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A PROPOSAL FOR A HYDROGEOLOGIC STUDY OF THE WATER RESOURCES OF GOLD CREEK BASIN, JUNEAU, ALASKA

by

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INTRODUCTION

The City and Borough of Juneau (CBJ) water system derives most of its water from the Last Chance Basin well field located in the Gold Creek watershed (figs. 1 and 2). This well field is CBJ's only dependable year-round water supply. Because of its importance in meeting CBJ's water needs, any proposed industrial development near or within the Gold Creek watershed requires careful evaluation for its potential effects on ground waters In the Gold Creek drainage system. Such evaluations can only be done satisfactorily with detailed hydrological and geological data. This project is designed to obtain, evaluate, manage and disseminate these data to increase our understanding of the hydrogeologic conditions in the Gold Creek drainage basin.

The primary goals of this study are to: 1) collect hydrologic data from all source areas within the Gold Creek drainage basin; 2) expand the baseline of water chemistry data, and use these data to identify and track possible contamination; 3) develop both a conceptual and a computer model of the sources and areas of basin recharge: 4) use the water chemistry and hydrologic data to determine the direction of the ground water flow systems, mixing ratios for waters, and residence times within the aquifer: and 5) identify aquifer recharge boundaries for future development of a well field protection plan by CBJ agencies.

The results of this study will assist in the identification and evaluation of potentially adverse effects of proposed developments in and around Gold Creek Basin so that appropriate mitigating measures can be devised. These developments include the planned reopening of the **Alaska-Juneau (AJ) gold mine and the associated long-term diversion of up to 20 percent of Gold Creek** flow. Because Gold Creek may be a major source of recharge to the Last Chance Basin aquifers, impacts caused by any changes to its flow must be carefully assessed and fully understood. Additionally, industrial activities in and around the Gold Creek basin have the potential of introducing contaminants into the watershed. With a better understanding of the sources of recharge for the Last Chance Basin well field aquifer, recommendations can be made to regulate or restrict potentially hazardous activities in hydrologically sensitive areas. In this way, the results of this study can help Federal, State, and Municipal agencies address public concerns regarding potential impacts of industrial development on the quality of Juneau's water supply.

GEOLOGIC AND HYDROLOGIC SETTING

Last Chance Basin is located in a glaciated valley of metamorphic rock consisting of schists and phyllites. The ore body of the AJ mine, located east of Last Chance Basin (fig. 1), consists of a network of quartz veins containing sparse gold, pyrite, pyrrhotite, arsenopyrite, galena, sphalerite, chalcopyrite, and silver (Wernecke, 1932; Nokleberg and others, 1987). The total sulfide content of the ore body is generally less than five percent (OTT, 1989). The vein system, about 5.8 km long, and 600 m wide (fig. 1), dips to the northeast.

Based on well-logs (Waller, 1959; QUADRA, 1982; GeoEngineers, 1989) sedimentary layers within the basin consist of (from bottom to top, see fig. 3): 1) till: 2) glaciomarine silts and clays; 3) glacio-alluvial sands and gravels; 4) clays and silts possibly of lacustrine origin; and 5) alluvial sands and gravels, A rockslide-avalanche from the side of Mt. Juneau blocked Gold Creek just east of Mt. Maria, and probably created a temporary valley lake which subsequently filled with sediment. Basin bedrock geometry is unknown but well-logs show depth to bedrock in mid-basin exceeds 240 ft.

Gold Creek drains an area of 8.4 mi^2 above Last Chance Basin, may be a major supply of recharge to the Last Chance Basin aquifers, and varies in discharge from 1.8 - 1,850 cfs (period of record, 1985 to current year). The principle aquifers in Last Chance Basin consist of an unconfined aquifer and a confined aquifer that is the CBJ production aquifer. The well field is the only year-round CBJ water supply and presently consists of 5 production wells. Production wells 4 and 5 (completed in 1989) are currently not in service.

An extended review of previous studies of Gold Creek and Last Chance Basin is contained in Appendix I. Preliminary hydrologic and geologic interpretations of Last Chance Basin were made by Waller (1959) and Anderson (1 959) following the drilling of several test wells in Last Chance Basin by the U.S. Geological Survey (USGS). Later studies have mostly concentrated on the engineering evaluation of the Last Chance Basin aquifer to determine water supply characteristics such as transmissivity, hydraulic conductivity, safe yield and maximum or optimum pumping rates (QUADRA, 1982; JMM, 1985; OTT, 1989) (cf. Appendix I). Data acquired in these engineering studies mainly address the aquifer response to pumping, and not the actual recharge or geologic setting of the ground water system. The engineering studies have concluded that recharge occurs primarily in the lower part of Last Chance Basin or through a leaky confining layer. They failed to consider an equally or more plausible scenario described by Anderson (1959) under which water is recharged near the head of Last Chance Basin where the confining unit may be thin or absent. They also failed to consider the possibility that recharge may originate from the side valley walls of Last Chance Basin. An understanding of the relative importance of these mechanisms is important to the long term management of the Last Chance Basin aquifers.

Water quality of Gold Creek is excellent, but is only monitored at the stream gauging station (fig. 1) by the USGS at this time. Routine testing of the well water by the CBJ water department is conducted to verify that the water meets ail drinking water requirements. Analysis of mine tunnel discharge reported by Echo Bay Exploration indicates that concentrations of most constituents are elevated with respect to Gold Creek water.

Engineering studies were conducted by James M. Montgomery (JMM) Consulting Engineers in 1985 and 1988 to determine the best way to meet the CBJ water requirement of 4860 gallons per minute (gpm) for three hours. The completion of production wells 4 and 5 in the summer of 1989 provides enough water to meet these water requirements. The CBJ water system operates on a gravity flow design with pumping of wells as needed.

NEED FOR STUDY

Although this project is designed to address potential Impacts associated with any development in the Gold Creek basin, public attention has largely been focused on the proposed reopening of the AJ mine by Echo Bay Exploration because of its potential for affecting the supply and quality of water within the CBJ. The mining project is located within portions of two watersheds, one draining into Gold Creek (fig. 1), and the other into Sheep Creek, located in the valley south of Gold Creek.

At the head of Gold Creek, water is currently being captured by old glory holes (sink holes created by the collapse of underground mine workings). Captured water drains through old mine workings and is redirected back to Gold Creek via a tunnel which presently discharges into Gold Creek near the head of Last Chance Basin (fig. 2). Presently, 5 - 6.5 percent of summer, and 11 - 14 percent of winter flow in Gold Creek is intercepted and diverted by a mine drainage tunnel 'back to Gold Creek (OTT, 1989). OTT (1989) estimates that up to 20 percent of flow could be intercepted due to increased glory hole size and number. During the life of the mine, estimated at

13 to 25 years, Echo Bay Exploration proposes to block the tunnel and divert the water to Gastineau Channel to prevent contamination of Last Chance Basin waters.

During mining, the reduction in Gold Creek flow could reduce the recharge to the Last Chance Basin aquifers, particularly during times of low flow. Data indicate that the highest percentage of capture occurs during times of low flow in the winter (OTT, 1939). At present, old glory holes capture up to 14 percent of stream flow which is reunited with Gold Creek near the head of Last Chance Basin. It is therefore useful to determine the recharge contribution to the production aquifer from the various sources, including the discharge tunnel waters on a seasonal basis, to assess the impact of future loss of these waters from Last Chance Basin.

The loss of flow may be particularly severe during the winter when stream flow is the lowest. CBJ water consumption during winter months has historically averaged 4.5 cubic feet per second (cfs) but averaged 6.6 cfs for the month of January 1990 (CBJ Water Utilities Data File, 1990). Records show that Gold Creek flow was less than 4.5 cfs for periods of 30 or more consecutive days during the winter months for 14 years since 1950 and was less than 6.4 cfs for periods of 45 or more consecutive days during the winter months for 12 years since 1950 (USGS Water Resources Data File). Loss of the drainage tunnel flow to Last Chance Basin during periods of low flow in Gold Creek could therefore cause water shortages, and could increase pumping costs because of lower well water levels. The existing alternate water supply, Salmon Creek reservoir, suffers from turbidiiy problems related to heavy rain events, seasonal melting, and other causes that exceed Alaska Department of Environmental Conservation (ADEC) and U.S. Environmental Protection Agency (USEPA) guidelines. This surface water source cannot reliably supply water year-round without extensive and expensive treatment plant modifications.

During and after mining, surface and ground water quality may be affected. As previously mentioned, Echo Bay Exploration proposes to divert drainage tunnel water to Gastineau Channel to prevent contamination of water in Last Chance Basin. Only during floods exceeding a 10 year, 24 hour storm event would mine drainage and tunnel water be diverted back into Gold Creek. During such events Echo Bay Exploration expects any contamination associated with mining activity to be diluted to within safe limits by the increase in Gold Creek flow. Echo Bay Exploration does not expect any contaminated mine waters to enter the Last Chance Basin water supply system through any other avenues. Because no safe limits have been established for some potential mining related contaminants, data on the hydrology and geology of the Gold Creek drainage system and the Last Chance Basin aquifers are necessary to verify the expectations of Echo Bay Exploration. These data would also aid in identifying hydrologically sensitive areas so that activities in such areas can be appropriately conducted.

After mining operations, Echo Bay Exploration proposes that the tunnel flow be redirected back into Gold Creek. The effect of this redirection on Last Chance Basin water quality is of major concern. Available chemistry on present tunnel discharge waters show them to have elevated concentrations of sulfate, bicarbonate and some trace metals as compared to Gold Creek water (Appendix I). After the mine closes, tunnel water could be expected to have substantially higher concentrations of dissolved solids. The higher dissolved solids could be from an increase in oxygen and water contact time on fresh surfaces of bedrock (increasing oxidation and dissolution of sulfide minerals), an increase in the amount of flow through the abandoned mine workings, and the resuspension of sediments or contaminants left in the mine. Infiltration of these waters into the aquifer tapped by the CBJ well field could result in the deterioration of ground water quality from the wells. However, OTT (1989) believes that besides an increase in suspended sediment, because of the nature of the ore body, little change in water quality will occur, and expects stream dilution to reduce any impact of mine drainage to within allowable limits. OTT does not expect any acid mine drainage to occur because the mine is a low sulfide ore with some talc-silicate host rocks. The expected pH is between 7 and 8 (OTT, 1989). Determination of recharge sources and the proportion of contributions to the aquifer could help guide agency planning and public policy decisions with regard to returning tunnel flow to Last Chance Basin following cessation of mining operations. It could also help alleviate public concern regarding future degradation of water quality.

APPROACH

To better understand the Last Chance Basin ground water system, including sources and areas of recharge, and to help determine the best way to safely manage the CBJ water supplies, this project examines the geology, hydrology, and water chemistry of the Gold Creek watershed. An understanding of the geologic processes that formed the aquifers in Last Chance Basin will help in determining where aquifer recharge is taking place. These areas may include the upper part of Last Chance Basin, along the creek bed, and along valley walls on the periphery of the basin. Because of the long term nature of concerns in Last Chance Basin, this study will design all installations for long term monitoring.

A review of previous work is contained in Appendix I. An outline of the project work plan is contained in Appendix II. The study is composed of two interrelated phases. The first phase concentrates on hydrology and a systematic geochemical and isotopic sampling program designed to establish baseline geochemical parameters and to provide information on basin recharge. The second phase, which involves a drilling program, seeks to determine basin geometry and aquifer geology, explore water sources below the present production aquifers, and help confirm recharge models. The two phases may be implemented simultaneously, sequentially, or partially overlapping.

Phase 1

Phase one will include a review of available literature, previous chemical data, and air photos. Unpublished information will be obtained from CBJ personnel, consulting firms, and well drillers. A working base map (scale: 1 :10,000) will be compiled based on Miller's (1975) surficial deposits map, other bedrock geologic maps, and supplemental field geologic mapping.

Data acquisition will include measurement of potentiometrfc heads and mapping of springs and seeps in Gold Creek Basin. Potentiometric head measurements have been done in previous investigations, but were commonly influenced by pumping, or were not time-synchronous. This investigation will attempt to map potentiometric or water table surfaces under both pumping and non-pumping conditions. One or more automatic water level recorders will be installed, provided suitable observation wells can be found.

In cooperation with the USGS two additional stream gauges will be installed on Gold Creek and operated for one year to complement data from thestation presently located below the drainage tunnel. One gauge will be positioned at Silverbow Basin; the other station will be placed below the bridge at the west end of Last Chance Basin (Fig. 1). Data derived from the Silverbow basin gauge will help delineate the maximum possible flow that can be captured by glory holes (i.e., all of upper Gold Creek), and data derived from the west end of Last Chance Basin gauge will help determine the amount of Gold Creek flow going to the recharge of the Last Chance Basin aquifers. A series of flow discharge measurements will be made between the USGS gauging stations on Gold Creek in Last Chance Basin to determine segments of the stream that gain or lose water. Drainage tunnel flow will also be monitored to help obtain better estimates of current glory hole stream capture and to determine the proportions of tunnel drainage vs total Gold Creek flow on a seasonal basis.

A geochemical and isotopic sampling program will be done to determine water types, provide baseline water chemistry of all waters in the basin, and trace any trends such as higher sulfate mine waters entering the ground water system. The water sampling program will follow a quality assurance plan such as established by Munter and others (1990). The sampling program will sample up to 15 locations quarterly for major anions and cations, selected trace metals, turbidity, stable (oxygen-18 and deuterium) ground water isotopes, tritium, and field parameters. In conjunction with basin geology and flow system mapping, water chemistry and isotopic composition will help identify recharge sources and areas, seasonal trends, and aquifer residence times.

Based on these data, both a conceptual ground water flow model, and an appropriate computer model, such as the USGS Modular Three-Dimensional Finite-Difference Ground-Water Flow model (MODFLOW) by McDonald and Harbaugh, will be developed. A report will be produced that: 1) addresses the residence time of water in the aquifer: 2) estimates areas of artesian conditions and recharge zones; 3) provides chemical and isotopic identification of waters in Gold Creek Basin; 4) determines any chemical trends; 5) determines the percentage of flow in Gold Creek from each section of the basin with the stream gauges; 8) determines the percentage of Gold Creek and mine outflow waters in well water; 7) establishes a baseline water quality data base; and 8) assesses potential effects of development on aquifer recharge and ground water quality.

Phase 2

The second phase of the study will include a program of geophysical exploration, well drilling, and sampling. These investigations will help delineate the basin geology and geometry, and determine if the production aquifer is unconfined in the upper (east) end of the basin.

Geophysical methods (consisting mainly of seismic refraction or reflection surveys of the basin) will be completed principally to delineate the bedrock surface underlying Last Chance Basin. Secondarily, the surveys may be useful for determining if talus and slide rock extend vertically downward to the production aquifer providing a route for recharge off valley walls, and give a better estimate of total water availablliiy within the basin.

A limited number of shallow monitoring wells (approximately 20 ft deep) will be placed in the basin. These wells will be used to map the water table during pumping of the lower aquifer and under static conditions to determine if the “confining” bed actually leaks, and to test the water quality of the unconfined aquifer. If leakage through the “confining” layer is significant, it would have implications for protection of the production aquifer: oil spills or releases of hazardous materials In Last Chance Basin could quickly affect the quality of water from the public supply wells.

A single test well, approximately 60 feet deep and located in the upper (East) end of Last Chance Basin will be used to determine the extent of the confining layers. Results of previous investigations suggest that the confining bed for the production aquifer pinches out to the east (Anderson, 1959; JMM, 1966). If this is the case, then the production aquifer is actually unconfined, and may be receiving a majority of its recharge at this location.

The final phase of drilling will include one or two wells drilled to bedrock. These wells will be used to explore the lowest aquifer. A geochemical identification of the water will be made, and the water levels will be monitored during pumping from the middle production aquifer. This deep well will also provide information on the structure and geologic history of the basin. The estimated depth of these wells is 300 feet.

Waters from the newly drilled wells will be sampled, geochemlcally and isotopically analyzed on two separate occasions, and added to the geochemical data base. The final report data base will include these samples, along with the four seasonal sample rounds from phase one. It is recommended that the CBJ initiate a long term sampling plan to follow up this report to monitor any changes in Gold Creek water quality.

Results of these Phase 2 investigations will be used to: 1) confirm and refine the recharge models from Phase 1; 2) generate geologic cross-sections of Last Chance Basin; 3) help establish the geologic history of Last Chance Basin; 4) determine any difference in water types between the production and lower aquifers; 5) determine the potential for using the lower aquifer as a future CBJ water supply; and 6) reassess impacts of development on aquifer recharge and water quality.

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APPENDIX I

REVIEW OF PREVIOUS STUDIES

INTRODUCTION

A geologic investigation on the origin of Last Chance Basin was conducted by the USGS, and is contained in Waller (1959). A hydraulic investigation for the CBJ by Keith Anderson was completed about the same time as the USGS 1959 study, and summarizes the hydrology of Last Chance Basin. More recent studies have generally dealt with the engineering characteristics of the aquifer materials and were done in connection with further development of the CBJ well field.

GEOLOGY OF GOLD CREEK BASIN

The bedrock geology of the Gold Creek drainage basin consists mainly of Upper Triassic chlorite-hornblende-biotite phyllites and schists, with some areas of granitic gneiss. The metamorphic grade increases from green schist facies in the west around Juneau, to amphibolite facies in the eastern headwaters area of Gold and Granite Creek (Ford and Brew, 1973). The Silverbow fault strikes in an east-west direction along the axis of Last Chance Basin, up Snowslide Gulch and through the old AJ mine glory holes (sink holes created by the collapse of underground mine workings).

The ore body of the AJ mine consists of a network of quartz veins containing sparse gold, pyrite, pyrrhotite, arsenopyrite, galena, sphalerite, chalcopyrite, and silver (Wernecke, 1932; Nokleberg and others, 1987). The total sulfide content of the ore body is generally less than 5 percent (OTT, 1989). The vein system, about 5.8 km long, and 800 m wide (fig. 1), dips to the northeast.

Last Chance Basin lies northeast of the city of Juneau in a narrow glaciated valley. It is the lowest of several basins on Gold Creek, and is approximately 4,000 feet long in an east-west direction, with a maximum width of 700 feet. The east and west ends of the basin are at elevations of 330 and 260 feet respectively (Waller, 1959).

Based on well-logs (Waller, 1959; QUADRA, 1982; GeoEngineers, 1989), sedimentary layers within the basin consist of five units (from oldest to youngest, see fig. 3): 1) till; 2) glaciomarine silts and clays; 3) glacio-alluvial sands and gravels; 4) clays and silts of possibly lacustrine origin; and 5) alluvial sands and gravels. Unit 5 thins to the west, unit 4 thins to the east, while unit 3 is wedge shaped and thins to the west and south (JMM, 1985). JMM (1986) found some evidence that unit 4 pinches out to the east, but did not present the evidence (it is probably the thinning of the bed). Basin bedrock geometry is unknown but well-logs show depth to bedrock in mid-basin exceeds 240 ft. A pre-historic rockslide-avalanche from the side of Mt Juneau blocked Gold Creek just east of Mt. Maria (Spencer, 1906), and probably created a temporary valley lake which subsequently filled with sediment.

USGS test wells drilled to a maximum depth of 236 feet in 1959 did not penetrate bedrock in the lower (west) end of the basin (Waller, 1959). Bedrock was encountered at 60 feet in the upper end of the basin in only one test well (Waller, 1959). Problems with large boulders were encountered at depth during drilling through all units and prevented the drilling to bedrock as planned in all but one well.

Unit 1 was penetrated in 1959 by only one test well and no data exist regarding its thickness or lateral continuity (JMM, 1985). The lowest clay bed (in unit 2) contains shell fragments, indicating a possible marine origin (Waller, 1959, C. Lindsay, pers. comm., 1990).

HYDROLOGY

Gold Creek drains an area of 8.4 mi^2 above the head of Last Chance Basin where it is presently gauged (fig. 1). The gauge was moved from the outlet of Last Chance Basin in 1984 because the CBJ well field may have been removing water from the creek by infiltration during pumping (H. Seitz USGS, oral comm., 1990). The maximum discharge since 1984 was 1,850 cfs on 11 September 1988, and the minimum was 1 .6 cfs on 20 February 1985 due to a snowslide upstream causing temporary storage (USGS Water-Data Report, 1988). At present a small percentage, 5-6.5 percent in the summer and 11-14 percent in the winter (OTT, 1989), of Gold Creek flow is captured by glory holes connected with the old AJ mine workings. This captured water is returned to Gold Creek via a tunnel at the head of Last Chance Basin.

The aquifers in Last Chance Basin consist of an unconfined water table (in unit 5), a semi-confined to confined aquifer (unit 3), which is the present production aquifer for CBJ, and a possible aquifer of unknown extent at depth (unit 1) (fig. 3). Unit 4 acts as an upper confining layer for the production aquifer. Unit 2, an extensive clay layer, confines the production aquifer from below.

The CBJ well field produces water from the confined aquifer between approximately 60 and 100 feet. The production aquifer, along with an unconfined aquifer, are located above a thick clay layer in the upper 100 feet of sediment (Waller, 1959, GeoEngineers, 1989). JMM (1985) subdivided this upper 100 feet into an unconfined and a single confined aquifer, while GeoEngineers (1989) found evidence for two confined aquifers. The difference in interpretation may be due to the well locations in the basin (GeoEngineers only worked in the upper basin on production wells 4 and 5), and differences in drilling and well togging methods.

Water levels in the 1959 USGS test welts were found to correlate with Gold Creek level changes and Waller (1959) concluded that the “confined” production aquifer is directly connected with lower Gold Creek. Because downstream water levels changed prior to upstream levels, Waller (1959) further inferred that recharge occurs in the west end of the aquifer and that pressure differentials are transmitted back up the confined aquifer (Waller, 1959). Although Waller (1959) did not address recharge in other parts of Last Chance Basin, subsequent authors appear to have disregarded other potential sources without cause. The downstream wells that the USGS used in their work were apparently abandoned and not used in any other study, as no other mention of data collected from these wells is ever made.

The Anderson (1959) report appears to have been completed concurrently with the USGS 1959 open fife report, but with a more thorough discussion of recharge processes. According to Anderson (1959), the waters in the shallow unconfined aquifer were at about the same level as the water in Gold Creek, and a pump test showed that these shallow gravels are hydraulically connected to Gold Creek by infiltration. Anderson (1959) concluded that the water entering the sands and gravels of the confined aquifer originate at the upper (eastern) end of the basin from the flow in Gold Creek, with the amount of recharge from Gold Creek about 3 cfs based on stream discharge measurements.

From the pump test done in 1959, Anderson calculated a transmissivity of 150,000 gpd/ft. This pump test was done at only 100 gpm because low entrance velocities from an improperly sized screen would not allow a higher pumping rate. This low pumping rate produced changes in the monitoring well of less than a foot, and this could cause a large error in the calculation. Anderson (1959) found that the well levels stabilized within a relatively short time.

WATER QUALITY AND CHEMISTRY

Water quality of Last Chance Basin and Gold Creek is generally good, except for water discharging out of the AJ mine tunnel (BLM-AJ PDEIS, 1989), and one sample from production well 5 after installation (GeoEngineers, 1989).

The mine discharge was sampled for the Preliminary Draft EIS (PDEIS), but only one sample, taken on 8 September 1989, is included in the Appendix of the PDEIS. This water is a Ca-Mg-SO_4-HCO_3 type water, with a sulfate level of 295 mg/l. Three samples of the tunnel water taken in July, August, and September of 1988 were included in the OTT (1989) report, and are all Ca-Mg-SO_4-HCO_3 type waters. Of the OTT (1989) samples, all had hardness greater than the drinking water standard of 250 mg/l. Two samples had iron greater than the drinking water standard of 0.3 mg/l, and one sample had lead and manganese greater than the drinking water standards of 0.01 mg/l and 0.05 mg/l respectively.

It is unknown if Gold Creek water above the tunnel has been sampled. The Preliminary Draft EIS lists a sample from 8 September 1989 (sample site is only Identified as Gold Creek) in its Appendix 1 that has very low sulfate levels. Because of these low sulfate levels, it is presumed that this sample could be from above the mine drainage tunnel. The water differs from the tunnel drainage and Gold Creek water collected below the tunnel mixing zone. This water is a Ca-HCO_3 type, with a sulfate level of only 8 mg/l. All solutes in this sample appear to be lower than the other samples reviewed. This sample could also be low because of dilution from very high flow rates in Gold Creek.

Between 1983 and 1988 nine samples from Gold Creek were taken by the USGS from their gauging station site below the tunnel discharge. These samples are a mixture of Gold Creek and tunnel drainage waters. This water is a Ca-SO_4-HCO_3 type, with sulfate values between 13.0

and 48.0 mg/l. The range of values in these samples are: hardness 28-80 mg/l as $CaCO_3$; specific conductance 65-185 mhos/cm; calcium 8.3-21 .O mg/l; magnesium 1.8-6.7 mg/l; bicarbonate 18.0-44.0 mg/l; iron 3.0-l 6.0 mg/l, and sodium, chloride, fluoride and nitrate all less than two mg/l (BLM-AJ PDEIS, 1989).

The USGS in 1959 sampled two wells in Last Chance Basin and found the water to be $Ca-SO_4-HCO_3$ type. Sulfate levels were 34 and 37 ppm. No trace metals analysis were conducted on the 1959 samples. Samples from production wells 4 and 5 did not have an analysis for a full set of major chemical parameters, but the sulfate levels were 40.3 and 28.0 mg/l respectively. The CBJ utilities sample the wells every three to five years to insure that the water meets federal and state requirements. These data consist mainly of trace metals concentrations which are used to compare against primary and secondary drinking water standards. The only trace metals found above drinking water standards in any of the production wells occurred in well 5, and were chromium (0.086 mg/l) and iron (4.58 mg/l). Major anion and cation analyses, which are useful for distinguishing different water types, are lacking from CBJ data.

ENGINEERING STUDIES AND PARAMETERS

In 1985 and 1986 JMM conducted two studies of the CBJ Last Chance Basin well field (production wells 1, 2, and 3). Both JMM reports were concerned with increasing the water supply to meet existing CBJ fireflow requirements of 3,500 gpm for three hours, plus the maximum average hour demand of 1,160 gpm, for a total of 4680 gpm for three hours. The present CBJ system operates on a gravity flow design with pumping of wells as needed. After the installation of production wells 4 and 5 in 1989, pump tests were performed by GeoEngineers Inc.

JMM (1985) conducted a pump test on the field by pumping production well 3 at 1,200 gpm for 48 hours. The results of the pump test were inconclusive and required JMM to return in 1986 to retest the well field. The major problems of the 1985 JMM pump test were that: 1) most wells did not have water level changes large enough to determine realistic aquifer parameters (well levels changed by only 0.2-3.52 ft.); and 2) most data was not collected from the start of the pumping (some water levels were not collected until 125 minutes after the pump test started). JMM (1985) did recommend that: 1) the wells be monitored monthly: 2) that all flows from wells be recorded; 3) flow in Gold Creek should be monitored at the head and outlet of Last Chance Basin; 4) precipitation should be measured in the basin; 5) a digital ground water model of Last Chance Basin should be constructed; and 8) development in the drainage area of Gold Creek should be limited. Besides limiting development in the basin, no other recommendations were implemented.

Because the work of JMM in 1985 did not yield the information needed to determine the best way to develop the ground water system, another testing program was conducted in 1988 by JMM. This test used an In-Situ, Inc. SE200A Hydrologic Analysis System to collect data. The SE200A employs pressure transducers to measure and record data. Water levels were monitored for 15 hours prior to the pump test, and it was found that the levels Increased by 0.4 ft. due to the increase in Gold Creek level (JMM, 1988). Production well 2 was used for pumping. The first pump test was stopped by a tripped circuit breaker. At that time it was found that production well 1 was flowing by gravity flow. It was not possible to stop the flow out of production well 1 during the pump test. A 2-hour recovery period preceded the restart of the test. Production well 2 was pumped at 1,000 gpm for 1,300 minutes with a 325 minute recovery test. Besides well 1 flowing at the same time as the pump test (estimated at 5-7 percent of the flow) a constant pumping rate was not maintained. After two hours the flow from the pumping well was diverted and this caused a change in back pressure that increased the pumping rate. The pumping was adjusted. At three hours, another change caused a decrease in pumping rate and again the pump had to be adjusted. At 10.5 hours flow was again diverted for a “brief period” but no adjustments were made. Almost all wells stabilized in response to the pumping, and some increased in response to an increase in stream level and a decrease in barometric pressure. At the end of the recovery test, most wells were higher than at the start.

JMM (1988) used early time data to determine the aquifer characteristics, and found the transmissivity to be 18,000-22,000 gpd/ft., with a storage coefficient of 10^{-3}. A plot of drawdown versus distance gave a transmissivity of 22,000 gpd/ft. These transmissivities are significantly lower than other reported values (see below). The reason for the difference is the use of early-time data before boundary effects are seen. This suggests that recharge from Gold Creek is rapid. The early-time data gives a more representative value of transmissivfty without any effects from recharge boundaries.

From the 1988 testing, JMM found the aquifer to be semiconfined and to exhibit a large amount of leakage through the confining layer. JMM (1988) found the production aquifer approaches steady state within a few hours when being pumped at 1,000 gpm, and believed this steady state condition demonstrates hydraulic connection between the confined and unconfined aquifers.

After the installation of production wells 4 and 5 in 1989, GeoEngineers conducted a pump test on each well with the other well used as a monitoring well. Both wells had a 4 hour stepped pump test (740-l ,710 gpm), and then a 24 hour constant rate test at 1,710 gpm for production well 4, and 1,560 gpm for production well 5. Production well 3 was pumping at 1,200 gpm before, during, and after the tests on both wells 4 and 5. GeoEngineers (1989) found that both wells reached steady state after 2 hours, and that both wells could be pumped to the maximum allowed by screen entrance velocities. The estimated transmissivity is 184,000 gpd/ft. The estimated interference to production wells 3, 4, and 5, if all were pumping at their maximum capacity, would be 10.6, 20.4, and 23.9 ft. of drawdown respectively.

APPENDIX II

WORK PLAN OUTLINE

Hydrogeologlc Study of the Water Resources of Gold Creek Basin

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Juneau Office

I. PHASE 1

A. Review and Summarization of Previous Work
   1. Review of available literature
   2. Review of previous chemical data
   3. Obtain unpublished information
      a) CBJ personnel
      b) Past consulting firms
      c) Well drillers
   4. Review air photos
   5. Compile working base map
      a) Surficial deposits (Miller, 1975)
      b) Bedrock2

B. Data Acquisition
   1. Piezometric head measurements
   2. Mapping of springs and seeps in Gold Creek Basin
   3. Recondition monitoring wells and install datapods
   4. Install additional stream gages
      a) Lower Last Chance Basin
      b) Lower Silver Bow Basin
   5. Water geochemical identification and sampling program
      a) Establish quality assurance program
      b) Sample locations: up to 15 samples per quarter
         1) Ground water in Last Chance Basin
         2) Gold Creek
         3) Mine tunnel discharge
         4) Surface runoff of side slopes
         5) Springs
      c) Field parameters: pH, conductivity, alkalinity, temperature, flows when applicable
      d) Laboratory parameters: major anion and cations, selected trace metals, turbidity, stable isotopes, tritium

C. Data Reduction
   1. Enter into Lotus data base
   2. Check anion-cation balance
   3. Plot chemistry (Piper plots)

D. interpretation of Results
1. Identify chemical or isotopic trends
2. Interpret water level measurements
3. Derive preliminary recharge model based on results
4. Plan next sample round based on results

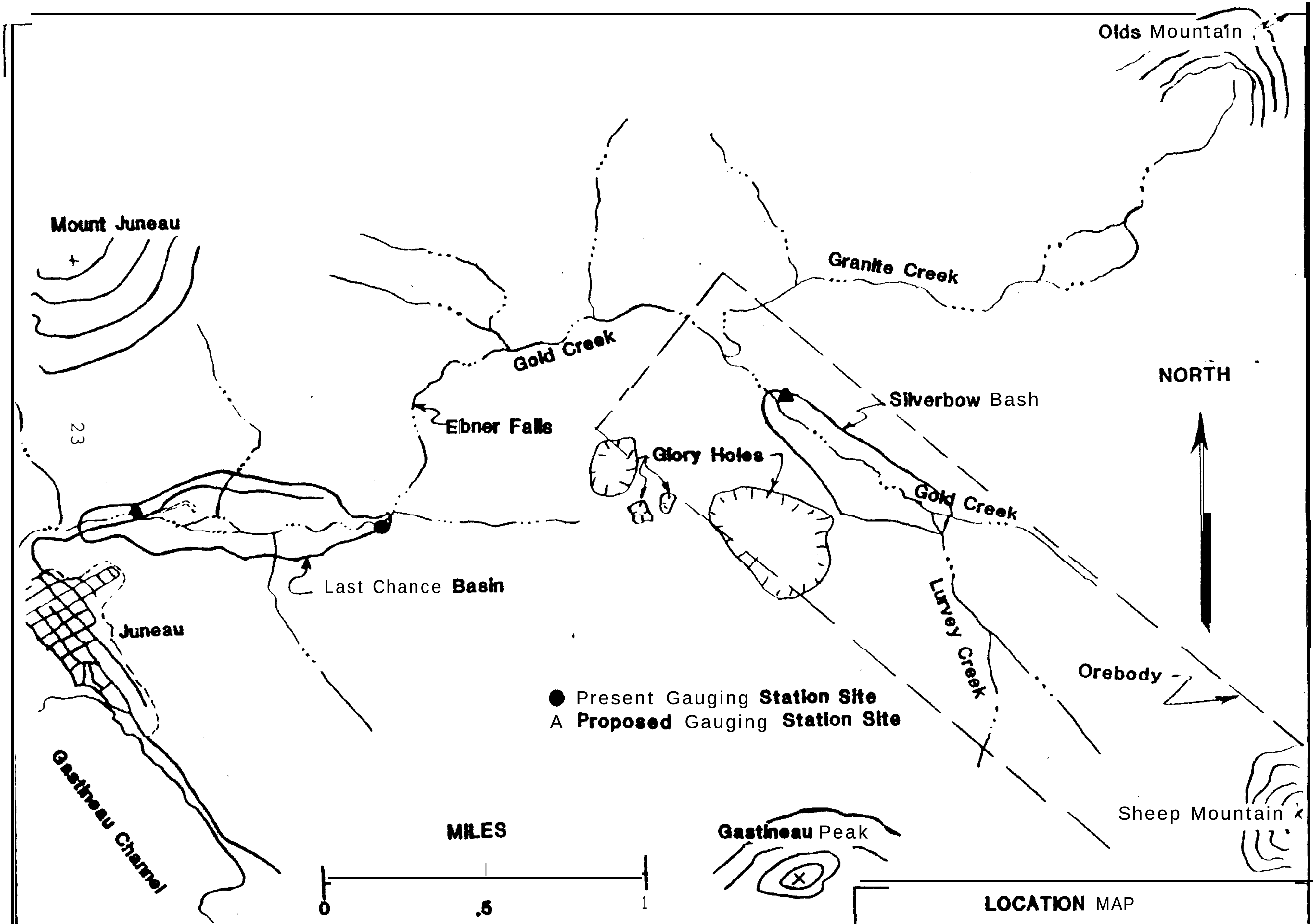
E. Prepare Reports
1. Determine residence time of water in aquifer
2. Define area of artesian conditions
3. Determine background chemical and isotopic identification of waters in Gold Creek Basin
4. Determine any surface to sub-surface trends
5. Determine the percentage of flow in Gold Creek from each section of the basin with the stream gages
6. Prepare preliminary conceptual hydrogeologic model of basin
7. Assess potential impacts from development on aquifer recharge and water quality

II. PHASE 2

A. Last Chance Basin Delineation
1. Seismic survey
   a) Define basin shape and depth
   b) Determine extent and depth of talus slope

B. Monitoring and Test Wells
1. Shallow wells to test unconfined aquifer
   a) IO-20 feet deep
   b) Geochemical identification of water
   c) Monitor during pumping of middle aquifer
   d) Cluster near deeper well to determine head difl erences
2. Test well in upper end of Last Chance Basin
   a) 50-80 feet deep
   b) Geochemical identification of water
   c) Sediment sampling for geologic cross-section
   d) trace extent of confining layers
3. Deep test well to bedrock
   a) Install two cored wells
   b) 300-350 feet deep
   c) Geochemical identification of water
   d) Monitor during pumping of middle aquifer
   e) Cluster near shallow and middle aquifer wells

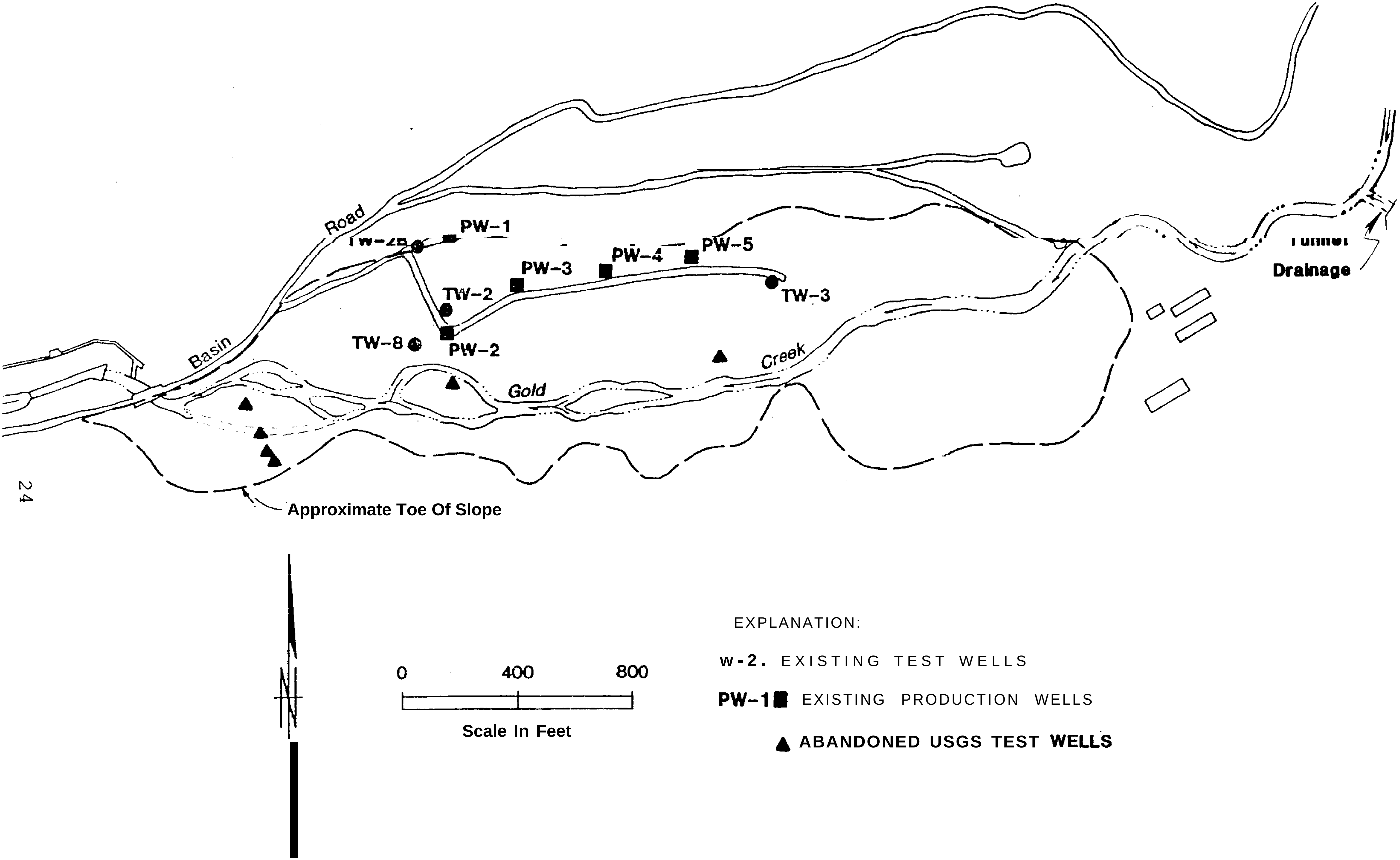
C. Prepare Reports
1. Confirm and refine recharge model
2. Prepare geologic cross-sections of basin
3. Determine geologic history of Last Chance Basin
4. Determine differences in water types between aquifers
5. Determine potential for using lower aquifer as CBJ water supply
6. Reassess impacts of development on aquifer recharge and water quality



LOCATION MAP

FIGURE 1

Modified After Juneau B-2 **Topographic Map Scale 1:25,000**



Modifiid After GeoEngineers 1989	‘SITEPLAN
	FIGURE 2

UNIT 1--Surficial **fluvial** sand and gravel deposit, 20 to 30 feet thick, thins to the west.

UNIT 2--Sandy silt and clay deposit, 15 to 30 feet thick, thins to the east.

UNIT **3--Bouldery** sandy gravel deposit, 20 to 70 feet thick, forming a wedge that thins to the south and west.

UNIT 4--Sandy gravelly clay deposit with shell fragments, at least 120 feet thick.

UNIT 5--Fine sands and gravels with boulders and clay, thickness unknown.

Metamorphic bedrock.

Stratigraphic Section of Last Chance Basin	FIGURE 3