0.001		0.003	22.6	<0.001	0.476	0.003	13.90	<0.001	5.8		0.0018		0.011	4.94	<0.005		0.003	4.90		0.132
07/24/96	2.010	<0.005		<0.001		0.002	21.1	<0.001	0.142	0.002	14.60	<0.001	5.7	0.180	0.0006		<0.005	5.34	<0.005		<0.001	5.83		0.098
08/19/96	0.095	<0.005	0.082	<0.001	0.033	<0.001	22.0	<0.001	<0.005	0.003	<0.050	<0.001	5.6	<0.050	<0.0002	0.003	<0.005	5.65	<0.005	8.48	<0.001	5.44	<0.001	<0.050
09/18/96	2.610	<0.005	0.015	<0.001	0.062	0.002	21.8	<0.001	0.487	<0.001	0.63	0.001	6.8	0.178	<0.0002	<0.001	0.025	5.65	<0.005	<1.00	<0.001	5.47	<0.001	0.795
10/07/96	1.960	<0.005	0.024	<0.001	<0.050	0.003	23.6	<0.001	0.277	<0.001	5.00	0.001	6.0	0.158	<0.0002	<0.001	0.028	5.68	<0.005	21.60	<0.001	18.50	0.003	0.348
MAX	2.610	0.009	0.082	0.000	0.142	0.003	107.0	0.009	0.487	0.003	14.60	0.008	14.3	0.180	0.0018	0.007	0.028	16.00	0.005	21.60	0.003	19.90	0.025	0.795
MIN	0.012	0.000	0.015	0.000	0.000	0.000	21.1	0.000	0.000	0.000	0.00	0.000	5.6	0.000	0.0000	0.000	0.000	4.94	0.000	0.00	0.000	4.90	0.000	0.000
AVE	0.897	0.001	0.049	0.000	0.069	0.001	54.7	0.001	0.159	0.001	3.77	0.001	9.6	0.073	0.0003	0.002	0.008	7.42	0.001	8.06	0.001	13.07	0.011	0.163
GW Stand		0.050	2.0			0.005		0.10	1.3			0.015			0.002				0.050		0.050			

DATE	Gross Alpha pCi/l	Radium 226 pCi/l	Radium 228 pCi/l	Rn222 pCi/l	Uranium pCi/l
05/29/92	2.4 +\- 2.6	<0.02 +\-	<1.0 +\-	2387 +\- 61.8	<0.0003
GW Stand	15	5	5		0.02

Wharf Resources, Lead, SD Annie Creek/Foley Ridge Mine
Surface Water Data

SAMPLE STATION False Bottom Spring

DATE	pH	Temp (C)	EC umho cm	FLOW RATE g/min	TDS mg/l	F mg/l	NH4 mg/l	NO3 mg/l	NO2 mg/l	TOTAL ALKAL CACO3	TOTAL HARD CACO3	TOT CN mg/l	WAD CN mg/l	TSS mg/l	CATIONS Ca mg/l	Mg mg/l	K mg/l	Na mg/l	ANIONS HCO3	CO3 mg/l	Cl mg/l	SO4 mg/l	MAJOR CATION %	MAJOR ANIONS %	CAT-AN DIFF. %
06/27/90	5.89	8.0	617	10.00	410	0.12	<0.01	1.55	<0.01	43	256		<0.010		82.0	13.0	5.0	14.0	52.0	0.0	7.0	229.0	5.85	5.92	0.59
07/30/90	5.86	16.0	583		390	0.28	0.02	1.55	<0.01	44	245		0.020	<1.0	82.0	10.0	7.0	15.0	54.0	0.0	5.0	222.0	5.74	5.75	0.09
08/27/90	5.99	16.0	553		425	0.16	<0.01	1.61	<0.01	44	242		<0.010	<1.0	79.0	11.0	7.0	15.0	53.0	0.0	6.0	221.0	5.66	5.76	0.88
10/20/90	5.62	14.0	560		408	0.12	<0.01	1.67	<0.01	39	238		0.020	1.2	78.0	11.0	7.0	13.0	47.0	0.0	7.0	208.0	5.49	5.41	0.73
12/01/90	5.77	0.5	515		373	0.22	<0.01	1.82	<0.01	34	223		<0.010	4.8	74.0	9.0	8.0	17.0	41.0	0.0	7.0	214.0	5.37	5.47	0.92
06/07/91	6.60	4.0	816	15.00		0.32	0.07	1.80	<0.05				<0.010		85.1	16.6	6.8	12.7	26.8	0.0	9.5	280.0	6.34	6.68	-2.61
08/26/91	6.55	7.0	609	17.87		0.16		1.53	<0.05			0.026	<0.010		38.3	11.2	7.0	15.1	53.7	0.0	7.5	220.0			
01/27/92	6.13	4.0	588	1.00	363	0.16		1.79	<0.05	38		<0.010			72.3	15.0	6.9	16.0	46.4	0.0	8.5	217.0	5.71	5.65	0.57
04/30/92	6.33	9.0	551	30.00	382	0.23		1.19	<0.05	42		0.016	<0.010	<10.0	74.2	10.9	8.3	15.0	51.2	0.0	10.0	197.0	5.46	5.32	1.36
05/29/92	6.31	5.0	707		493	0.18		1.84		46		0.025	<0.010	<10.0	103.0	13.7	9.4	16.9	56.1	0.0	11.5	277.0	7.24	7.15	0.67
08/24/92	6.23	7.7	560		428	0.15		1.90		48		0.022		<10.0	82.8	12.0	7.1	17.3	58.6	0.0	8.5	236.0	6.05	6.25	-1.63
05/19/93	6.60		730		385	0.33	<0.05	2.18	<0.050	46		0.040		<10.0	104.0	12.0	8.4	15.6	56.1	0.0	10.5	281.0	7.07	7.23	
01/27/95	6.78		548		281			1.24	<0.050	46		0.017	<0.010	<10.0	77.8	10.1	6.1	14.6	56.1	0.0	5.5	197.0	5.50	5.26	2.26
04/28/95	6.24		615			0.28		1.17	<0.050	56		0.02	<0.010	10	84.0	12.6	6.8	14.2	68.3	0.0	8.5	237	6.02	6.39	-2.98
05/15/96	6.52	8.0	584		313	0.35	<0.05	0.96	<0.050	45	232	0.023	<0.010	<10.0	75.6	10.4	7.1	13.6	55.2	0.0	9.0	214.0	5.40	5.70	-2.67
8/19/96	6.97	11.0	450		216	0.20	<0.05	0.76	<0.050	49	177	<0.010		31.0	59.9	8.5	5.9	10.6	59.1	0.0	7.0	162.0	4.30	4.60	-3.37
9/25/96	6.53	3.0	453	10.00	218	0.19	<0.05	0.89	<0.050	47	176	0.016	<0.010	38.0	56.5	8.6	5.9	7.8	57.1	0.0	7.0	149.0	4.02	4.31	-3.5
10/3/96	6.38	9.0	458	15.00	221	0.16	<0.05	0.92	<0.050	45	206	0.014	<0.010	<10	68.2	8.6	6.1	5.8	54.9	0.0	6.0	169.0	4.52	4.66	-1.55
MAX	6.97	16.0	816	30.00	493	0.35	0.07	2.18	0.00	56	256	0.040	0.020	38.0	104.0	16.6	9.4	17.3	68.3	0.0	11.5	281.0	7.24	7.23	2.26
MIN	5.62	0.5	450	1.00	216	0.12	0.00	0.76	0.00	34	176	0.000	0.000	0.0	38.3	8.5	5.0	5.8	26.8	0.0	5.0	149.0	4.02	4.31	-3.50
AVE	6.29	8.1	583	14.12	354	0.21	0.01	1.47	0.00	44	222	0.019	0.003	6.1	76.5	11.3	7.0	13.8	52.6	0.0	7.8	218.3	5.63	5.74	-0.64
SW Stand	6.0-9.0							87.5/50				0.02		157.5/90							100				

DATE	TOT Al mg/l	TOT As mg/l	TOT Ba mg/l	TOT Be mg/l	TOT B mg/l	TOT Cd mg/l	TOT Cr mg/l	TOT Cu mg/l	TOT Au mg/l	TOT Fe mg/l	TOT Pb mg/l	TOT Mn mg/l	TOT Hg mg/l	TOT Mo mg/l	TOT Ni mg/l	TOT Se mg/l	TOT Si mg/l	TOT Ag mg/l	TOT V mg/l	TOT Zn mg/l
06/27/90													<0.0002							
07/30/90	0.290	0.011	0.131		0.190	<0.0005	<0.001	0.018		0.59	<0.005	0.03	<0.0002	<0.020	0.008	<0.002	7.22	<0.0002	<0.10	0.036
08/27/90	<0.100	0.008	0.117		0.090	<0.0005	<0.001	0.002		0.09	<0.005	<0.01	<0.0002	<0.020	0.004	<0.002	5.57	<0.0002	<0.10	0.031
10/20/90	<0.100	<0.002	0.115		0.120	<0.0005	<0.001	<0.001		0.06	<0.005	<0.01	<0.0002	<0.020	0.004	<0.002	7.83	<0.0002	<0.10	0.007
12/01/90	0.180	<0.002	0.107		0.090	<0.0005	<0.001	0.002		0.06	<0.005	<0.01	<0.0002	<0.020	0.006	<0.002	6.58	<0.0002	<0.10	0.009
06/07/91	0.036	0.007	0.117		0.084	<0.001	0.005	0.013		0.12	0.001	0.01	<0.0002	0.009	0.008	<0.005	6.90	0.0010	0.016	0.054
08/26/91		0.017	0.094			<0.001	0.002	0.011		0.36			<0.0002			<0.005		<0.001		<0.05
01/27/92		0.002				<0.001	<0.001	0.026		0.05			<0.0002			<0.005		<0.001		0.146
04/30/92		0.007	0.072			0.0290	0.001	0.049		2.37	0.009	0.02	<0.0002			<0.005		0.0070		0.175
05/29/92		0.001	0.100			<0.001	0.002	0.003		0.14	0.007	0.00	<0.0002			<0.005		0.0010		0.071
08/24/92		0.006	0.094			<0.001	0.002	0.025		0.11	<0.001	0.01	<0.0002			<0.005		0.0020		0.400
05/19/93	0.118	0.019	0.103	<0.001		<0.001	<0.001	<0.001	<0.001	<0.05	<0.001	<0.05	<0.0002	0.002		<0.005		<0.001		0.103
01/27/95		<0.001	0.099			0.0010	0.001	0.010	<0.001	0.05	0.007	<0.050	<0.0002			<0.005		0.0020		0.050
04/28/95		0.011	0.12			<0.001	<0.001	<0.005	0.001	0.06	<0.001	<0.050	<0.0002			<0.005		<0.001		<0.050
05/15/96	0.192	<0.005	0.087	<0.001		<0.001	<0.001	<0.005	0.002	0.08	<0.001	<0.050	<0.0002		<0.005	<0.005		0.0020		<0.050
8/19/96	0.555	<0.005	0.078	<0.001	0.012	0.0010	<0.001	<0.005	<0.001	0.06	<0.001	<0.050	<0.0002	<0.001	<0.005	<0.005	8.78	<0.001	<0.001	0.058
9/25/96	0.107	0.011	0.082	<0.001	0.287	<0.001	0.001	0.015	0.004	0.30	0.003	<0.05	<0.0002	<0.001	0.006	<0.005	11.60	<0.001	<0.001	0.059
10/3/96	0.192	<0.005	0.095	<0.001	0.174	0.0010	0.001	<0.005	<0.001	0.07	<0.001	<0.05	<0.0002	<0.001	0.006	<0.005	10.90	<0.001	<0.001	0.056
MAX	0.555	0.019	0.131	0.000	0.287	0.0290	0.005	0.049	0.004	2.37	0.009	0.03	0.0000	0.009	0.008	0.000	11.60	0.0070	0.016	0.400
MIN	0.000	0.000	0.072	0.000	0.012	0.0000	0.000	0.000	0.000	0.00	0.000	0.00	0.0000	0.000	0.000	0.000	5.57	0.0000	0.000	0.000
AVE	0.167	0.006	0.101	0.000	0.131	0.0019	0.001	0.010	0.001	0.27	0.002	0.00	0.0000	0.001	0.005	0.000	8.17	0.0009	0.002	0.074
SW Stand		0.3325				0.10/0.05		0.30/0.15			0.60/0.30		0.002/0.001			0.00875				1.50/0.75