Georgia Tech

Attenuation of Peruvian Mining Leachates and Effluents Using Porous Geochemical Barriers

Report of Activities for June 1 - September 1, 1997

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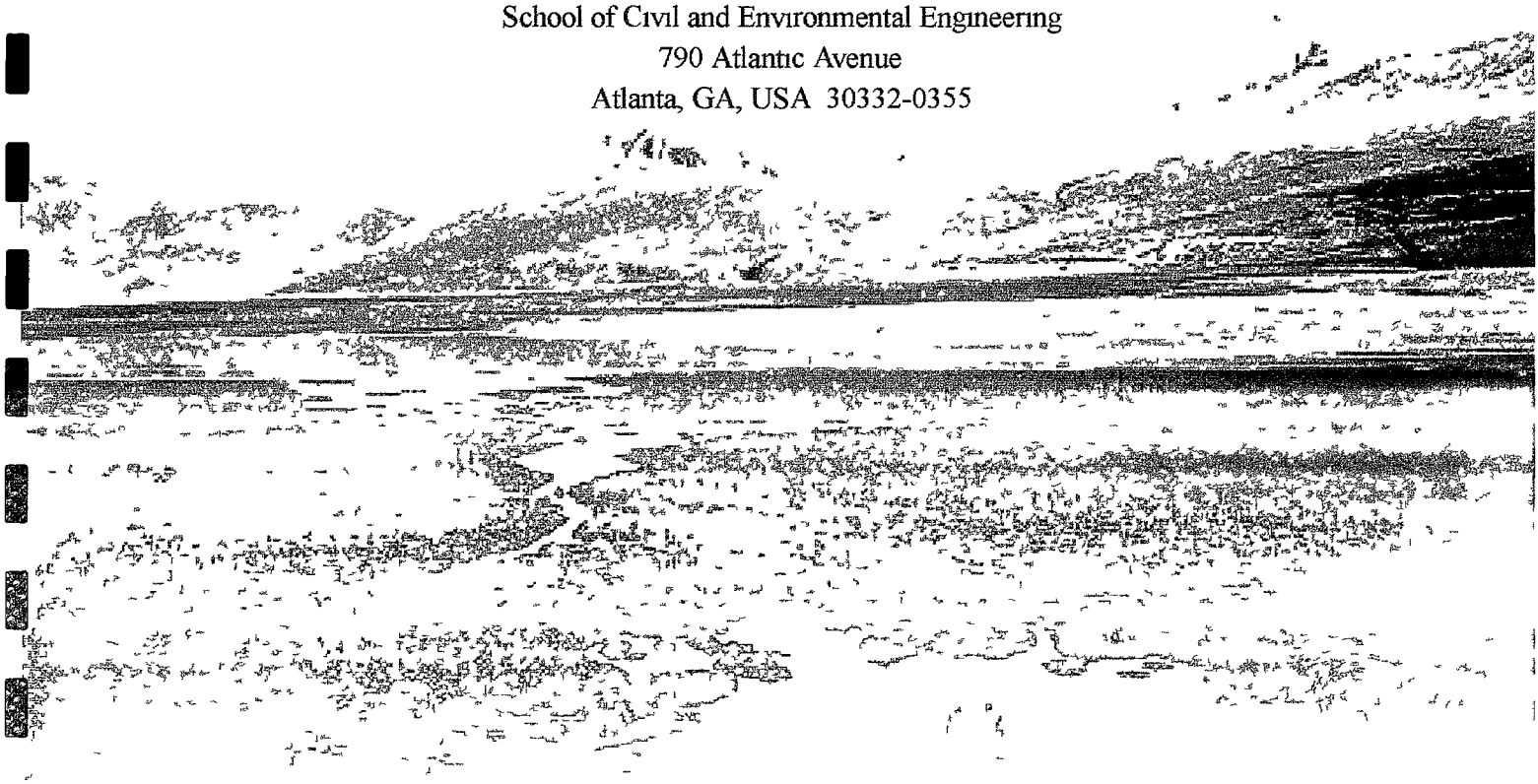

Presented to

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RE 1st Quarterly Report, June-August, 1997

Dear Ing Pacora

This letter report and attachments comprises the first Quarterly Report on the activities completed during the period of June 1 to August 31, 1997, on the project jointly sponsored by the United States Agency for International Development (USAID) and Corporacion Minera Nor Peru (CMNP) The purpose of this project is to identify and evaluate passive treatment technologies for potential implementation to mitigate acid water problems in Peru More specifically, the feasibility of this approach is being evaluated at the San Felipe tailings dam for Unidad Minera Quiruvilca due to the new effluent standards established by the Programa de Adecuacion y Manejo Ambiental (PAMA) The San Felipe tailings dam[1] was operated in the 1970's and closed in approximately 1980 The dam is situated at an elevation of approximate 3570 meters, approximately 3 km from Shorey (3700 meters) At the lower, northeastern end of the valley, the width of the tailings dam at the crest is approximately 380 meters and 180 meters at the base The maximum height at the crest is approximately 30 meters The tailings dam is approximately 750 meters long, with its long-axis stretching from the upgradient, southwestern end of the valley down to the crest situated in the northeastern end

Since the month of June was primarily dedicated to planning the summer trip to Peru (July 1 to August 28) and ordering of laboratory and field equipment, emphasis will be placed on the activities in Peru in July and August The report is divided into several parts This letter report assimilates and summarizes the information gathered during discussions with CMNP personnel and from the visits to Trujillo and Unidad Minera Quiruvilca Several appendices are attached to this letter report Appendix A contains all of the meetings that the Georgia Tech team (GT, Dr Dennis G Grubb and Mr Gregg W Hudock) participated in Peru during the months of July and August, 1997 The two individual trips to Quiruvilca during the periods of 13-18 July and 7-13 August are summarized as Appendices B and C, respectively The environmental reconnaissance trip (17 July) to the Esperanza Mine in Salpo appears in Appendix B A description of the environmental, soil and industrial byproduct sampling activities completed in Trujillo and Quiruvilca during August are contained in Appendix D Based on a preliminary cost estimate, the utilization of geosynthetics and a subdrain system appears to be a more cost effective solution than the capping and re-grading scheme proposed by Klohn-Crippen Therefore, the use of geosynthetics to retrofit the face of the tailings dam to prevent erosion and to improve seismic stability of the tailings is discussed in Appendix E A list of the literature, reports and documents provided to GT by CMNP during 1 July - 28 August is presented in Appendix F The text that follows includes a summary of our observations and recommendations concerning the management of the San Felipe Tailings dam

1st Quarter Objectives

The main objectives of the site visit to Quiruvilca in July were to survey drainage trenches (D1-9, C10-12) at San Felipe tailings dam and to identify the locations for soil, tailings and industrial byproduct sampling for the August trip We have not been able to process the survey data since the actual benchmarks and coordinates of the San Felipe valley remain in dispute by surveyors from the Peruvian Government Once these data are finalized we

[1] Cover photo of re-vegetated areas and ponded water near the center of the San Felipe tailings dam, looking due East from the midpoint of the northern side of tailings (October 1996)

can provide you with a summary of our findings In August, selected water quality parameters in San Felipe valley were quantified and locally available soils and industrial byproducts were collected in vicinity of Unidad Minera Quiruvilca Trujillo, and along the transportation corridor between the two sites Samples of San Felipe tailings also were collected These geomaterials were needed for the experimental program at GT in Atlanta to test the preliminary feasibility of utilizing soils and industrial byproducts to buffer pH and immobilize metals in a porous geochemical barrier (PGB) for acid mine drainage (AMD) mitigation The evaluation of the geotechnical engineering parameters of the soils and industrial byproducts is now underway

Integrated Management Approach

The key strategies to mitigate acid mine drainage (AMD) involve reducing the exposure of sulfide minerals to both moisture (water) and oxygen (O_2) As such, water management programs are initiated to divert ground and surface waters around tailings dams and impermeable caps are often used to minimize infiltration Water management is important for several other reasons Since tailings are usually cohesionless silt-size particles, they are prone to liquefaction under water-saturated conditions during seismic events and are prone to erosion during rainfall events Many sulfides are reduced compounds that were formed under limited oxygen conditions and they are therefore relatively stable under anaerobic conditions Also the general trend is that mono- di- and some tri-valent metals are most soluble under oxidized and acidic conditions so the promotion of reduced and anaerobic conditions is favorable for metals immobilization Other key strategies for controlling AMD include buffering pH of pore or surface waters to neutralize the acidity generated by sulfur and iron oxidation reactions which are often catalyzed by microorganisms Since many of these microorganisms are acidophillic (acid loving) the rate of AMD generation can be reduced by buffering the pH above the optimal pH for organisms such as *T ferrooxidans* (optimal pH~2 5-3 5)

The longevity of a passive technology such as the porous geochemical barrier (PGB) is proportional to the quantity and quality of water to be treated This is generally true for any passive technology to be used at San Felipe The required treatment time in a PGB and the hydraulic conductivity of the PGB both limit the volume of water that can be conveyed for a particular flow geometry The lowest possible flows are therefore desirable Re-routing of the water from the decantation line (D-4) and the diversion canals flanking both side of the tailings dam (i e , C-12) around the passive technology is an important strategy In addition to reducing the volumetric flow and mass loading of arsenic on the passive technology, there is considerable legal motivation to isolate the effluent from the La Paloma mine from the acid water from San Felipe and the clean surface water flowing around the tailings dam (C 12) Sediment transport from the San Felipe tailings dam also should be minimized to reduce the contaminant loading and potential for pore clogging of the PGB because sediments can render passive technologies ineffective An evaluation of the geotechnical stability of the tailings dam must therefore include an erosional protection component As discussed with CMNP personnel, several societal constraints are also placed on the project Since there is currently no solid waste or sewage treatment management approaches currently in place, there is an impetus to incorporate these schemes with the environmental strategy employed at San Felipe Environmental protection must be undertaken in such a way as to minimize the potential for theft of infrastructure Also the application must not severely impinge on the current land use by indigenous peoples so that they will not interfere with the overall approach taken at San Felipe The optimal geo-environmental solution for the AMD conditions at the San Felipe tailings dam must integrate and balance these issues GT believes it has identified an integrated approach, which at this preliminary stage appears to satisfy these challenges Future work will be geared to verifying the appropriateness of the approach outlined below

Surface Water Management Plan

To minimize the quantity of water to be treated by the passive technology, as much surface water as possible should be diverted away from the San Felipe tailings dam and the passive technology used to treat the AMD This strategy achieves multiple objectives 1) the overall amount of water to be treated is reduced, 2) a lower flow rate through the passive technology corresponds to a longer treatment time for pH buffering and metals immobilization 3) the longevity of the passive technology is increased and, 4) increased water diversion around the passive technology corresponds to an increased dilution factor once the flows are merged together prior to Environmental Monitoring Point XIV The approach also involves the diversion of the surface water on the tailings dam toward the intake of the decantation line at the southwestern end of the tailings Diversion of surface water on the tailings dam also necessitates the repair of the drainage trench (C-10) excavated in the northern corner of the

tailings dam and face of the tailings dam The recommended approach to achieve these goals must be well integrated with the other aspects of the management scheme for the San Felipe tailings dam

Re alignment of the Existing Drainage Canals and Trenches

An important part of the surface water management plan is the re-alignment of several existing drainage canals and trenches in the vicinity of the northwestern corner of the tailings dam The current alignment entails the removal of the acidified surface water from the tailings in drainage trench C 10 which later merges with the arsenic laden effluent emanating from the La Paloma Mine portal, as shown in Figure 1 After the convergence of C 10 and the effluent from La Paloma, the combined flow is referred to as drainage trench C 11 Approximately two hundred meters later, the clean surface water flowing in diversion canal C-12 outfalls into C 11 There are three main complications that arise with the current drainage trench configuration 1) The surface water ponding on the surface of the tailings dam near the north-western corner which flows in C-10 becomes acidified unnecessarily, 2) the arsenic-laden effluent from the La Paloma mine (not owned by CMNP) outfalls into the drainage trenches which flow to sampling point XIV, which is regulated by the PAMA for CMNP, and, 3) the clean surface water flowing in C-12 outfalls into C-11 and is unnecessarily contaminated by effluents from San Felipe and La Paloma

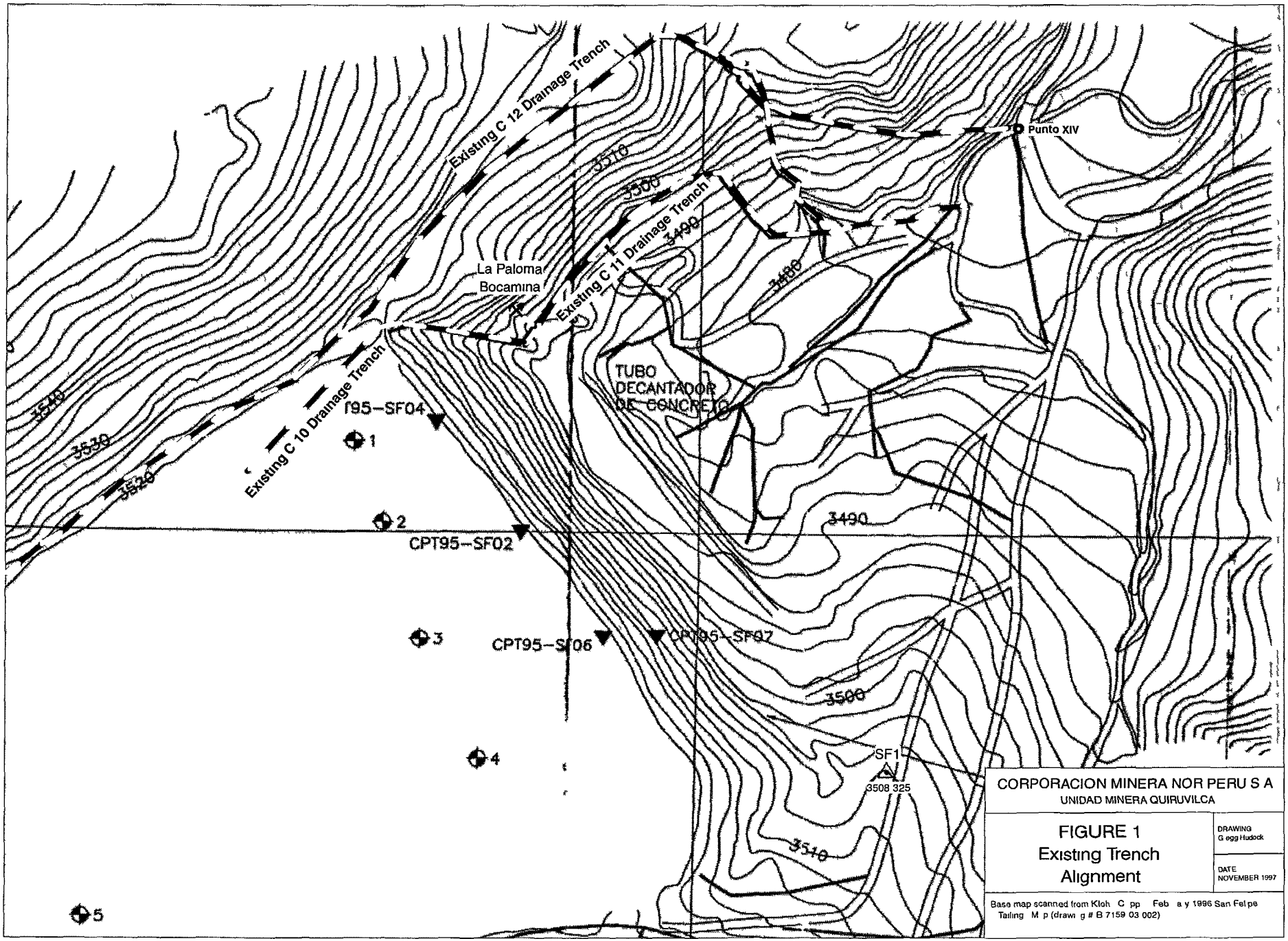
Mitigation of these problems involves re-alignment of the several drainage trenches The key feature is to eliminate the current environmental liability born by CMNP under their PAMA due to the mixing of the La Paloma mine portal effluent with the acid waters from San Felipe One long-term solution for eliminating the unnecessary contamination of clean surface water in the diversion canal C 12 is to prevent it from outfalling into C-11 For example, although a new pipe will be required it is desirable to re-align C-11 so that it flows under the Shorey Road at a location downgradient of sampling point XIV, as shown on Figure 2 If this change is made, it then makes sense to relocated the existing C-12 canal to a position between the face of the tailings dam and the La Paloma mine portal The re-aligned trench should extend further downhill from the current 90 degree bend in C 10 where it turns to flow toward La Paloma as shown in Figure 2 The flow in the new C-12 should not merge with the existing C-11, but should flow somewhat parallel to the existing C-11 trench The proposed C-12 trench will ultimately merge with the other San Felipe trenches near sampling point XIV This alignment enables the clean water in C-12 to be used for dilution after the acid waters in the other trenches (D1-9) are treated by passive techniques such as the PGB In the long-term, only uncontaminated water will flow in the re-aligned C-12

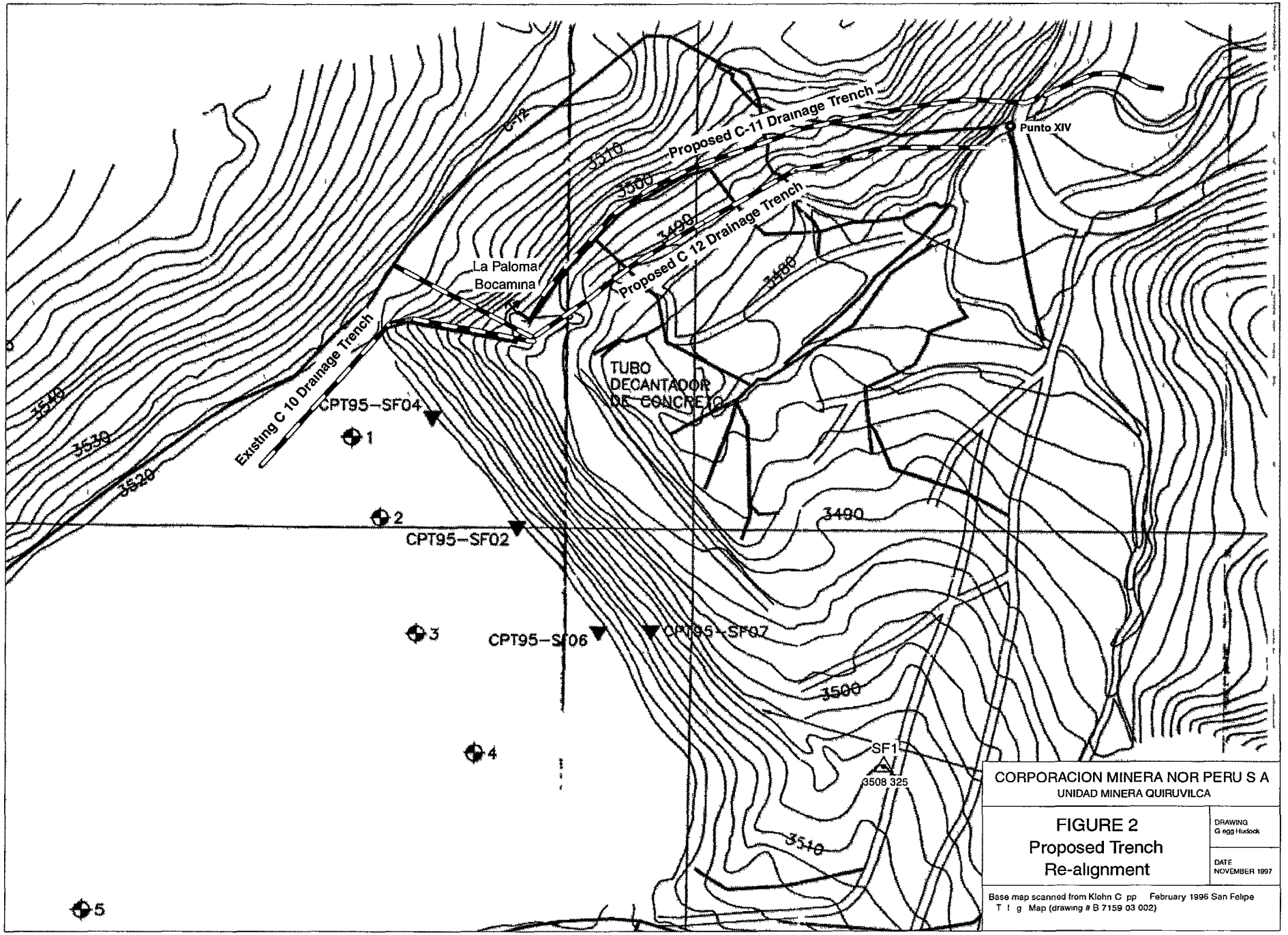
The short-term solution for the management of flows in trench C-10 involves its disconnection with C-11 and confluence with the re-aligned C-12 trench The net result of the re-alignment of C-10 and C-12 effectively isolates the La Paloma effluent in the existing C-11 trench The proposed geosynthetic re-inforced wall design calls for the complete elimination drainage canal C-10 (see Appendix E) The ponded water which currently flows into drainage trench C-10 will be re-directed toward the inlet to the decantation line at the southwestern end of the San Felipe tailings dam In the long term, the decantation line will be extended to outfall on the downgradient side of the PGB near sampling point XIV Like C-12, this cuts down on the volume of water to be treated by a passive treatment technology and provides maximum dilution of post-treated water

Coupled with trench re-alignment the existing diversion canals flanking both sides of the tailings dam should be dredged to improve the flow capacity of these canals Since the dredged material is likely to be very fertile, it should be spread on the tailings to encourage re-vegetation near the southern end of the tailings The same practice should be followed for the soils excavated for the new trench alignments C-11 and C-12 because more soil fertility is needed on the tailings than in the portions of the existing trenches that will be backfilled and decommissioned There are several piles of soil having marginal fertility on the San Felipe valley floor that can be used to backfill the decommissioned portions of drainage trenches

Erosional and Seismic Stability of the San Felipe Tailings Dam

The PAMA for Unidad Minera Quiruvilca incorporates a $1 2 million estimate for the closure of the San Felipe tailings dam based on a re-grading scheme and capping of the tailings dam with low permeability soils The rehabilitation and capping option was prepared by Klohn-Crippen (1996) There are two main issues pertaining to the erosional and geotechnical (seismic) stability that must be addressed to ensure the long-term stability of the San Felipe tailings dam, regardless of which environmental protection option is ultimately implemented


Existing C 12 Drainage Trench
Existing C 11 Drainage Trench
Existing C 10 Drainage Trench
Punto XIV
La Paloma
Bocamina
TUBO
DECANTADOR
DE CONCRETO
3510
3500
3490
3480
3540
3530
3520
CPT95-SF04
CPT95-SF02
CPT95-SF06
CPT95-SF07
1
2
3
4
5
SF1
3508 325
CORPORACION MINERA NOR PERU S A
UNIDAD MINERA QUIRUVILCA
FIGURE 1
Existing Trench
Alignment
DRAWING
G egg Hudock
DATE
NOVEMBER 1997
Base map scanned from Kloh C pp Feb a y 1996 San Fel pe
Tailing M p (drawi g # B 7159 03 002)


Proposed C-11 Drainage Trench
Punto XIV
Proposed C 12 Drainage Trench
La Paloma
Bocamina
Existing C 10 Drainage Trench
TUBO
DECANTADOR
DE CONCRETO
CPT95-SF04
CPT95-SF02
CPT95-SF06
CPT95-SF07
SF1
3508 325
1
2
3
4
5
3490
3500
3510
3520
CORPORACION MINERA NOR PERU S A
UNIDAD MINERA QUIRUVILCA
FIGURE 2
Proposed Trench
Re-alignment
DRAWING
G egg Hudock
DATE
NOVEMBER 1997
Base map scanned from Klohn C pp February 1996 San Felipe
T l g Map (drawing # B 7159 03 002)

There are three major concerns where erosion is concerned The face of the tailings dam is highly eroded and sediment transport of tailings affects both the overall geotechnical stability of the dam as well as the efficacy of any passive treatment technology that may be used to treat the acid waters at San Felipe During the July site visit the Georgia Tech team observed small crystals of pyrite flowing with other sediments in the drainage trenches and on the surface of the tailings Judging from the accumulation of sediments where the toe drains outfall into the drainage trenches, it appears that the existing toe drain system does not prevent the piping of tailings into drainage trenches D 1 to D-3 and D-5 to D-9 The piping of tailings has long-term consequences on geotechnical stability and ongoing differential settlement of the surface of the tailings dam A new subdrain system or additional drains may be needed to minimize the flows in the existing toe drains There is another facet of erosion that has a more social dimension Animals such as frogs, birds, pigs, cows, bulls, sheep, and burros in combination with their tracks (footprints) were ubiquitous in and around the San Felipe tailings dam This observation suggests in part, that open grazing of livestock on the re-vegetated portions of the tailings is a common practice encouraged by the indigenous peoples Pigs were observed burrowing in the re-vegetated areas of the San Felipe tailings dam Birds were nesting in the same areas The impact of these animals on the long term performance of an impermeable liner is discussed at the end of the next section

Another issue of great concern is the geotechnical and seismic stability of the San Felipe tailings dam Regional seismic activity (1970) resulted in the liquefaction and failure of the Amirvilca tailings dam There are several factors which suggest that the San Felipe tailings dam may be susceptible to a liquefaction type failure during an earthquake The term liquefaction is used to describe the uncontrolled deformation of a porous material when excessive pore water pressures are not dissipated When the pore pressure equals the effective stress ($u = \sigma$), liquefaction occurs Large porewater pressures greatly impact the liquefaction potential of soils and tailings under repeated or sudden strains During the November 1996 and the July 1997 visits, large areas of ponded water were observed on the surface of the tailings, a water saturated condition being one of the main issues related to poor seismic performance of tailings In contrast to previous site visits, in August 1997 the tailings were observed to be much drier, with lower flowrates and less ponded water However an artesian condition (an upward flow of water) was discovered at peizometer #5 A similar condition was reported by Klohn-Crippen (October 18, 1995) Although the state of stress and liquefaction potential of the tailings in the vicinity of peizometer #5 was not specifically evaluated, the observed artesian condition in peizometer #5 indicates a large pore water pressure buildup within the tailings Ground movements (i e , earthquakes) increase the probability of liquefaction occurrence, therefore, a detailed liquefaction analysis of San Felipe tailings should be completed to evaluate the likelihood of a tailings slope failure In the interim dewatering the tailings to decrease the pore water pressures throughout is recommended

In the letter dated 18 October 1995, Klohn-Crippen recommended that a detailed seismic evaluation be conducted for the San Felipe tailings dam These recommendations were based on the observed water elevations in the existing peizometers which suggested a relatively large thickness of saturated tailings While it is clear that Klohn-Crippen evaluated the liquefaction potential based on corrected SPT values $(N_1)_{60}$ derived from correlations utilizing available CPT test data (ConeTech, 1995) for the Santa Catalina Tailings dam it is not known whether they have repeated the analysis for San Felipe Our preliminary analyses using CPT- and SPT-based methods indicate that the San Felipe tailings dam has marginal stability with respect to seismic shaking We (also) recommend that the seismic stability of the San Felipe tailings dam be more thoroughly investigated A study of this kind is envisioned to be an integral facet of any closure or remediation strategy implemented at San Felipe If the San Felipe tailings dam liquefies, any passive technology located downstream of the tailings will be destroyed

San Felipe and the Programa de Adecuacion y Manejo Ambiental (PAMA)

The PAMA currently incorporates the re grading scheme and capping of the tailings dam with low permeability soils as the remedial approach for San Felipe based on a review of the PAMA and two reports authored by Klohn-Crippen (1995,6) The proposed rehabilitation and closure alternative is estimated to cost $1 2 million with a 10% annual maintenance cost The Klohn-Crippen scheme has a purely geotechnical and hydrological emphasis, i e the cost of treating the acid waters from San Felipe is not addressed While a capping option may potentially reduce the flow of acid waters, it will not eliminate them Given the high concentrations of iron (3-5,000 mg/l), copper (1-300 mg/l), zinc (1-600 mg/l) and manganese (20-100 mg/l) emerging from the drainage trenches at San Felipe, some form of water treatment will almost certainly be required As such, the true environmental cost for

compliance with the PAMA may be under-estimated by the Klohn-Crippen rehabilitation and closure alternative Moreover, with the exception of its own agreement with CMNP, Georgia Tech is not aware of any consulting engineering reports furnished to CMNP which have as their primary focus the water quality objectives to be attained in the San Felipe valley for purposes of compliance with the PAMA

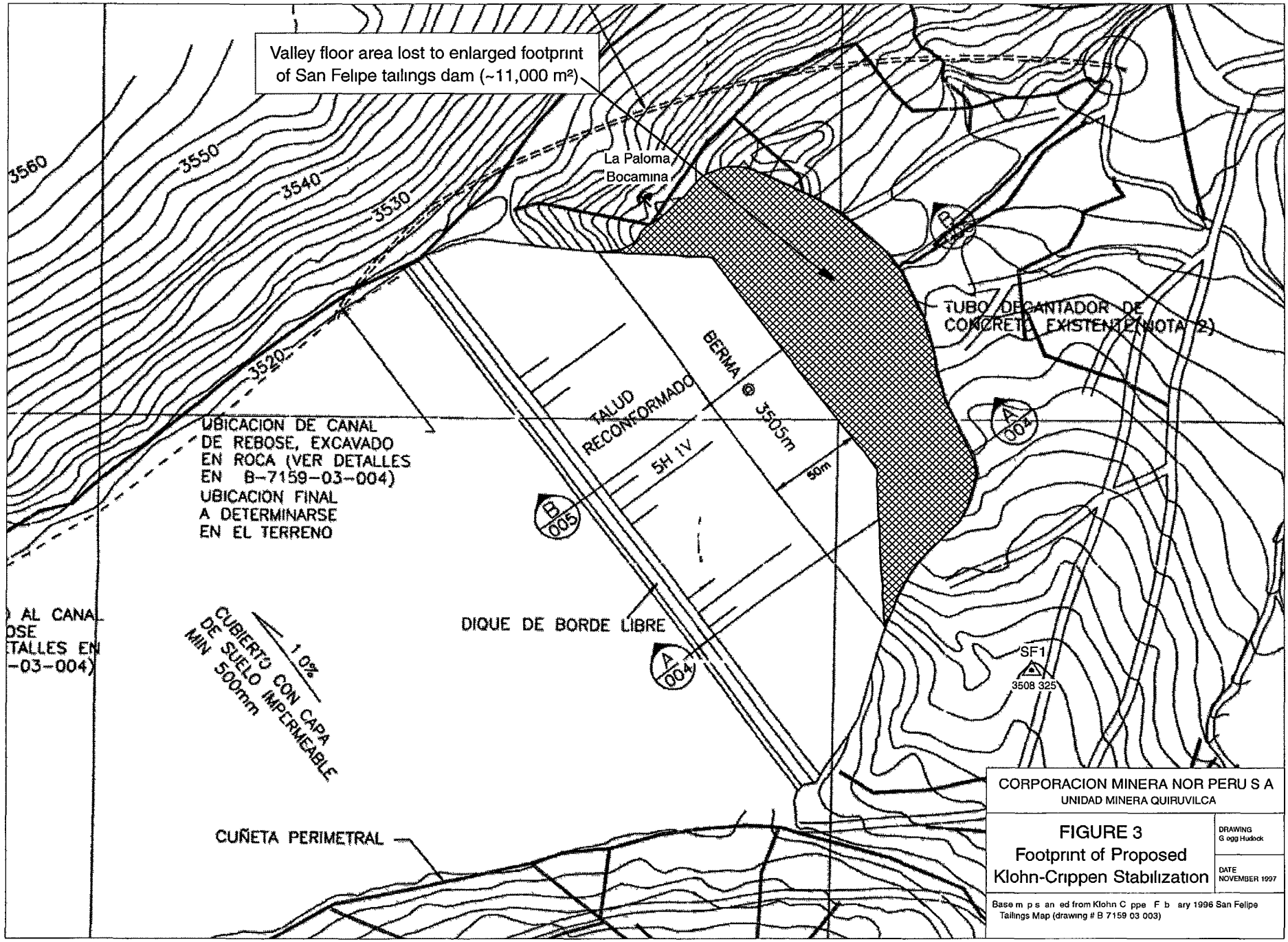
In addition to not directly addressing the environmental treatment of acid waters, the contract documents and drawings provided to CMNP by Klohn-Crippen (7 March 1996) for the rehabilitation and closure plan are not accompanied by a seismic study demonstrating the superior performance of the new geometry over the existing configuration of the San Felipe tailings Another drawback to the Klohn-Crippen scheme is that it does not illustrate how the La Paloma effluents will be de-coupled from the San Felipe effluents Also the re-graded profile abuts C 10/C 11 adjacent at the La Paloma mine portal, as shown by the approximate footprint of the re-graded tailings on Figure 3 Although the exact locations are not known, there are a few unmapped crevasses located near the northeastern corner of the tailings dam in the vicinity of surveying point SF1 which may be intersected by the new footprint Moreover, the extension of the tailings toward the Shorey road reduces the physical space available on the valley floor by approximately 11,000 m^2, i e , a portion of the space required to implement passive remediation of the acid waters The space reduction may potentially eliminate passive technologies from consideration leaving CMNP with two main options pumping the acid waters to the proposed SX/HDS plant in Shorey, or constructing a water treatment plant at the bottom of the San Felipe valley The extension of the tailings dam also increases the total surface area of the tailings (top, bottom and sides) through which rainwater can infiltrate and groundwater can permeate The re-sloped surface of the tailings dam in the Klohn-Crippen scheme has the potential to also convert the existing C-12 to an acid water if erosion of the cap occurs Since extension of the tailings will submerge the existing drainage trenches (D-1 to D-3 and D 5 to D 9) it is not clear how these flows will be managed in the granular subbase If sediments continue to enter the existing drainage trenches, it is conceivable that the granular subbase may eventually clog with fines While these issues may not be insurmountable, they are issues that must be addressed

Also with a capping option several non technical issues arise The long term integrity of an impermeable cap placed on the San Felipe tailings dam is likely to be highly compromised by grazing livestock and burrowing animals (pigs) During meetings with CMNP personnel and their consultant, Ing Felipe Injoque, it was discussed that fencing-off the tailings dam was an undesirable option due to theft of the fence, or its being breached by indigenous peoples to permit livestock grazing Therefore, a closure plan which does not interfere with the indigenous peoples or draws their attention is likely to be the most effective in the long term

Coupled Environmental Restoration and Geotechnical Stability at the San Felipe Tailings Dam

The conceptual strategy outlined here stems from the opportunity presented by the wetlands at the southwestern end of the tailings Water quality data recently obtained on 14 August 1997 by CMNP for Punto 'A' located near the inlet to the decantation line at the southwestern end of the tailings indicates that the surface water in the already re-vegetated zone of the tailings surpasses the effluent standards set forth in the PAMA for Unidad Minera Quiruvilca In essence water flowing on the tailings through the re-vegetated area is not only buffered, but acidification is prevented and metals concentrations are suppressed

In order to take advantage of existing wetlands processes, the eroded face of the existing tailings dam should be retrofitted with a geosynthetic wall which provides reinforcement of the cohesionless tailings, as described in Appendix E Briefly, the existing face of the tailings has a 2H 1V slope and is deeply channeled by erosion The geosynthetic wall can be constructed beginning at the base of the face of the existing tailings dam with a vertical slope of 1V 1H, or in a terraced style with 5 meter benches depending on the optimization of geotechnical and seismic stability, wall angle and cost The geosynthetic wall will be coupled with the installation of a new subdrain system consisting of approximately five horizontally-drilled subdrains to de-water a 300 meter wide section or block of tailings running parallel to the existing crest of the tailings dam This reinforced, dry block of tailings will contain the potentially liquefiable wetlands portion of the tailings dam to the southwest In essence, the geosynthetic wall and subdrain systems will provide for the overall erosional, geotechnical and seismic stability of the San Felipe tailings dam while fostering enlargement of the wetlands


Valley floor area lost to enlarged footprint of San Felipe tailings dam (~11,000 m²)
La Paloma Bocamina
3560
3550
3540
3530
3520
TUBO DECANTADOR DE CONCRETO EXISTENTE (NOTA 2)
BERMA @ 3505m
TALUD RECONFORMADO
5H 1V
50m
UBICACION DE CANAL DE REBOSE, EXCAVADO EN ROCA (VER DETALLES EN B-7159-03-004)
UBICACION FINAL A DETERMINARSE EN EL TERRENO
B 005
A 004
DIQUE DE BORDE LIBRE
CUBIERTO CON CAPA DE SUELO IMPERMEABLE MIN 500mm
1.0%
SF1
3508 325
CUÑETA PERIMETRAL
CORPORACION MINERA NOR PERU S A
UNIDAD MINERA QUIRUVILCA
FIGURE 3
Footprint of Proposed Klohn-Crippen Stabilization
DRAWING
G ogg Hudock
DATE
NOVEMBER 1997
Base m p s an ed from Klohn C ppe F b ary 1996 San Felipe Tailings Map (drawing # B 7159 03 003)

This approach to geotechnical and seismic stability is compatible with the hydrological, environmental and social issues pertaining to the San Felipe tailings dam The synergy between the geosynthetic wall and wetlands makes it possible to convert the acid water currently flowing in C-10 to a clean water source for dilution purposes by re-directing it into the decantation line The geometry of the geosynthetic wall does not interfere with the flow emerging from the La Paloma mine and it also provides for the space to re-align C-12 to a position downgradient of C-11, eliminating their confluence Without changing the existing footprint of the tailings dam, the geosynthetic wall option allows for the physical space for passive treatment technologies (such as the PGB) of the acid waters from San Felipe

A special opportunity exists to merge the geosynthetic re inforced wall, subdrain system and porous geochemical barrier (PGB) with the primary treatment of the sewage and wastewater from Shorey The current estimate for treating the wastewater in the PAMA is $125,600 with a 10% operating cost During the July and August trips the use of the sewage and wastewater to neutralize the acid waters from San Felipe was discussed The method of conveyance for the wastewater from Shorey would occur mostly in a pipe or trench dug along the Shorey road The soil excavated in the process of trenching also could be used to provide a cover on the tailings to promote re-vegetation The location and conveyance method from the Shorey road to the tailings has not been evaluated Another strategy would be to retrofit the Tubería Depositade Relaves San Felipe to carry wastewater

The long-term strategy is to convey (by gravity flow) the wastewater from Shorey to San Felipe where it would outfall into the acid waters from San Felipe at a location immediately upgradient of the PGB in order to dilute the acid water with a microbially diverse, buffered, and nutrient (organic carbon, nitrogen) rich water solution The rationale behind this is that the eH-pH characteristics of the acid water and wastewater are essentially opposite and that an anaerobic and reduced condition is needed to rapidly neutralize the acid water and to immobilize the metals It therefore may be possible to achieve long-term treatment of both effluents with very little effort

In the short-term, the wastewater from Shorey could be used to accelerate the re-vegetation of the San Felipe tailings dam Recall that C-10 will be eliminated and the surface re-sloped near the crest so that the surface water on the tailings drains toward the southeastern end The surface water may still become acidified as it flows toward the wetlands zone, inhibiting the extension of the wetlands toward the crest of the dam As the re-vegetated zone slowly enlarges toward to the crest of the dam, an organic layer will form on the tailings This layer, once formed, will reduce the quantity of water and oxygen diffusing into the surface of the tailings resulting in the acidification of the tailings Re-vegetation process can be accelerated by releasing the sewage and wastewater along the crest of the tailings dam in a fashion similar to the original placement of tailings As the sewage flows toward the southwestern end, the surface water is buffered and the tailings are fertilized in the process

The surface water quality on the tailings appears to be satisfactory in the wetlands area of the San Felipe tailings Since there is only one water quality measurement recorded for Punto "A", this location should be monitored to establish the long-term trend in surface water quality on the surface of the tailings dam Since the measurement of Punto 'A" was obtained in the dry season, it is expected that results obtained in wetter periods to be of better quality However there is one unresolved issue pertaining to this geo-environmental strategy that may be of concern While the surface water is of good quality at the southwestern end of the tailings, it is not known whether there are any potential toxicological effects on the local livestock and wildlife due to the concentrations of arsenic, copper and lead in the tailings themselves (as evidenced by their corresponding concentration in the acid waters from the toe drains) It may turn out that the burrowing and nesting activities in the wetlands should be prevented due to their deleterious impact on the health of the local animals and livestock It is not known whether the grasses and shrubs are metals tolerant, or if they concentrate metals that are subsequently ingested by animals

Conclusions and Recommendations

The environmental remediaton and monitoring of the San Felipe tailings dam is closely linked to other activities which may alter or affect the geotechnical or hydrological aspects of the tailings dam Changes in any of these features without due consideration of other governing issues in the valley may negatively impact any or all of the works necessary in the San Felipe valley We have identified the following issues of concern

1 Georgia Tech should be constantly updated with information pertaining to geotechnical, hydrological and environmental work occurring at Unidad Minera Quiruvilca New environmental data waste streams and engineering works can significantly impact the remedial strategy for San Felipe and its associated cost For example, arsenic concentrations emanating from the San Felipe tailings were first observed in November 1996 (again in August 1997) However, Georgia Tech was not made aware of the November 1996 data while the agreement was negotiated with CMNP (finalized May 1997) As a result we have had to subsequently revise our strategy and testing approaches for our work at San Felipe

2 The effluent from the La Paloma mine portal should be isolated from the San Felipe effluents since it represents an unnecessary environmental liability under the PAMA for Unidad Minera Quiruvilca The concentrations of arsenic emanating from this portal alone exceed the PAMA An approach similar to the re alignment scheme identified above should be designed and implemented as soon as possible

3 The drainage canal flanking both sides of the San Felipe tailings dam should be dredged and repaired as soon as possible Substantial flow of surface water onto the tailings occurs near the midpoint of the southern edge of the tailings Construction of a temporary dike may be necessary to direct the surface water toward the decantation line and away from the center of the tailings

4 A detailed seismic study should be conducted of the San Felipe tailings dam as soon as possible The seismic study should be geared to collecting data that will also provide baseline data that can be used for geotechnical design of either the rehabilitation and closure scheme proposed by Klohn-Crippen, or alternative geotechnical and hydrological solutions such as the geosynthetics re-inforced wall and subdrain Some data exists on earthquake recurrence intervals magnitude, ground motions, etc, in Quiruvilca but this needs to be better integrated with specific site information This evaluation should include laboratory and field components to determine cyclic triaxial testing under varied densities and overburden pressures, resonant column torsional shear to evaluate the variation of properties with strain, and CPT and in-situ shear wave testing

5 The proposed geosynthetic wall and subdrain system should be evaluated more thoroughly as soon as possible At the present time it appears not only more cost effective than the Klohn-Crippen option but it appears to provide CMNP with more management options and flexibility for long term care This evaluation should include a laboratory component to determine UV and chemical resistance of the geosynthetics, pullout tests geosynthetic-tailings interfacial shear behavior, permittivity, etc

The experimental and analytical aspects of issues 4 and 5 are beyond the scope of the existing agreement between the Georgia Institute of Technology and Corporacion Minera Nor Peru However, we believe that if our scope of work is expanded and work commences in January 1997, activities related to issues 4 and 5 can be completed and included with our annual report due May 1997 We are currently preparing a summary report and proposal which prioritize data needs to be submitted to CMNP for consideration during our upcoming visit to Peru in December It has been a pleasure working with you on this project and we look forward to continued cooperation in this and other matters If you have any questions please do not hesitate to contact me

Sincerely Yours,

Dennis G Grubb
Assistant Professor of Civil & Environmental Engineering

cc
Mr Michel Robert Pan American Silver
Ing Andres Dasso, Pan American Silver
Ing Mario del Rio, Gerente General
Mr Alan Davis, USAID/Peru
Mr Gilbert S Jackson, USAID/DC-LAC
Dr Joseph P Martin, Drexel University

APPENDICES

Appendix A

CMNP/USAID Daily Meeting Log, 1July 1997 - 28 August, 1997

Tuesday, July 1, 1997

Depart Atlanta Hartsfield International Airport at approximately 12 00 All luggage and necessary equipment was checked in with American Airlines Global Positioning System (GPS) shipped as air cargo via American Airlines (not possible to check as excess baggage) Arrive Lima Peru at approximately 11 00 P M Escorted through Peruvian Customs by USAID personnel Learned from American Airlines personnel that air cargo would arrive in Serlipsa and that it would have to clear customs before being released

Wednesday, July 2, 1997

00 30 - Arrived at the Hostal El Doral
09 00 - Security Briefing with the Resident Security Officer (RSO) at U S Embassy
10 30 - Meeting with Embassy Cultural Affairs Officer, Mr Helmut Fischer Grubb presented details of acid mine drainage work Fischer provides member list for Fulbright Commission and recommends that Grubb contact Guillermo Payet of Southern Peru, a member of the Fulbright Comission
11 00 - Meeting with Embassy Economics Secretary Krishna R Urs to brief him on acid mine drainage work Fulbright Fellowship, and additional resources to support environmental work in the mining sector According to Urs the Fulbright Commission has a strong interest in mining project due to the sociological and environmental emphasis
12 45 - Meeting with Dr Marcia Koth de Paredes Executive Director of US-Peru Fulbright Commission Dr Grubb describes work to be conducted a survey of the environmental mining problems in Peru, and their applicability to passive treatment techniques Fulbright focus has a Peru-wide emphasis whereas USAID sponsored project is focused on the mining activity in Quiruvilca Koth de Parades requests that Grubb participate in US Embassy-PUCP teleconference during Fourth of July party to publicize Fulbright activities Grubb agrees
14 45 - Meeting with Ing Giselle Naranjo Naranjo Mining Engineering Section Coordinator of Pontificia Universidad Catolica del Peru (PUCP) Discussed Fulbright Fellowship (teaching and research components), toured the laboratory facilities of the Mining Engineering Section Naranjo introduced Grubb to Mr Daniel Landers and Mr David Machuca, mining engineering students interested in coloaborating with Dr Grubb on environmental projects in the mining sector Naranjo and Grubb agree to research and inventory Peruvian mining effluent problems with end goal of publishing a journal article in the international mining journals The second foci of the research is to inventory the types of industrial byproducts available in Peru

Thursday, July 3, 1997

09 00 - Meeting with Mr Alan Davis at the USAID office Discussed unresolved clause issues attached to USAID purchase order with Georgia Tech Discussed strategies to expedite clearance process for GPS equipment held in Peruvian Customs office Grubb signs affidavit releasing equipment to US Government to facilitate customs process since the equipment is in Peru under auspices of USAID
11 30 - Lunch with Mr Alan Davis and two visiting scholars from the University of Kent researching optimization strategies to enhance productivity and environmental protection in the fishmeal industry
15 00 - Organizational meeting at US Embassay-PUCP teleconference to be conducted on 4 July
16 00 - Organizational meeting with Mr Luis Jaime Castillo, Director of Promotion and Development at PUCP and Naranjo about Fulbright Approach of Fulbright discussed along with stratagies for long term cooperation between PUCP and Georgia Tech including student and faculty exchanges, recruiting and joint research proposals

Friday, July 4, 1997

10 00 - Grubb participates in teleconference with Ms Erica Fields another Fulbright Fellow

14 00 - Luncheon with Dr Oscar Frias of Consorcio Minero Horizonte The Horizonte Mine is located in Parcoy, La Libertad Department Frias outlines needs to control cyanide waste effluent waste problems and invites Georgia Tech team to visit mine to evaluate preliminary feasibility of passive treatment technologies to attenuate cyanide Grubb discusses the US Government requirements for in-country travel under activities sponsored by USAID Grubb later learns that Parcoy is in travel restricted area and that obtaining a security clearance is not likely

15 00 - Met with Naranjo and Landers to discuss strategy to identify the locations of various agricultural, mining and heavy industries in Peru to correlate the location of available industrial by-products and mining sites Discussed plan to obtain various mines' PAMAs to understand the nature of the Peruvian mining effluent problems by region Also discussed the need to undertake a survey of the watershed studies sponsored by the Ministry of Energy and Mines (MEM) to index the river quality in Peru Discussed importance of metals immobilization and amieloration with natural plant species

Saturday, July 5, 1997

09 00 - Grubb conducts teleconference between US Embassy- PUCP from PUCP campus

Sunday, July 6, 1997 - No meetings

Monday, July 7, 1997

09 30 - Grubb and Hudock meet with Landers and Muchaca at PUCP Action items are to

a) Identify native plant species in the Andes, specifically any species which can be classified as metalophiles The plan is to work in cooperation with the Instituto Nacional de Recursas Naturales (INRENA)

b) Identify industries throughout non-coastal Peru to quantify and classify the available industrial by-products in close proximity to various mining towns

c) Identify the materials and natural resources utilized by mines, stock supplies, and the by-products of such a consumption

d) Identify the native soils throughout the Andes

e) Coordinate with MEM to analyze EVAP and PAMA for Peruvian mines by regional department

f) Use the above information to conclude on the practicality of utilizing a passive treatment technology to treat mining effluent problems (cyanide, mercury, acid mine drainage) in Peru

16 00 - Meeting with Ing Andres A Dasso, and Ing and Mario del Rio, the respective General Directors of Pan American Silver (PAS) and Corporacion Minera Nor Peru (CMNP) to discuss the Quiruvilca/Shorey project Dr Grubb reviews project focus to integrate the passive technology intended to treat the acid waters and sewage simulatenously that utilizes locally available soils, industrial and agricultural by-products, and sewage Natural re-vegetation of the San Felipe tailings dam is discussed and the interest of Georgia Tech team to evaluate the potential of local grasses and shrubs to grow in the tailings Heavy equipment inventory requested for Shorey/Quiruvilca. Information requested concerning environmental testing database and weather station data for Quiruvilca Inquiries made about wastewater management plan, treatment facilities and layout of piping network in Shorey Dasso indicates that Mr Felipe Injoque, an environmental consultant, is assisting CMNP in Quiruvilca Grubb informs Dasso of CESEL reports that have bias toward contamination form Quiruvilca and Salpo Dasso indicates PAS is interested in acquiring rights in Salpo Grubb offers to visit Esperanza mines in Salpo to conduct site walk to guage potential environmental problems

Tuesday, July 8, 1997

11 00 - Meeting with Mr Felipe Injoque, an independent environmental consultant Injoque was retained to develop and recommend environmental sound protocols, hygiene and practices Unidad Minera Quiruvilca can utilize Grubb and Injoque exchange information on work efforts at Quiruvilca to ensure compatibility of aims and work effort Mr Injoque who also consults for Empresa Minera Iscaycruz S A , suggests that Georgia Tech team present passive environmental techniques to Iscaycruz as they are likely to be very interested in such approaches

13 00 - Hudock and Landers consult with staff in PUCP Geography department to follow-up on actions items from 7 July Geographic information, if available, is over very large scale Various ministries of the Peruvian government posses this information in GIS format Therefore an attempt will made to access this data

15 00 - Meeting with Castillo of PUCP Grubb and Castillo discuss framework for inter university cooperation on USAID-CMNP project Discuss contracting mechanisms for potential utilization of laboratory facilities for analytical and column testing

Wednesday, July 9, 1997

08 30 Meeting with Ing Jose Mogrovejo, Director General Asuntos Ambientales of the Ministerio de Energia y Minas (MEM) and Grubb, Hudock, Naranjo, and Landers Disucssed focus of Fulbright Fellowship and the USAID/CMNP Project Grubb requests access to EVAP, PAMA and watershed study informtion for mining activities in Peru by Department Mogrovejo indicates that watershed reports are in review Also while all reports and data are public information MEM maintains a policy that copies cannot leave the premises nor can personal photocopiers be used MEM can provide copies at a cost of $1 00/page Mogrovejo suggests that perhaps it may be possible to loan some reports to the university Grubb and Mogrovejo agree that the first Departments to be evaluated are La Libertad and Hauncavelica (Grubb toured Huancavelica in June 1996) Grubb offers to review the CESEL report for the Rio Moche Valley watershed in La Libertad Mogrovejo accepts

Thursday, July 10, 1997

09 00 - Hudock, Landers, and Machuca visit INRENA and the Agricultural Institute to obtain information on local soils available in the La Libertad and Huancavelica Departments Soil maps, agricultural maps, and plant life maps are available at IRENA for both La Libertad and Huancavelica Departments and were both expensive and incomplete (partial) The agricultural map for La Libertad contained data for several watersheds No information about metalophiles and native plant species was obtainable for the Andes from IRENA Similar informational resources are available at the Agricultural Institute, however, this data revealed the same trends and gaps as those at IRENA

15 00 - Grubb meets with CESEL Engineers, Luis Moreno and Jorge Salas Their sampling methods and locations for the Rio Moche watershed are discussed CESEL does not provide exact locations of sampling points either descriptively or on maps It appears that CESEL has focused on identifying contamination inputs from known mining sources Inputs to Rio Moche from villages, towns municipalities (sewage and garbage), and industry other than mining such as agriculture automobile repair facilities have not been quantified This suggests an unfair bias leaning toward mining industry as sole contributors to poor river water quality

Friday, July 11, 1997

08 30 - Grubb, Hudock, and Landers all arrive at MEM to review the watershed study entitled *Estudio de Evaluacion Ambiental Territoral y de Planteamento para la Reduccion o Eliminacion de la Contaminacion de Origin Minero en la Cuenca del Rio Moche* prepared by CESEL Engineers In several areas the report did not satisfy the statement of work prepared by MEM Several mistakes and inconsistencies were discovered throughout the report CMNP's PAMA and EVAP are also reviewed Unfortunately, the review of this report was not completed prior to leaving MEM at 16 30 hrs Return visit planned

16 00 - Grubb and Hudock are informed that the GPS equipment has cleared customs and has been delivered to the Mining Engineering Section at PUCP

17 00 Grubb, Hudock and Landers arrive at head office of CMNP to finalize travel arrangements to Trujillo and Quiruvilca Travel arranged for 13 July

18 00 - Grubb, Hudock, and Landers arrive at PUCP to inspect and collect GPS equipment

Saturday, July 12, 1997

Grubb and Hudock test GPS equipment in Miraflores The windows of opportunity for the best configuration of the NAVISTAR satellites with the GPS receivers are established for San Felipe valley

Sunday, July 13, 1997

10 00 -Grubb and Hudock depart Lima for Trujillo with a driver and CMNP van

18 00 -Grubb and Hudock arrive in Trujillo

Monday, July 14, 1997

08 00 - Grubb and Hudock eat breakfast with Mr Michel Robert of Pan-American Silver to discuss the overall strategy for environmental programs for Unidad Minera Quiruvilca According to Robert a new water treatment plant will be built in Shorey near the crusher to intercept and treat the combined effluents from the mine adits and tailing dams The high density sludge solvent extraction (HDS/SX) plant will produce gypsum ($CaSO_4$ $2H_2O$) and is planned for a Nov 1998 start-up Robert suggests that the re-use of gypsum as a cover material may be beneficial at San Felipe Grubb informs Mr Robert of conceptual approach for the San Felipe tailings and the types of industrial byproducts under consideration Robert indicates that the construction of a coal-fired power plant is under consideration approximately 10 km from Quiruvilca owing to a large local deposit of anthracite coal Grubb suggests that fly ash may serve as excellent material to buffer pH from San Felipe and immobilize metals in the AMD To identify other potential sources of industrial byproducts a consensus emerges that a mass balance should be conducted on Shorey/Quiruvilca to evaluate incoming materials and goods and outgoing waste streams Grubb discusses simultaneous treatment of sewage and AMD from San Felipe Robert describes CMNP s support of environmental programs in the town of Quiruvilca and suggests that Georgia Tech consider or attempt collaboration with the municipality of Quiruvilca on wastewater issues to further enhance environmental awareness in the community Grubb and Hudock describe the land survey to be conducted with the GPS equipment and Robert indicates that a survey of the San Felipe valley, as well as an entire geotechnical investigation was completed in the last 2 years Depart Trujillo for Quiruvilca at 08 30 hrs

12 00 Grubb and Hudock arrive in Shorey and lunch with Mr Jose (Pepe) Pacora, Superintendente de Ingenieria y Proyectos at Unidad Minera Quiruvilca, and Mr Felipe Injoque, CMNP's environmental consultant

13 00 - Grubb, Hudock Pacora, Injoque and Mr Jorge Quispe, Jefe de Media Ambiente meet to discuss the San Felipe tailings dam Grubb requests a copy of the Klohn-Crippen reports dealing with San Felipe Santa Catalina and Amirvilca tailings dam, the conce penetrometer test (CPT) data, and costs estimates associated with each tailings dam The cost of re-grading the tailings without any treatment of the acid waters is estimated at $1 2 million The treatment of Shorey sewage is estimated to cost $125,000 with an operating cost of 10% capital The use of sewage to neutralize AMD is discussed along with a conveyance system to deliver sewage from Shorey to the San Felipe Valley The use of the gutter system along road appears to be most cost-effective alternative The soil and rock excavated to improve the road-side gutter can be used in San Felipe as a cover soil or construction material in San Felipe

The water quality data measured and its frequency are discussed Currently one sampling point is located in the San Felipe Valley point XIV The water quality parameters measured monthly include pH, conductivity, temperature, total dissolved solids (TDS) flowrate, and total copper (Cu) lead (Pb), zinc (Zn), and iron (Fe) Biannually, total arsenic (As), cadmium (Cd), Magnessium (Mn), and cyanide (CN) are also tested Grubb and Injoque recommend expanding the monthly water quality

testing program the drainage ditches (D1-D9) in the San Felipe tailings dam to include the following parameters

Water level/flowrate
Temperature (Centigrade)
pH (field and lab)
Conductivity
Alkalinity (as CaCO3)
Total Dissolved Solids (TDS)
Dissolved Oxygen (DO)
Biochemical Oxygen Demand (BOD)

Aluminum (Al)
Arsenic (As)
Barium (Ba)
Cadmium (Cd)
Calcium (Ca)
Chlorine (Cl)
Chromium (Cr)
Copper (Cu)
Fluorine (F)
Iron (Fe, total)
Lead (Pb)
Magnesium (Mg)
Manganese (Mn)
Mercury (Hg)
Nitrate (NO3)
Potassium (K)
Selenium (Se)
Silver (Ag)
Sodium (Na)
Sulfate (SO4)
Cyanide (CN, total)

It is recommended that these parameters be evaluated on a monthly basis by a third party laboratory which has established effective and reliable data quality assurance/quality control (QA/QC) procedures to ensure the integrity of the environmental testing results It is also recommended that at least two field blanks be included to determine the background concentrations and accuracy of the analytical equipment used by the third party laboratory

14 00 - Grubb, Hudock and Injoque conduct site walk of the San Felipe tailings dam and valley The water in the diversion channels flanking the perimeter of the tailings dam was stagnant in places and seepage was occurring through the embankment allowing water to accumulate in large quantities on top of the tailings dam The south-western and western portions of the tailings dam appeared to be essentially re-vegetated by natural grasses and shrubs, and a natural wetlands has formed which is home to a variety of wildlife including pigs, frogs, tadpoles, insects and birds The pigs have greatly disturbed the surface of the tailings in places effectively converting the tailings into a sty The water leaking onto the tailings eventually split, flowing in opposite directions due to ditches that were naturally eroded into the surface of the tailings toward the decantation line and toward to the face of the tailings dam The surface water ponded on the northern end of the dam flowed into a drainage trench cut into the surface of the tailings dam at approximately 10 liters per minute In turn, this water drained down the face of the tailings dam where the dam intersects the valley wall The drainage trenches below the tailings dam (D1, D2 D3 D5, D6, D7 D8, D9), with the exception of the decant line (D4), all discharged water with a pH between 1 & 3 Arsenic contaminated effluent continues to seep from the La Paloma and merge with the effluent from the San Felipe tailings The face of the tailings dam is heavily eroded with washed-out tailings scattered in the valley below

18 00 - Grubb, Hudock, and Injoque discuss intergrated passive treatment concept for the San Felipe tailings The plan includes diverering all surface water on the tailings to the decantation line at the southwestern end of the tailings tam where the river water is intercepted Judging from the water quality of decantation line and the abundance of biota and vegetation on the tailings, the surface water on the tailings is anticipated to be neutral Even if it not, the water quality at D-4 suggests that the surface water on the tailings does not significantly impact the quality in the decantation line The redirection of the surface water to the decantation line has the potential to significantly reduce the amount of water to be treated by passive treatment technologies such as the PGB

The second aspect of water management involves isolating the acid waters from San Felipe from the La Poloma effluent containing arsenic The re direction of the surface water on the tailings to the

decantation line will eliminate the need for drainage trenches C-10 and C-11 Realignment of C-10 and C-11 can also enable the drainage from the western perimeter channel to be permanently isolated from La Poloma effluents This can be achieved by feeding the westerm perimeter channel into the top of trench C-10 at the face of the tailings dam Then, by disconnecting C-10 and C-11 and by extending C-10 further downhill than the existing C-11 trench, it is possible to isolate the La Poloma effluents from those originating from San Felipe The downgradient portion of C-11 could be re-aligned so that it does not merge with the San Felipe waters until (or after) Sampling Point XIV

The third aspect of the water management plan for San Felipe involves the diversion of the perimeter channels and decantation line water to a location immediately downgradient of the PGB to achieve additional dilution and pH buffering of San Felipe waters prior to Sampling Point XIV This may require an additional section of buried pipe for the decantation line (D-4) since it empties into the central drainage trench

The fourth aspect of the water management plan for San Felipe involves the utilization of sewage from Shorey to help neutralize the acid waters and to provide a continuous source of nutrients, microorganisms and organic carbon immediately upgradient of the PGB This strategy should foster metals immobilization and pH buffering prior to water infiltration into the PGB Pore clogging of the PGB is therefore potentially reduced while the sorption and buffering capacity of the PCB are preserved, extending the service life of the PGB The use of the gutter system along Shorey road is envisioned to be most cost-effective method to convey the sewage to San Felipe The soil and rock excavated to improve the road-side gutter can be used in San Felipe as a cover soil or construction material in San Felipe A question to be resolved involves the sewage loading rates

Tuesday, July 15, 1997

09 00 - Commenced all day GPS survey of the San Felipe tailings dam, piezometers, and drainage trenches Results contained in trip report

Wednesday, July 16, 1997

09 00 - Continued with the survey of the San Felipe tailings dam Locations of seepage through perimeter channels and surface vegetation on the tailings surface were mapped BASE receiver batteries expire before completion of survey

13 30 - While batteries recharge, Grubb, Hudock visit Quiruvilca, CMNP's saw mill and the Santa Catalina tailings dam

18 00 - Evaluation of surveying data indicates that more than half of the survey points from the morning session cannot be processed because the reference data from the BASE receiver were not collected after the battery supply was exhausted It is also learned that approximately 20 points from surveying session on Tuesday could not be processed due to bad satellite/rover configurations and position dilution of precision (PDOP) values

Thursday, July 17, 1997

08 00 - Re-surveyed missing data points from Tuesday and Wednesday sessions Malfunctions with BASE were encountered again Fifty percent of data points lost due to satellite tracking problems at BASE receiver

13 00 - Grubb, Hudock, and Mr David Des Rosiers of PAS visit the Esperanza mine located near Salpo in the La Libertad Department Trip lasts five hours including round trip commuting time Details of site visit to Salpo contained in trip report.

20 00 - Hudock re-tests the BASE GPS receiver which now appears to operate properly

Friday, July 18, 1997

08 00 - Grubb and Hudock return to San Felipe to complete the survey of the vegetation on the tailings No problems are encountered

11 30 - Grubb and Pacora hold meeting on CMNP/USAID project while Hudock processes final surveying data and packs equipment Grubb requests the following information

1- Detailed description of stormwater and wastewater system in Shorey for water from toilets, households and casino including layout, flow rates and entry points to Rio Moche Water quality for roadside ditches containing septage also requested
2- UTM or latitude longitude coordinates for reference points SF1 ' and ' C" in San Felipe valley
3- Copy of weather station data from Shorey
4- Monthly quantities of sawdust produced and wood extracted at crusher
5- Copy of reports for HDS/SX plant
6- Copy of PAMA
7- Copy of all water quality data obtained in San Felipe
8- CAD file for San Felipe valley map
9- Inventory of heavy and earth moving equipment
10- List of new public works and construction and any anticipated waste streams
11- Extra copies of San Felipe maps
12- Monthly generation rates of construction debris
13- Facilities to be de-comissioned in next five years
14- Basis of estimate provided by Klohn-Crippen for San Felipe
15- Cost estimate for wastewater treatment in Shorey/Quiruvilca
16- Map of Esperanza mines in Salpo
17- Timetable when earthworks can be undertaken at San Felipe

14 00 - Grubb and Hudock depart Quiruvilca for Trujillo and Lima
22 00 - Grubb and Hudock arrive in Lima

Saturday, July 19, 1997 No Meetings, Grubb departs to US for one week for other Georgia Tech business
Sunday, July 20, 1997 No Meetings

Monday, July 21, 1997

Mr Hudock returns to Pontificia Universidad Catolica del Peru to begin work on transcribing all surveying data to the field books Global positioning system surveying data cannot be completely processed until the baseline control point locations from the surveyors at Corporacion Minera Nor Peru are received

Tuesday, July 22, 1997

Hudock, Landers, and Machuca meet to locate information categorizing the different types of industries throughout Peru The *Peruvian Atlas* available from the Peruvian National Geographic Institute, contains maps of the different agricultural crops grown in Peru as well as locations of various Peruvian industries

Wednesday, July 23, 1997

Hudock, Landers, and Machuca meet to compile all the necessary information found in the Peruvian Atlas Color photocopies are made for use back in the United States

Thursday, July 24, 1997

Mr Hudock searches for a book of plants native to Peru Once again, the *Peruvian Atlas* has a comprehensive list of these No other books are located In US, Grubb has USAID/Georgia Tech contract approved

Friday, July 25, 1997

Hudock begins to set the plans to visit several mines in various departments Likewise, Ing Oscar Frias Martinelli of Consorcio Minero Horizonte S A will be consulted to obtain copies of the all Environmental

Watershed Mining reports conducted by the MEM These reports will be utilized to compose an article about the environmental state of mining in Peru as well as the potential for passive treatment systems at various sites throughout Peru Grubb also wishes to buy a Peruvian Atlas for use back in the United States

Saturday, July 26, 1997 No meetings
Sunday, July 27, 1997 No meetings
Monday, July 28, 1997 No meetings Grubb returns to Lima
Tuesday, July 29, 1997 No meetings

Wednesday, July 30, 1997

13 00 - Grubb presents results of Quiruvilca trip to Davis of USAID and discusses upcoming sampling trip Grubb obtains signed copy of approved USAID/Georgia Tech contract
15 00 - Grubb and Naranjo review lecture materials for *Landfills and Geosynthetics* presentation
20 00 - Grubb, Frias and Hudock meet to discuss strategies and consulting arrangements under USAID contract which includes Frias and PUCP Frias reiterates interest to have Georgia Tech visit the Consorcio Minero Horizonte S A Mine in Parcoy Grubb doubts that U S Embassy will grant clearance Site information is collected for purposes of applying for security clearance Grubb inquires how Frias can help locating and quantifying industrial and agricultural by-products in Trujillo and La Libertad Grubb inquires if Frias can assist in obtaining the watershed reports, PAMAs or EVAPs from MEM for various mines throughout Peru

Thursday, July 31, 1997

09 00 - Grubb lectures on *Landfills and Geosynthetics* at PUCP with Naranjo providing the translation Hudock begins data analysis of CPT data from San Felipe tailings dam collected by Conetec, Inc in 1995 Mr Hudock also begins to research other possible methods to remediate the San Felipe tailings dam
13 30 - Lunch with Naranjo and Landers to discuss the plans for the next month of work Next week, the researchers plan to visit the MEM to finish the review of CESEL Engineer's - Rio Moche Cuenca report, *Estudio de Evaluacion Ambiental Territoral y de Planteamento para la Reduccion o Eliminacion de la Contaminacion de Origin Minero en la Cuenca del Rio Moche* The plan also includes reviewing other mining reports to catalogue Peru-wide problems to prepare a journal article Information needed includes types of metal and ore mined, effluent types and concentrations (i e , water chemistry data), tailing and waste rock storage conditions (i e , property, time of exposure, storage environment, volume, drainage control, closure control plans), actual and potential geochemical behavior of the major and minor elements in the effluent, and a list of industrial/agricultural by-products available throughout Peru

Friday, August 1, 1997

08 00 - Grubb lectures on *Landfills and Geosynthetics* Hudock and Landers arrange meeting with Mogrovejo of MEM for Tuesday at 9 00 A M
13 00 - Grubb completes *Landfills and Geosynthetics* lecture PUCP closes for the weekend
17 30 - Grubb, Hudock and Injoque travel to office of Empresa Minera Iscaycruz, S A , to meet with Mr Juan Jose Herrera, Gerente General The Iscaycruz mine is located approximately 6 hours from Lima at an altitude of approximately 4700 meters The mine produces 1400 tons/day of zinc and lead concentrate GLENCOR owns the Iscaycruz, Perubar and Casapalca mines Perubar and Casapalca produce zinc and lead concentrates Iscaycruz is a relatively new operation and acid water have not yet become an issue At Iscaycruz, the oxidation of the tailings is prevented by depositing the tailings into a lake under 2 meters of water Grubb nevertheless details passive barrier approaches which draw upon geochemical, environmental, and geotechnical concepts Herrera provides overview and layout of the Iscaycruz mine Interestingly, the lake has an elevated pH because of the high quantity of limestone in the tailings, therefore any bocamina acid drainage is transported back to the lake and utilized to neutralize the basic water Grubb also suggests various seismic and hydraulic ways to

consolidate the tailings in the lake to increase longevity of disposal operation and improve geotechnical stability

Herrera describes excessive coliforms problem associated with the Imhoff tank for treating the sewage from the mining town Because the mine is located at approximately 4600 meters the lack of oxygen prevents the Imhoff tank from functioning properly The idea of an anaerobic treatment system appears more feasible in this situation Grubb suggests that the problem might be solved using a passive treament technology or weeping tile bed comprised by sand/silt and locally available industrial by-products

Saturday, August 2, 1997 - No Meetings
Sunday, August 3, 1997 No Meetings

Monday, August 4, 1997

09 00 - Grubb and Pacora discuss upcoming mine visit on Friday through Sunday (8/8-10) with additional three day stopover in Trujillo (through 8/13) to locate and sample various industrial by-products in the Trujillo area Pacora grants permission for Landers to accompany the Georgia Tech team to Quiruvilca To solve the erosional problems with the face of the San Felipe tailings dam and the need to improve seismic stability, Grubb describes retrofitting of the San Felipe tailings dam face with a geotextile retaining wall and plans to dewater the slope to avoid liquefaction Pacora reveals Klohn-Crippen plans to stabilize the tailings dam, not previously known to Georgia Tech team

The design proposed by Klohn-Crippen consists of two slopes joined by a single terrace The bottom slope is 3 1 and would extend approximately 30 meters from the current toe of the tailings dam The upper slope is 5 1 and would end approximately 50 meters behind the current crest of the tailings dam After reviewing this design, Grubb realizes that if Klohn-Crippen s design is followed, the constructed treatment barrier with a wetlands down stream could not be constructed because of the limited space available below the tailings dam A conceptual design for the geotextile retaining wall is offered to Jose Pacora Arrangements are made for 5 gallon sampling buckets to arrive up the mine over the weekend Travel arrangements to Quiruvilca are made

14 00 Grubb and Landers discuss the possibility of coming to graduate school at Georgia Tech and collaborating on this USAID/CMNP project

Tuesday, August 5, 1997

09 00 - Grubb, Hudock, Landers and Muchaua review CESEL report at MEM A six page review is submitted to Mogrovejo

15 00 - Grubb and Pacora discuss CESEL report, copies provided to Pacora and Dasso Landers introduced to Pacora, trip to Quiruvilca is finalized

Wednesday, August 6, 1997

09 00 - Grubb has a meeting with Mr Edward Alarcon of USAID to discuss the spending flexibility within USAID contract Alarcon indicates that experimental and supplies budget includes both the US, Peru, and shipping charges as described in the main proposal

13 00 - Grubb, Hudock, and Landers visit and tour Envirolab-Peru analytical laboratory Sampling equipment from Phase I left with Envirolab-Peru (in June 1996) is retrieved for to Quiruvilca Grubb obtains price listing for the analytical tests performed by Envirolab-Peru

Thursday, August 7, 1997

09 00 - Hudock and Landers visit the Institute of Geography to purchase a Peruvian Atlas and maps of the Lima and Huancavelica departments The La Libertad map is sold out and not available

12 00 - Georgia Tech team packs research equipment

16 00 - Georgia Tech team departs for Trujillo

22 00 - Georgia Tech team arrives in Trujillo

Friday, August 8, 1997

09 00 - Georgia Tech team departs Trujillo for Quiruvilca
12 30 - Arrival at the Unidad Minera Quiruvilca mine in Shorey
14 00 - Grubb, Hudock, and Landers conduct site walk at San Felipe Walk around the base of the San Felipe tailings dam and utilize the HORIBA water quality checker to determine the quality of the water seeping from the toe drains at the base of the tailings dam The measured water quality parameters are pH conductivity turbidity dissolve oxygen, temperature and salinity Drainage canals D1 D2, D3 D4, D5, D6 and point XIV are sampled See the water quality sampling results

Saturday, August 9, 1997

10 00 - Two buckets of native soil/structural fill from the southern slope of San Felipe valley are gathered while additional water quality data is collected for the remaining points throughout the valley with the HORIBA water quality checker Drainage canals C10, C11, D7, D8, and D9 are tested Likewise, the water pond on the tailings draining southwest towards the decantation line, the confluence of D3 D4, and D5 and a background water sample adjacent the waterfall behind the tailings are also tested See water quality sampling results
12 30 - Grubb leaves for Trujillo because of an illness
14 00 - Sampling of the sawdust pile located around the saw mill in Quiruvilca and coal ash from both Shorey and Quiruvilca Two buckets of sawdust and two buckets of coal ash are obtained The coal ash is the remnants of a 1 4 clay/coal mixture which the majority of the population around the mine utilizes
18 00 - Meeting with Ing Efrain J Bonilla, Jefe de ingenieria, and Mr Jorge Quispe to discuss the information requested by Grubb Hudock and Landers are provided with all water quality data for the San Felipe Valley, contact information concerning possible sources of industrial by products in and around Trujillo, Unidad Minera Quiruvilca's PAMA, and the UTM coordinates of the surveying benchmarks throughout the San Felipe Valley Ing Bonilla cautions Hudock and Landers that the Peruvian government has recently notified Corporacion Minera Nor Peru that the coordinates for two of the three surveying monuments utilized by Nor Peru are incorrect Therefore the surveyors are unsure whether the given coordinates are correct We will be notified if the benchmarks are discovered to be incorrect

Sunday, August 10, 1997

08 00 - Sampling of the San Felipe tailings along the slope of the tailings dam and sampling of the oxisols around the bottom of the tailings dam Four buckets of tailings and two buckets of oxisols are obtained
10 00 - All twelve buckets of industry byproduct samples are sealed and packaged for delivery to Lima and Atlanta Georgia
13 00 - Departure for Trujillo
16 30 - Arrival at the Regents Hotel in Trujillo
20 00 - Meeting between Grubb, Landers, and Hudock discussing the information gathered up in the mine A serious discussion follows because of the high concentrations of arsenic discovered seeping from the San Felipe tailings It appears that arsenic was first discovered during the first arsenic screening in November, 1996 Dr Grubb has never seen this water quality information before and is worried about its implications Arsenic in acid mine drainage is much more difficult to treat and this project was solicited on the basis that the only arsenic in the San Felipe valley originated from the La Paloma mine This does not appear to be true and plans are made as to the next steps It is unknown whether the arsenic originates from the tailings or is naturally occuring in the ground/surface water The researchers begin to wonder whether the HDX treatment plant design, submitted by Simmons, properly accounts for the arsenic Later, a literature search reveals that arsenic can be precipitated with the addition of an alkaline, however disposal of arsenic contaminated waste then becomes a significant problem

Monday, August 11, 1997

10 30 Leave for a tour of the Laredo Sugar Cane Factory Mr Carlos Casos Cabanillas, Periodista and Relacionista Publico, of Cooperativa Agraria Azucarera Laredo LTDA provides a tour of the entire sugar production process (from cane to bagged sugar) During this time 4 buckets of samples are collected, 2 of the post processed shreded sugarcane bagasse and 2 of sugar cane bagasse ash It is learned that this facility has a gigantic stock pile of sugar cane bagasse ash with which they cannot dispose

16 00 Arrange meetings with the Pilsen Trujillo Brewery and a local rice producer to tour their facilities, while looking for industrial by-products

22 00 - Meeting with Jose Pacora concerning the Arsenic discovered in the San Felipe tailings effluent In the PAMA, tests on waste rock piles illustated that the waste rock contained on the average 200 ppm of arsenic Besides the problems with the arsenic fouling up the passive geochemical barrier project, concern was voiced over the newly designed water treatment/copper extraction plant and its ability to precipitate the arsenic Furthermore, arsenic contamination in the passive geochemical barrier and water treatment plant by products creates a much more difficult disposal problem

Tuesday, August 12, 1997

11 00 - Meeting with Mr Walter Protzel Reelits Jefe del Departmento de Elaboracion, at the Pilsen Trujillo brewery Dr Grubb describes the scope of the Georgia Tech/USAID/Corporacion Minera Nor Peru project and his desire to identify industrial by products which could be of use Mr Reelits describes the beer making process and outlines all of the by-products and their uses A tour of the facilities follows, in which diatomaceous earth is identified as a possible useful industrial by-product Currently the diatomaceous earth is dumped directly into the sewer and is never recycled or re-utilized This by-product is very surface active and biologically active, making it a perfect candidate for the PGB

Wednesday, August 13, 1997

10 00 - Arrive at the Corporacion Minera Nor Peru Trujillo office for a brief meeting with Mr Teodorico A Zambrano Villanueva (Director Asuntos Legales) Grubb also briefly talks on the telephone with Ing Jose Pacora providing details of the successful meetings in Trujillo and Laredo with Pilsen Trujillo and Laredo, LTDA

11 00 - Return to the Pilsen Trujillo brewery for another brief meeting with Mr Reelits Reeelits requests Grubb to provide a detailed statement of the Georgia Tech/USAID/Corporacion Minera Nor Peru project's objective to the Pilsen headquarters in Lima This protocol is necessary before the Pilsen head office will grant Grubb access to the diatomaceous earth

17 30 - Arrive at the Trujillo airport for the trip back to Lima

20 00 - Arrive in Lima.

Thursday-Tuesday, August 14 - 19, 1997 No meetings - Travel to Arequipa, Cuzco and Machu Picchu

Wednesday, August 20, 1997

10 00 - Grubb arrives at PUCP to prepare for his *Remediation Technologies* lecture, to be given the following day Landers secures prices to ship the soil, tailings, and by-product samples back to the United States through Panalpina Transportes Mundiales, S A

Thursday, August 21, 1997

08 30 - Grubb and Hudock arrive at PUCP to prepare for *Remediation Technologies* lecture

09 00 - Grubb commences the full day *Remediation Technologies* seminar, while Hudock converts the UTM control points for the San Felipe Valley into longitude and latitude geodetic coordinates and processes

the GPS surveying data Environmental sampling data collected during trip 2 is entered into Microsoft *EXCEL*

Friday, August 22, 1997

08 30 - Grubb arrives at PUCP to prepare for the second half of his *Remediation Technologies* lecture
09 00 - Grubb commmences Part 2 of *Remediation Technologies* Seminar (full day lecture)

Saturday, August 23, 1997 - No Meetings
Sunday, August 24, 1997 - No Meetings

Monday, August 25, 1997

09 00 - Grubb and Hudock begin compilation of trip reports Grubb arranges meetings with Luis Jamie Castillo (PUCP) and Jose Pacora (CMNP)

10 00 - Meeting with Jose Pacora at CMNP Lima office Grubb provides CMNP with a letter of declaration for customs documents, for containers of soil and industry by-products Grubb presents Pacora with a memo recommending the expansion of the water quality testing program in the San Felipe valley A memo describing the site visit to Salpo is presented to Andres A Dasso (PAS) Grubb briefs Pacora on the progress of the CMNP/USAID project Pacora is informed that upon returning to the United States, the research team will conduct a geotechnical evaluation of the soil and industrial byproducts This work will be completed during the Fall 1997 quarter Depending on the availability of soils and industrial byproducts after the completion of the geotechnical evaluation, column leaching tests should commence in January, 1998

12 00 - Grubb and Hudock arrive at PUCP Hudock prepares meeting log Grubb prepares final Fulbright Fellowship report Grubb's office is packed

Tuesday, August 26, 1997

10 00 - Arrive at PUCP Hudock continuously updates the daily meeting log while Grubb completes the Fulbright Fellowship report

Wednesday, August 27, 1997

05 00 - Grubb departs Lima for Atlanta
20 00 - Hudock departs Lima for Atlanta

Appendix B

Quiruvilca Trip Report, 13-18 July, 1997

Team Members

Dr Dennis G Grubb, Georgia Institute of Technology
Mr Gregg W Hudock, Georgia Institute of Technology

Objective To survey drainage trenches (D1 9, C10-12) at San Felipe tailings dam and to identify locations for soil, tailings and industrial byproduct sampling for August trip

Sunday, 13 July, 1997

10 00 hrs Grubb and Hudock travel from Lima to Trujillo driven by Corporacion Minera Nor Peru (CMNP) staff, for purposes of surveying the San Felipe tailings dam with a Global Positioning System (GPS)

18 00 hrs Arrive in Trujillo, El Gran Marques Hotel

Monday, 14 July, 1997

07 30 hrs Breakfast at Hotel with Michel Robert of Pan American Silver Discussed the focus of the USAID-CMNP sponsored research project at the San Felipe tailings dam When Grubb and Hudock described the types of industrial byproducts which are of interest, Robert suggested that the construction of a new coal-fired power plant being considered approximately 10 kilometers from Quiruvilca may serve as a potential future source of fly ash Robert indicated that the inventory and purchasing records for the mine warehouse may also suggest materials that may be of potential use on the project Robert also informed Grubb and Hudock that the planned SX/HDS acid water treatment plant in Shorey will produce gypsum Since the gypsum may be of potential use on the project, Grubb requests a copy of the Simmons design report to learn more about the SX/HDS plant

08 30 hrs Depart for Shorey

12 00 hrs Arrived in Shorey, unloaded global positioning system (GPS) surveying equipment

13 00 hrs Meeting between Grubb, Hudock, Pacora, Bonilla, and Felipe Injoque Discussed sampling needs for the drainage ditches downgradient of the San Felipe tailings dam (D1-D9), the decantation line, and the canals flanking both sides of the tailings dam It was recommended that the sampling program be expanded to include the following parameters

Water level/flowrate
Temperature (Centigrade)
pH (field and lab)
Conductivity
Alkalinity (as CaCO3)
Total Dissolved Solids (TDS)
Dissolved Oxygen (DO)
Biochemical Oxygen Demand (BOD)

Aluminum (Al)
Arsenic (As)
Barium (Ba)
Cadmium (Cd)
Magnesium (Mg)
Manganese (Mn)
Mercury (Hg)
Nitrate (NO3)

Calcium (Ca)
Chlorine (Cl)
Chromium (Cr)
Copper (Cu)
Fluorine (F)
Iron (Fe, total)
Lead (Pb)
Potassium (K)
Selenium (Se)
Silver (Ag)
Sodium (Na)
Sulfate (SO4)
Cyanide (CN, total)

It was discussed that these parameters should be evaluated on a monthly basis by a third party laboratory which has established effective and reliable data quality assurance/quality control (QA/QC) procedures to ensure the integrity of the environmental testing results At least two field blanks should be included with each sampling round to determine the background concentrations and accuracy of the analytical equipment used by the third party laboratory It was mentioned by Grubb that the costs associated with the proposed sampling parameters and locations can be counted as matching funds on the USAID-CMNP project

The water samples from drainage trenches D1 through D9 should be collected at the most upgradient location in the drainage trenches, i e , where the water emerges from the tailings dam The trench which drains the surface water that ponds on the tailings dam should also be included, i e , in C10 at locations just prior to and after its confluence with the effluent emanating from the La Paloma mine portal (C11) These data will provide additional context to the information already being obtained from sampling Location XIV, situated next to the road to Shorey

The water from the decantation line and the two drainage canals flanking both sides of the San Felipe tailings dam (i e , C12) should be monitored on a monthly basis for the first eight parameters listed above (at a minimum) The drainage canals should be sampled at locations prior two their confluence with the drainage trenches below the San Felipe tailings dam

It was requested that fax copies of all water quality data associated with the San Felipe valley including existing and newly collected data be sent to Georgia Tech to assist in modeling and experimental research To permit data analysis and interpretation, such as plotting trends in the environmental quality data, it was also suggested that CMNP place all of the environmental data in a database management or spreadsheet program Electronic copies of environmental quality test data can often be obtained from third party laboratories at no additional charge

When reviewing the cost estimates in the PAMA, it became apparent that the cost estimate (~$1 2 million) provided by Klohn-Crippen was for tailings re-grading and capping only, the treatment of the acid waters from San Felipe was not included The possibility was then discussed of simultaneously treating the wastewater food processing water and sewage from Shorey (herein collectively referred to as septage) and the acid waters from San Felipe To take advantage of gravity flow it was suggested by Grubb that the septage from Shorey be diverted to San Felipe using a pipeline and/or the ditch along the access road to Shorey The septage contains sufficient organic carbon, nitrogen, phosphorus and dilution potential to promote the necessary microbial activity to create the anaerobic and reducing conditions which favor pH buffering of acid waters with immobilization of metals It was also suggested that the rock and soil excavated to improve the drainage ditch along the road could potentially be used for re-vegetation or to improve slope stability at San Felipe The need for an estimate of the septage generation rates in Shorey was discussed A rough estimate for the trench work was also prepared

15 00 hrs Conducted three-hour site walk of San Felipe tailings dam to describe the focus and strategy of USAID-CMNP sponsored project to Hudock and Injoque, while identifying locations for the GPS survey The tree saplings planted along the diversion canals flanking the tailings dam were missing--presumable stolen by indigenous peoples or eaten by livestock grazing at large in and around the tailings dam The presence of water was noted in both diversion canals flanking the San Felipe tailings dam In places the water was stagnant and flowing slowly which contributed to

the seepage of water through the embankments onto the tailings It was concluded that dredging of the diversion canals may be necessary In this case it would make sense to re-deposit the dredged soils on top of the tailings to in an effort to promote re-vegetation and to reduce infiltration of oxygenated water into the tailings It was estimated that approximately 50% of the tailings are already re-vegetated, particularly at the south western upgradient end of the tailings dam It was also observed that the tailings are serving as a habitat or nesting area for insects frogs birds and even grazing animals such as pigs and cattle Several large areas of the tailings had been disturbed by the pigs as it is believed that they feed on worms in the re vegetated areas of the tailings Thus, the long-term survivability and effectiveness of a capping system is a major concern and may be precluded altogether since any fencing system intended to keep animals off the tailings is likely to be breached or stolen by the indigenous peoples Visual inspection revealed that almost all of the seedlings planted by CMNP along the diversion canals to mitigate erosion of the embankments are missing and presumed stolen

The site walk revealed that effluent from the La Paloma mine portal still merges with the effluent from the San Felipe tailings dam creating an unnecessary environmental liability for CMNP Strategies for diversion of San Felipe tailings water away from the La Paloma were discussed The options include, in order of preference (i) eliminating the flow in C-10 by repairing the trench in the northwest corner of the tailings dam and re directing all of the surface water on the tailings dam in a southerly direction to the entrance of the decantation line, (ii) closing off the bend in C10 immediately upstream from La Paloma and creating a new C10 trench at a location downhill, but parallel, to the existing C11 trench and (3) isolating the existing C11 trench downgradient of La Paloma from all other San Felipe drainage trenches including the possible installation of another pipe underneath the road to Shorey See main text of report for enlarged discussion and figures

18 00 hrs Return to Shorey

Tuesday, 15 July, 1997

10 00 hrs Grubb and Hudock survey the San Felipe tailings dam with the GPS equipment Area surveyed includes the drainage trenches below the tailings dam (D1-D9) and the trench excavated in the top of the tailings dam to drain ponded surface water (C10) Two reference stations were used for the survey Survey monument SF1 is located near the southern edge of the tailings dam Survey monument C is located near the portal to La Paloma

13 00 hrs Break for lunch

14 00 hrs Return to San Felipe to continue survey from morning session The alignment of the drainage trenches from their starting point below San Felipe to the Shorey road are surveyed The alignment of C10 is surveyed from its beginning on the surface of the tailings dam to its convergence with C11 C11 is also surveyed to the Shorey road

17 00 hrs Return to Shorey

Wednesday, 16 July, 1997

08 30 hrs Grubb and Hudock survey the seeps along the two drainage canals flanking both sides of the tailings dam (i e , C12 and trench on southern side) An attempt is made to approximate the area on the surface of the tailings that has already been partially or fully re-vegetated After completion of the survey it was discovered that the GPS base station batteries were expended, and that many data points were not recorded Allowed batteries to recharge for rest of day

12 00 hrs Lunch

13 00 hrs Grubb and Hudock visit saw mill in Quiruvilca Grubb identifies where samples will be collected during August trip Visit to Santa Catalina tailings dam on return ride to Shorey

15 00 hrs Reviewed PAMA and Simmon s and Klohn-Crippen's engineering reports on the HDS/SX and geotechnical stability of the Santa Catalina dams, respectively Met with Michel Robert to obtain more details on proposed coal plant Coal deposit is anthracitic and has a low sulfur content Project supposedly financed/supported by Japan Robert suggests that more details may potentially be available from MEM

Thursday, 17 July, 1997

08 00 hrs Return to San Felipe to re-survey data points not recorded during Wednesday session

12 00 hrs Lunch

13 00 hrs Five-hour Georgia Tech visit completed in cooperation with Mr David Des Rosiers to the Esperanza mine owned by Banco Wiese in Salpo, La Libertad Department The trip originated in Shorey at approximately 1 00 pm The purpose of the visit was to visually evaluate the environmental liabilities associated with the Esperanza mine which may be potentially incurred if Pan American Silver (PAS) or Corporacion Minera Nor Peru (CMNP) acquires mining rights for the Esperanza Mine Three mine portals were visited Esperanza 3130, Esperanza 3170 and Rumatyllo 3350 (mine references provided by Des Rosiers) It should be noted that July is the peak of the dry season in Salpo

The first portal visited was Esperanza 3130 The steepness of the mountain in this area is approximately 45 degrees or greater As such, there is very little room for engineered structures However an abandoned crusher is located at the Esperanza 3130 level which is in extreme disrepair Apparently the mining activity was abandoned by ASARCO in the 1940s The mine portal was open Des Rosiers indicated that PAS/CMNP has been doing some exploration to evaluate the quality of the ore veins and to improve the rail line into the mine Consequently, a small quantity of muck has been removed from the mine and has been dumped down the surface slope of the mountain directly opposite of the mine portal An analysis of the muck was not conducted but given the small quantity of muck present, the hazard is not anticipated to be significant Water emanating from the mine portal was observed at a flow rate less than approximately 1 liter/sec The quality of the water was not evaluated No visible signs of contamination related to acid mine drainage were observed

The preliminary final report recently submitted by CESEL S A to the Ministry of Energy and Mines (MEM) entitled *Estudio de Evaluacion Ambiental Territoral y de Planteamento para la Reduccion o Eliminacion de la Contaminacion de Origin Minero en la Cuenca del Rio Moche* indicates that mining related effluents in the Salpo region are similar in composition to the acid waters emanating from Unidad Minera Quiruvilca. However, CESEL S A did not indicate the exact sampling locations in their report of the Salpo region, so it is difficult to establish whether CESEL s data applies to the areas visited by Des Rosiers and Georgia Tech personnel Moreover Des Rosiers indicated that due to scarcity of water in the Salpo area, the water now emanating from the Esperanza 3130 portal would be recycled for mining purposes If this practice is instituted upon re-opening of the mine, it is likely that the water will pose minimal environmental risk to the environment

The Esperanza 3050 portal was visible below Esperanza 3130 but was not actually visited A waste rock pile was observed at Esperanza 3050 which appeared to have a radius of approximately 15 meters Des Rosiers indicated that a road would be constructed to reach the Esperanza 3050 as it was anticipated that the excavated ore would be removed at this level and shipped via truck to Shorey Des Rosiers also indicated that the water flowing from this portal was also on the order of 1 liter/sec and that this water would be recycled once the mine re-opened As before, it is likely

that this water will pose minimal environmental risk if water recycling is instituted upon re-opening of the mine The remaining challenge involves the management of the waste rock pile at Esperanza 3050 which is known to contain iron pyrite The leaching and acidification hazard posed by the existing waste rock pile is related to the moisture content of the rock pile and hence rainfall The same is true for the waste rock that will be excavated once the mine re-opens

There are several strategies for managing the waste rock A few ideas come to mind considering the proposed plans and site conditions at Salpo It may be possible to cover the existing waste rock pile with the soil that will be excavated when the access road is cut to Esperanza 3050 This may require a geotechnical stability analysis Minimizing the exposure of the waste rock to oxygen and moisture using a soil cover will mitigate the formation of acid waters It also may be possible to re-vegetate the waste rock pile once covered with soil or soil-like materials Another strategy worth exploring would be to use the gypsum generated from the planned HDS/SX plant in Shorey (once it comes on line) as an impermeable cover for the waste rock piles in Salpo By bringing a quantity of gypsum from Shorey on the return haul to Salpo, the long-term gypsum disposal capacity in Shorey is lengthened The ability of the gypsum to serve as an impermeable barrier for the waste rock piles in Salpo would need to be evaluated with a treatability study

The waste rock pile at Esperanza 3170 was also visited According to Des Rosiers, the rights to this portal are owned by a private owner not Banco Wiese While the rock was predominately quartz, flecks of iron pyrite (perhaps 1 wt %) were sparsely distributed throughout the quartz matrix in one rock sample that was visually inspected The acid generating capacity of the waste rock was not evaluated However, the rock pile appeared to be bone dry No water flow was observed in the adjacent creek A management scheme similar to that proposed at Esperanza 3050 may be considered for the present and future quantities of waste rock at Esperanza 3170 if rights are acquired by PAS or CMNP at this level

Rumatyllo 3350, situated just below the town of Salpo, was also visited There appeared to be minimal leakage of water from the mine portal (< 1 liter/sec) No tailings or waste rock piles were observed in the area Approximately fifty meters upgradient of the Rumatyllo 3350 portal, a contractor was beginning the grading and foundations for a new wastewater treatment plant for the town of Salpo Des Rosiers indicated that not only would the water from the mine portal be recycled if mining operations were renewed at this level, but acquisition of the rights to the effluent from the wastewater treatment plant would also be considered for mining purposes A closed loop circuit utilizing the recycled mine water and wastewater effluent from the Salpo treatment plant should pose minimal environmental risk

18 00 hrs Return to Shorey

Friday, 18 July, 1997

08 30 hrs Re-survey vegetated area on top of tailings

11 30 hrs Grubb and Pacora hold meeting on CMNP/USAID project while Hudock processes final surveying data and packs equipment Grubb requests the following information

1- Detailed description of stormwater and wastewater system in Shorey for water from toilets, households and casino including layout, flow rates and entry points to Rio Moche Water quality for roadside ditches containing septage also requested
2- UTM or latitude longitude coordinates for reference points "SF1 ' and "C" in San Felipe valley
3- Copy of weather station data from Shorey
4- Monthly quantities of sawdust produced and wood extracted at crusher
5- Copy of reports for SX/HDS plant
6- Copy of PAMA

7- Copy of all water quality data obtained in San Felipe
8- San Felipe valley map CAD file
9- Inventory of heavy and earth moving equipment
10- List of new public works and construction with any anticipated waste streams
11- Extra copies of San Felipe maps
12- Monthly generation rates of construction debris
13- Facilities to be de-comissioned in next five years
14- Basis of estimate provided by Klohn-Crippen for San Felipe
15- Cost estimate for wastewater treatment in Shorey/Quiruvilca
16- Map of Esperanza mines in Salpo
17- Timetable for upcoming earthworks at San Felipe (excavated soil can be used as cover material)

14 00 hrs Depart Shorey for Trujillo

20 00 hrs Depart Trujillo for Lima

22 00 hrs Arrive Lima

Appendix C

Quiruvilca and Trujillo Trip Report, 8-13 August, 1997

Team Members

Dr Dennis G Grubb, Georgia Institute of Technology (GT)
Mr Gregg W Hudock, Georgia Institute of Technology (GT)
Mr Daniel G Landers, Pontificia Universidad Catolica del Peru (PUCP)

Objective To quantify water quality in San Felipe valley and to collect locally available soils and industrial byproducts in vicinity of Unidad Minera Quiruvilca, Trujillo and along the transportation corridor between the two sites Samples of San Felipe tailings also were to be collected These geomaterials are to be used in an experimental program at Georgia Tech in Atlanta to test the preliminary feasibility of using soils and industrial byproducts to buffer pH and immobilize metals in a porous geochemical barrier (PGB) for acid mine drainage (AMD) mitigation

Thursday, 7 August, 1997

16 00 hrs GT team departs Lima for Trujillo

22 00 hrs Arrive Regents Hotel, Trujillo

Friday, 8 August, 1997

09 00 hrs GT team departs Trujillo for Unidad Minera Quiruvilca (UMQ)

12 30 hrs Arrive at UMQ in Shorey

14 00 hrs Grubb, Landers and Mr Phillipe Cantin (Yvan Dionne Inc) conduct a site walk around San Felipe tailings, while Hudock calibrates the HORIBA water quality meter to measure the following parameters pH, conductivity (dissolved solids) turbidity (suspended solids) dissolved oxygen (DO), temperature, and salinity The quality of the water from San Felipe s toe drains and decantation line into drainage trenches D1 D2, D3, D5, D6 and D4 are measured respectively Similarly, the water quality of point XIV, the western diversion canal (C12) and drainage trenches (D1-D3, D5 D9 and C10-C11) the decantation line (D4) and the confluence adjacent to Shorey road was sampled See Appendix D for water quality test results

16 00 hrs Meeting between the GT team Ing Efrain J Bonilla and Mr Jorge Quispe Grubb requests a copy of UMQ's PAMA, a summary of all available water quality data for San Felipe, and the UTM coordinates corresponding to points SF1 and C used as benchmarks during the GPS survey at San Felipe Written records of the solicited water quality data are reviewed Arsenic contamination was first detected in the San Felipe drainage trenches during the November, 1996 sampling round Grubb first visited San Felipe in October 1996 prior to the detection of arsenic Unfortunately, the true extent of arsenic contamination in San Felipe Valley cannot be quantified due to the limited water quality data Thus, to better delineate contamination at San Felipe, Grubb recommends expanding the monthly water quality sampling program to include the following parameters

Water level/flowrate	Copper (Cu)
Temperature	Cyanide (CN total)
pH (field and lab)	Fluorine (F)
Conductivity	Iron (Fe total)
Alkalinity (as $CaCO_3$)	Lead (Pb)
Total Dissolved Solids (TDS)	Magnesium (Mg)

Dissolved Oxygen (DO)	Manganese (Mn)
Biochemical Oxygen Demand (BOD_5)	Mercury (Hg)
Aluminum (Al)	Nitrate (NO_3)
Arsenic (As)	Potassium (K)
Barium (Ba)	Selenium (Se)
Cadmium (Cd)	Silver (Ag)
Calcium (Ca)	Sodium (Ag)
Chlorine (Cl)	Sulfate (SO_4)
Chromium (Cr)	

Saturday, 9 August, 1997

09 00 hrs GT team meets with Ing Bonilla Strategy to sample industrial byproducts in Shorey and Quiruvilca is discussed Sampling containers arrived in Shorey without lids In the interim, GT team returns to San Felipe to finish water quality testing in the drainage trenches Samples to be collected include native soils around San Felipe, San Felipe tailings, sawdust from the UMQ sawmill, and locally available coal ash

10 00 hrs Two buckets of native loamy soil are sampled from the southern slope edge of the San Felipe valley The water quality of the drainage trenches, canals and ponded water in an around the San Felipe tailings dam is evaluated See Environmental Sampling Results in Appendix D for sampling procedures and locations

In contrast to the July 13-18, 1997 trip the tailings were much drier with lower flowrates and less ponded water observed throughout However an artesian condition (an upward flow of water) was discovered at peizometer #5 A similar condition was reported by Klohn-Crippen (October 18, 1995) The observed artesian condition in peizometer #5 indicates a large pore water pressure buildup within the tailings Large porewater pressures greatly impact the liquefaction potential of soils and tailings under repeated or sudden strains The term liquefaction is used to describe the uncontrolled deformation of a material when excessive pore water pressures are not dissipated The state of stress and liquefaction potential of the tailings in the vicinity of peizometer #5 were not specifically evaluated However, ground movements (i e , earthquakes) increase the probability of liquefaction occurrence therefore, a detailed liquefaction analysis of San Felipe tailings should be completed to evaluate the likelihood of a tailings slope failure In the interim, dewatering the tailings to decrease the pore water pressures throughout is recommended

Animals such as frogs, birds, pigs, cows, bulls, sheep, and burros and combined with their tracks (footprints) were ubiquitous in and around the San Felipe tailings dam This observation suggests, in part, that open grazing of livestock on the re-vegetated portions of the tailings is a common practice encouraged by the indigenous peoples Also, pigs were observed burrowing in the re-vegetated areas of the San Felipe tailings dam Birds were nesting in the same areas Several issues arise concerning the wildlife and livestock The long term integrity of an impermeable cap will be compromised by grazing livestock and burrowing animals (pigs) It was discussed that fencing-off the tailings dam was not a viable option due to theft of the fence or its being breached by indigenous peoples to permit livestock grazing One strategy is to allow the south western portion of the tailings dam a wetlands area as it currently is However, the composition of the tailings and the surface water quality may be such that the livestock and wildlife are being adversely affected by the presence or ingestion of toxic metals such as arsenic, lead, zinc and lead In turn, those people ingesting meat and dairy products derived from these animals may also be adversely impacted A detailed evaluation of the surface water quality on the tailings near the intake to the decantation line was requested by Grubb to begin developing a framework to establish whether the wetlands poses a hazard to animal life

12 30 hrs Grubb departs for Trujillo due to an illness

13 00 hrs — Remaining GT team (Hudock and Landers) breaks for lunch

14 00 hrs — Industrial byproduct sampling activities in Quiruvilca and Shorey Two buckets of fresh sawdust from beneath the blades of Quiruvilca s saw mill are collected Two buckets of coal ash are sampled one unweathered sample directly from the from the furnaces in Campartmento Quiruvilca, and one weathered sample from an outdoor disposal pile in Shorey For more details see Appendix D

18 00 hrs — Meeting with Ing Bonilla and Quispe The information requested by Grubb on August 8, 1997 is provided to Landers and Hudock All water quality data for the San Felipe valley, contact information for potential industrial byproduct sources in Trujillo, UMQ's PAMA, and the UTM coordinates of the surveying benchmarks throughout the San Felipe valley are received Bonilla cautions that the Peruvian government has recently discovered two of the three surveying benchmarks utilized by CMNP are inaccurate CMNP agreed to provide updated benchmark coordinates

Sunday, 10 August, 1997

08 00 hrs — Return to San Felipe valley for sampling of tailings and surface soils Four buckets of tailings from along the slope of the dam and two buckets of surface soils from below the dam on the valley floor, are collected See Appendix D for more details

10 00 hrs — Sample buckets (12) are packaged for exportation to USA

13 00 hrs — Departure for Trujillo

16 30 hrs — Arrival at the Regents Hotel in Trujillo

20 00 hrs — Meeting between Grubb, Hudock, and Landers Grubb is briefed on the activities and technical resources collected in Shorey and Quiruvilca The review of the newly acquired water quality data provided by CMNP from the November 1996 sampling round indicates the presence of arsenic in drainage trenches D1-D3 and D5-D9 at concentrations on the order of 200 mg/l During Grubb s original visit in October 1996, CMNP indicated that they believed the only source of arsenic in the San Felipe valley originated from the La Paloma mine portal since no water quality data on arsenic in the San Felipe valley was available prior to November 1996 Although it is not known whether the arsenic originates from the tailings or is naturally occurring in the ground or surface water, there is suggestive evidence that the source of arsenic is from the tailings for two main reasons 1) UMQ's PAMA reported that several waste rock piles contain up to 200 mg/l arsenic and, 2) Enargite (Cu_3AsS_4), chalcopyrite ($CuFeS_2$), and arsenopyrite (FeAsS) are among the ores mined at UMQ As such, arsenic may occur in all of the tailings dams (San Felipe, Amirvilca, Santa Catalina) The GT team expresses concern that the presence of arsenic may not only potentially affect the design approach the porous geochemical barrier for San Felipe but the potential exists that the performance of the SX/HDS treatment plant (proposed by Simmons) may be impacted as arsenic was not incorporated as a design parameter It is concluded that the management of arsenic contaminated materials may require treatment alternatives not previously envisioned in the original PGB proposal or Simmons proposal

Monday, 11 August, 1997

09 00 hrs — Transfer from Regents Hotel to El Gran Marques

10 30 hrs — The sugarcane industry in Peru is centered in Trujillo Mr Teodorico A Zambrano Villanueva, Director Asuntos Legales, CMNP (Trujillo) arranges GT team meeting with Mr Carlos Casos Cabanillas, Periodista and Relacionista Publico, Cooperativa Agraria Azucarera Laredo, LTDA The purpose of the visit was to explore if sugarcane waste products (bagasse and bagasse ash) are

suitable materials to treat the AMD from San Felipe Casos provides a detailed tour of the sugar production process (from cane to bagged sugar)

First sugarcane stalks are shredded through a series of machetes The moist, shredded fibers then pass through a wet sugar extraction process using sequential extraction (solubilization of the sugars) and roller pressing A series of approximately five grooved roller presses extracts the solubilized sugars Casos indicates that after the last pressing approximately 96% of the sugar has been removed and the moisture content of the fibers is on the order of 4% to 10% The bagasse is then conveyed to a furnace where it is incinerated to produce steam power for the processing plant a small portion of the bagasse is also used to make particle board furniture on the adjacent property The ash resulting from the sugarcane bagasse is removed from the incinerator, cooled and stockpiled The Chief Engineer informs the GT team that due to changing environmental regulations, there are few disposal options available for the sugarcane bagasse ash As such, available space for ash stockpiling is a growing concern The sugarcane bagasse sampling activities are described in Appendix D

16 00 hrs Arrange meeting time with the Pilsen Trujillo Brewery for the following day

22 00 hrs Dinner meeting with Pacora and Mr Antonio Mendoza Zavala at El Gran Marques concerning the arsenic concentrations observed in the San Felipe tailings effluent from the November 1996 sampling round GT team expresses concern that the new arsenic finding may impact environmental options at San Felipe Arsenic is more challenging to immobilize since it is usually more soluble (unless complexed) at high pH an operational parameter of the PGB Likewise, similar results for SX/HDS treatment plant are conceivable To ensure the arsenic concentrations in the effluent do not affect the design of the SX/HDS plant, CMNP should inform Simmons of this new development Grubb recommends quantifying the natural arsenic contamination in San Felipe valley through a metals analysis of the tailings and background water samples Pacora agrees to provide additional water quality test results for the drainage ditches throughout San Felipe valley, as soon as possible

Tuesday, 12 August, 1997

11 00 hrs GT team meeting with Mr Walter Protzel Reelits Jefe del Departmento de Elaboracion, of the Pilsen Trujillo The purpose of the meeting is to explore if waste byproducts (grains, hops etc) are suitable materials to treat the AMD from San Felipe Reelits provides a detailed tour of the brewery and brewing process Reelits explains that spent maize and hops are pelletized and recycled for agricultural purposes It is later learned that diatomaceous earth is utilized to clarify beer and wine, which results in an anaerobic, organic rich and surface and biologically active sludge with a high water content Reelits indicates that this material is directly discharged into a floor drain but that he has been looking for a recycle application for some time He is interested in exploring the potential be use of the material to mitigate another environmental problem Approval from the Lima office will be required However, no samples were available since they were in the middle of a production run

Wednesday, 13 August, 1997

10 00 hrs GT team meeting with Zambrano at CMNP Trujillo office Grubb informs Pacora of the successful meetings at Cooperativa Agraria Azucarera Laredo LTDA, in Laredo and Pilsen Trujillo Brewery The four containers of sugarcane bagasse and bagasse ash are sealed and packaged for export to USA

11 00 hrs GT team meeting with Reelits at Pilsen Trujillo Brewery Reelits indicates he is very interested in potential collaboration In order to obtain samples on future trips, Grubb must described recycle application and CMNP/USAID project to Mr Egid Metzger, Corporate Director of Technology in Callao to formalize cooperation and obtain approval

17 30 hrs	Depart Trujillo airport.
20 00 hrs	Arrive Lima

Appendix D

Environmental Sampling Activities in Quiruvilca and Trujillo, 8-13 August, 1997

Soil and Industrial Byproduct Sampling

Equipment

Spade, hand trowel, 20 liter buckets with sealable lids

Soil and Tailings Sampling Procedure

After type and location of sample was selected, approximately 6" of the weathered top soil/overburden was removed to gain access to undisturbed unweathered natural material A spade was utilized to collect and place the geomaterial sample into buckets The buckets were then properly sealed and taped to prevent moisture loss Sample type and location marked on container with permanent marker See Table D-1 for sampling locations and quantities

Industrial Byproducts Sampling Procedure

After type and location of sample was selected, representative samples were taken from each source A spade and/or hand trowel utilized to sample and place the geomaterial into buckets The buckets were then properly sealed and taped to prevent moisture loss Sample type and location marked on container with permanent marker See Table D-1 for sample locations and quantities

TABLE D-1
Inventory of Collected Soils and Industrial Byproducts

Date	Sample Type	Sample Source	Number of Containers	Container Weight (kilos)
8/10/97	Granular Top Soil	Southern San Felipe Valley, above tailings	2	30
8/10/97	Sawdust	Beneath blades of Quiruvilca Saw Mill	2	15
8/10/97	Coal Ash	Furnaces at Campamento Quiruvilca	1	30
8/10/97	Coal Ash	Coal ash disposal pile in Shorey	1	30
8/11/97	Tailings	San Felipe Tailings dam slope	4	35
8/11/97	Organic Top Soil	San Felipe Valley, below tailings	2	30
8/12/97	Sugar Cane Bagasse	Cooperativa Agraria Azucarera Laredo LTDA at last roller press	2	15
8/12/97	Sugar Cane Bagasse Ash	Cooperativa Agraria Azucarera Laredo LTDA ash disposal pile	2	25

Soil Sampling and Visual Classification

Granular Top Soil - Sample collected from the southern side of San Felipe Valley above tailings and diversion canals, see Figure D-1 The sampling area is sparsely covered by native grasses and shrubs Ground surface is dry crusty, and difficult to sample Top soil is medium-fine loam sandy-silty material, brown to orange-brown dry, blocky, and partially cemented

Sawdust - Residual product of eucalyptus tree milling operation in Quiruvilca for fabricating mine shaft supports Sample of fresh sawdust collected directly below space beneath sawmill blades Sawdust is medium sized, tan, fibrous, and dry A large pile of sawdust (approximately 18 m x 10 m x 8 m) is situated adjacent to the sawmill

Coal Ash - Two independent samples collected from different locations One fresh sample of ash is collected directly from the furnaces in Campamento Quiruvilca mining camp Quiruvilca coal ash is fine brittle dry gray-black material Second sample collected from an outside disposal pile in Shorey Shorey coal ash is weathered brittle, dry, gray-black, and contains debris Both samples are the residual product of a 1 4 clay/coal mixture utilized by the majority of the population for heating and cooking in Shorey and Quiruvilca

Tailings Four grab samples collected from different locations along the toe and slope of San Felipe tailings dam, see Figure D-1 Face of tailings dam is heavily eroded and loosely compacted Tailings are medium to fine silty-sandy material dense, gray, brittle, and cohesionless

Organic Top Soil - Samples collected from San Felipe Valley downgradient of tailings dam Both samples collected on western side of drainage trench adjacent to road, see Figure D-1 Sampled material appears to be the sediments and soil excavated from a drainage trench The collected soil sample is similar to the many patches of organic soil that are spread throughout San Felipe Valley In general, the valley is sparsely vegetated with shrubs and littered with mounds of excavated topsoil Organic soil is brown-black, medium to fine sized, dry poorly cemented organic smelling, and brittle A preliminary assessment of this soil suggests that it is potentially classified as cambisol, histosol, or lithosol [FitzPatrick, 1980] The actual classification will be verified with soils authorities in Peru

Sugarcane Bagasse - Two buckets of bagasse were collected at Cooperativa Agraria Azucarera, Laredo LTDA after the processed sugarcane bagasse emerges from the final grooved roller press The bagasse fibers are tan color, shredded, warm, wet, and approximately 2 to 8 cm in length and 0 1 to 1 0 cm in diameter During the site visit the chief engineer indicated that after processing the bagasse typically possesses a moisture content varying between 4 - 10% and contains approximately 4% residual sugar Typically, postprocessed bagasse is either incinerated to generate electricity or collected to manufacture press-board for the furniture industry

Sugarcane Bagasse Ash - After incineration, sugarcane bagasse ash at Cooperativa Agraria Azucarera, Laredo LTDA is stockpiled on site Two samples of cooled day-old sugarcane bagasse ash are sampled from the 4 m x 5 m x 50 m stockpile Ash is light, fine, dry, gray-black, stiff but brittle material Ash particles are sub-rounded and possess a varying gravel to fine grain size Larger conglomerated gravelly ash resembles pummice and is easily crushed

Water Quality Sampling

Equipment

HORIBA U-10 water quality meter, calibration solution uncontaminated water

Water Sampling Procedure

Daily autocalibration of HORIBA U-10 water quality meter performed with autocalibration solution Results recorded in calibration log for quality assurance and quality control (QA/QC) purposes, see Table D-2

The HORIBA water quality probe was carefully inserted into drainage trenches, canals, and ponded water to measure water quality parameters If sediments were disturbed during probe insertion, testing was terminated and retesting was delayed for approximately 30 minutes until the water flowing in the trenches flushed the suspended solids from the testing location Conductivity, pH, dissolved oxygen temperature and salinity were measured in triplicate at each location Between sampling locations, the HORIBA was cleansed with an uncontaminated rinse water solution Table D-2 presents the results of the water quality analyses (3 point averages shown)

Sample Locations

Background San Felipe Stream - HORIBA probe inserted directly into the flowing stream, adjacent to a waterfall located approximately 100 feet upstream of the inlet to the decantation line pipe located in the southwestern end of the of San Felipe tailings Water quality parameters were measured in a water pool is approximately 0 5 meters deep and 1 2 meters wide Surrounding terrain is well vegetated with waist-high grasses and shrubs

Surface Water on San Felipe Tailings Near Intake to Decantation Line - Water quality parameters tested by inserting the probe directly into the flowing surface water at approximately 6 meters north-east of the inlet to the decantation line This water originates from the ponded water in the center and north western portions of San Felipe tailings, Stream dimensions are approximately 0 3 meters wide by 0 3 meters deep Surrounding area is well vegetated with knee-high grasses and shrubbery

Drainage Trenches (D1-3 D5-9) & Decantation Line (D-4) - HORIBA probe inserted directly into the flowing AMD at the most upgradient location of each drainage trench, i e , as the AMD emerges from the toe drains Drainage trenches are approximately 0 7 meters wide and range between 0 3 to 2 meters in height Depth of flowing water varies between 5 to 25 centimeters

Confluence of D-3 D-4 and D-5 - Water quality parameters obtained approximately 1 5 meters from the decantation line (D-4) outfall in a pool approximately 1 meter in diameter and 0 5 meters deep Visual observations revealed that the volumetric rate of the water emerging from the decantation line was approximately four times greater than D-3 and D-5

Drainage Trench C-10 - Water quality parameters measured by insertion of the probe directly into the water flowing in the drainage trench at the bend in the C-10 drainage trench, approximately 15 meters upgradient of La Paloma mine portal The trench is approximately 0 6 meters wide and 0 6 meters deep The flowing water is approximately 15 cm deep

La Paloma Mine Portal - HORIBA probe inserted directly into the effluent approximately 5 meters from the La Paloma mine portal prior to its confluence with C 10 and C-11 Drainage trench is approximately 0 5 meters wide and 15 cm deep Green algae and a white slime precipitate is observed in the drainage trench

Point XIV - Water quality parameters measured by inserting the probe directly into water flowing in the trench adjacent to Shorey road approximately 100 meters upstream of the Rio Moche Acid water flow from San Felipe is approximately 15 cm deep and 1 meter wide

Table D-2

Water Quality Data for Unidad Minera Quiruvilca [1]

8-9 August, 1997

	Sample Location	pH	Conductivity (mS/cm)	Total Dissolved Solids[3] (mg/l)	Turbidity (NTUs)	Dissolved Oxygen[5] (mg/l)	Temperature (C)	Salinity (%)
01	San Felipe D 1	2 16	23 93	15312 0	see note 4	1 93	13 43	1 43
02	San Felipe D 2	2 01	24 97	15978 7	see note 4	4 29	12 10	1 50
03	San Felipe, D 3	2 14	20 13	12885 3	see note 4	1 09	13 27	1 20
04	San Felipe D 4 (Decantation Line)	6 63	0 33	209 1	see note 4	6 60	11 77	0 01
05	San Felipe D 5	2 05	21 37	13674 7	see note 4	1 81	12 60	1 27
06	San Felipe D 6	2 06	21 13	13525 3	see note 4	1 53	12 57	1 25
07	San Felipe D 7	2 03	26 20	16768 0	2	0 75	13 70	1 59
08	San Felipe D 8	2 03	27 60	17664 0	0	2 62	15 47	1 65
09	San Felipe D 9	2 82	4 11	2628 3	1	2 82	15 00	0 20
10	San Felipe Confluence of D 3 D-4 D 5	2 43	13 50	8640 0	5	4 75	14 37	0 68
11	San Felipe C 10 (above La Paloma)	3 51	0 56	358 8	2	4 25	17 90	0 02
12	San Felipe La Paloma mine portal	3 11	2 81	1796 3	8	5 13	18 20	0 13
13	San Felipe XIV	2 50	4 70	3010 1	see note 4	6 96	10 80	0 22
14	Background San Felipe Stream (see note 2)	7 30	0 07	45 9	3	6 04	15 63	0 00
15	Surface Water on Tailings Near Decantation Line	6 87	0 65	414 7	1	6 19	17 33	0 02
16	Rio Moche Upstream of San Felipe Confluence	3 47	3 12	1996 8	755	6 36	13 17	0 15
17	Rio Moche Downstream of San Felipe Confluence	3 15	3 28	2097 1	660	6 39	13 87	0 16
18	Porewater from Quiruvilca Sawdust Pile	5 40	0 56	358 4	180	0 15	15 60	0 02
	Calibration (08/08/97)	4 00	4 48	2867 2	0	5 55	19 7	0 23
	Calibration (08/09/97)	3 99	4 51	2886 4	0	5 98	16 5	0 23

NOTES All data obtained with HORIBA U 10 water quality meter

[1] Summary data averaged over three measurements except for the Quiruvilca sawdust sample

[2] San Felipe stream sampled at waterfall approximately 20 meters upgradient of the entrance to decantantion line

[3] Total Dissolved Solids (TDS) calculated by TDS = (Conductivity x 1000)(1 6x10 ^{5}/2 5x10 ^{5}) [Snoeyink and Jenkins 1980]

[4] Measured turbidity reading of 10 which yields little practical meaning Visually samples 1 15 were indistinguishable

[5] Measured dissolved oxygen readings corrected for average altitude of 3570 meters by $DO_{corrected} = (DO_{measured})\ (P_{3570}/P_{sea\ level})$ [Stumm & Morgan 1996]

P_{3570} = 651 327 hPa provided by HORIBA Instruments Incorporated Technical Information Reference Material

$P_{sea\ level}$ = 1013 hPa provided by HORIBA Instruments Incorporated Technical Information Reference Material

Rio Moche Locations Upstream and Downstream of San Felipe - HORIBA probe inserted directly into the middle of the Rio Moche at approximately 10 meters upgradient and downgradient of its confluence with the San Felipe effluent Rio Moche is approximately 5 meters wide, with varying water depths River water is a grayish-green color, extremely turbid with an odor characteristic of raw sewage Surrounding area is littered with rubbish and is sparsely vegetated with small grasses

Pore Water from Quiruvilca Sawdust Pile - Testing location is approximately 30 meters west and downgradient from the Quiruvilca sawmill Adjacent to the sawdust pile, several puddles are spread over an area of approximately 15 meters by 5 meters The HORIBA water quality probe was inserted directly into the northernmost puddle Puddles are black, covered by an organic sheen, and exude a odor characteristic of anaerobic decomposition The soil has been disturbed by the wheels of heavy equipment and supports no vegetation growth

Discussion of Water Quality Results

Two correlations were utilized to transform and normalize the data to the environmental conditions in San Felipe Valey Since conductivity directly relates to total dissolved solids (TDS) the following commonly used equation deriving TDS from conductivity was utilized [Snoeyink & Jenkins, 1980]

$$TDS = [\text{Conductivity } (\mu S/cm)][1\ 6 \times 10^{5}/2\ 5 \times 10^{5}]$$

The following equation was utilized to correct the measured DO readings at high altitudes and low atmospheric pressure [Stumm & Morgan, 1996]

$$DO_{CORRECTED} = (DO_{MEASURED})(P_{3570}/P_{SEA\ LEVEL})$$

where P_{3570} = 651 327 hPa the average atmospheric pressure at 3570 meters and
$P_{SEA\ LEVEL}$ = 1013 hPa, the average atmospheric pressure at sea level [HORIBA Corporation, 1991]

In several cases the measured dissolved oxygen concentrations exceeded the saturated dissolved oxygen predictions for 3570 meters (5 60 mg/l at 15 °C) It should be noted that the dissolved oxygen saturation values are calculated on the basis of dilute aqueous solutions, so deviations can be expected for concentrated effluents such as AMD

Background San Felipe Stream - Upgradient of San Felipe tailings, pH values are neutral, dissolved solids concentrations are insignificant and dissolved oxygen concentrations are elevated The impact of the tailings on San Felipe Valley can be quantified by comparing these water quality measurements to those at point XIV A substantial pH reduction of 4 8 occurs between these two points, while conductivity increases 65 times that of the background stream

Decantation Line (D-4) - Measurements indicate a pH neutral water with a low conductance Since water is isolated from tailings, elevated dissolved oxygen concentrations were observed Water quality parameters are consistent with background data collected upstream of San Felipe, see above

Surface Water on Tailings Near Decantation Line - Nearly neutral water quality test results (pH = 6 87) suggest that the presence of a wetlands covering San Felipe tailings significantly reduces the acidification of ponded water This trend is confirmed by analytical sampling conducted at Punto "A" by CMNP in August 1997

Drainage trenches (D1 3, D5-9 C-10) - Water quality parameters exhibit low pH and high conductivity Dissolved oxygen contents significantly less than predicted dissolved oxygen contents based on altitude corrections This suggests depletion of oxygen due to the oxidation processes associated with acid mine drainage

Confluence of D-3 D 4 and D 5 - Measured water quality parameters suggest that AMD is diluted by the clean stream water outfalling from the decantation line (D-4) In comparison with samples D1-3 and D5-9, an increase in pH of approximately 0 4 is observed As AMD is diluted with a larger pH source, pH increases dissolved metals are immobilized, and water conductivity is simultaneously reduced The large DO concentrations in D-4 promoted substantial increases in dissolved oxygen at the confluence

La Paloma Mine Portal - The leachate emanating from the La Paloma mine portal was observed to have a greater pH a lower conductivity, and a greater dissolved oxygen concentration than the San Felipe effluent It may be possible that elevated dissolved oxygen contents are attributed to the oxygen byproduct released during photosynthesis by the algae present in the drainage trench

Point XIV - After further dilution of the San Felipe AMD at the confluence of the drainage trenches with water from the diversion canal (C-12) and decantation line (D-4) pH measurements increased by approximately 0 5, precipitating metals and slightly decreasing conductivity Elevated dissolved oxygen values were measured due to the dilution, turbulence, and aeration of the AMD/stream water

Confluence of San Felipe Effluent with Rio Moche - Water Quality parameters collected upstream and downstream of the confluence of the San Felipe effluent with the Rio Moche suggest the San Felipe effluent has deleterious impacts on the Rio Moche The pH of the Rio Moche was lowered by 0 32 (3 47 to 3 15) However, it is clear from the already low pH that San Felipe is not the sole source of acidity to the Rio Moche

Porewater from Quiruvilca Sawdust Pile - Water quality parameter testing was conducted to test the hypothesis that the dark, "burned" appearance of the sawdust in the vicinity of the puddles was associated with the ongoing oxidation-reduction reactions between the sawdust and the puddles which were acidified due to the oxidation of naturally occurring iron pyrite in the soils Drawing on environmental microbiology and eH-pH principles, it was believed that once the observed organic sheen formed on the puddles, oxygen diffusion into the puddles would be inhibited and anaerobic and reducing conditions would begin to offset acidification Grubb suggested in October 1996 that the reactions occurring in the puddles were a microcosm of AMD mitigation processes envisioned to occur with a PGB incorporating industrial byproducts The measured water quality parameters add credibility to this hypothesis the measured pH (5 40) is within 0 1 of the lower bound legal limits conductivity (0 56 mS/cm) is comparable to that of clean water, and, the dissolved oxygen is very low (0 24 mg/l)

References

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Snoeyink, V L and Jenkins, D , *Water Chemistry*, John Wiley and Sons Inc New York, 1980

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Appendix E

Geosynthetics Retrofit of San Felipe Tailings Dam Face

Objective To provide an alternative to the Klohn-Crippen rehabilitation and capping solution currently specified in the PAMA at a cost less than $1 2 million while simultaneously accomplishing multiple objectives 1) to prevent erosion of tailings from the face of the San Felipe tailings dam, 2) to re grade and re-inforce the tailings dam face to improve geotechnical and seismic stability without utilizing additional space on the San Felipe valley floor where a passive treatment of acid waters can be implemented, and, 3) does not interfere with current land use patterns established by indigenous peoples or draws their attention

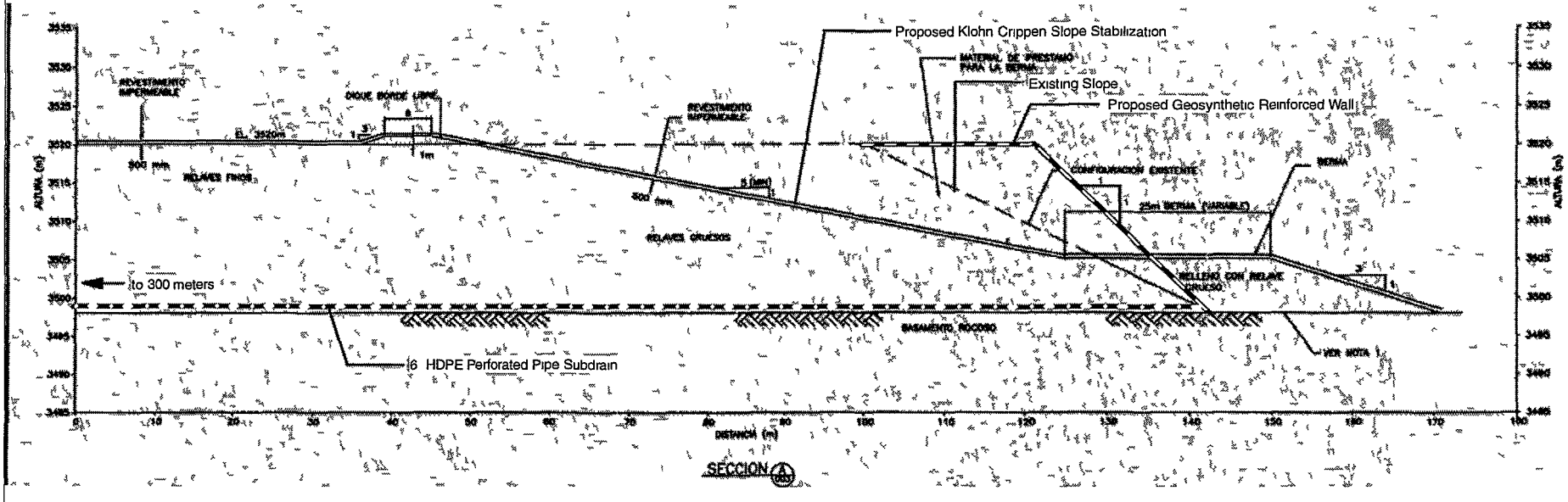
Conceptual Approach

This Appendix presents a conceptual approach to satisfy the above objectives without changing the overall footprint of the existing tailings dam The rationale driving the overall management scheme is related to several factors all of which must be optimized The primary factor is cost A reduced cost appears to be made possible by the unique conditions at San Felipe and the potential cost savings to be derived from the positive environmental benefit of the wetlands at the southwestern end of the San Felipe tailings dam Therefore the preservation and enlargement of the wetlands area is a key feature of this design and management alternative even though it may initially seem to be the worst possible thing to do by conventional thinking and remediation practices However, the proposed conceptual approach is consistent with natural re-vegetation and amelioration processes

Water quality data recently obtained on 14 August 1997 by CMNP for Punto A" located near the inlet to the decantation line at the southwestern end of the tailings indicates that the surface water in the already re-vegetated zone of the tailings surpasses the effluent standards set forth in the PAMA for Unidad Minera Quiruvilca In essence water flowing on the tailings through the re-vegetated area is not only buffered but acidification is prevented and metals concentrations are suppressed Hence a considerable financial benefit can be potentially realized if the surface of the tailings is re sloped so that all surface water drains to the inlet to the decantation line located at the southwestern end of the tailings and not via drainage trench C-10 This is a very attractive strategy since the flow in C-10 represents one of the largest acid water flows at San Felipe Therefore, with the construction of the proposed geosynthetic re-inforced wall (see below), the existing drainage canal C-10 will be eliminated and the only flow of water in the re-aligned C-12 will be uncontaminated surface water (see main text) The re direction of ponded water will correspond to an increase in the volumetric flow of D-4

In order to take advantage of existing wetlands processes, the eroded face of the existing tailings dam can be retrofitted with a geosynthetic wall which provides reinforcement of the cohesionless tailings Figure E-1 shows a schematic of the existing cross-section through the face of the tailings dam and the Klohn-Crippen rehabilitation scheme The existing face of the tailings has a 2H 1V slope and is deeply channeled by erosion Figure E-1 also shows the existing San Felipe profile superimposed with the anticipated cross-section of the proposed geosynthetic wall and subdrain system Although the wall is anticipated to have a slope of 1V 1H, the final profile will depend on the optimization of geotechnical and seismic stability, wall angle, and cost The chosen geosynthetic fabric must be characterized by a pore opening size which will retain the tailings particles to eliminate sediment transport while allowing flow of water to ensure continued de watering and minimization of acid water generation In this regard heavy non-woven geosynthetics are preferable The base layer of the terrace will be constructed on the granular starter berm where the eroding tailings are currently forming multiple tali or alluvial fans As such, the final configuration will not intersect or bury the La Paloma mine portal or any other existing features of the San Felipe valley floor such as the drainage trenches or depressions/crevasses in the ground

The geosynthetic wall will be coupled with the installation of a new subdrain system consisting of approximately five horizontally-drilled subdrains to de-water a 300 meter-wide section of tailings running parallel to the existing crest of the tailings dam, as shown in Figure E-2 It is anticipated that the subdrains will be fabricated of six-inch diameter slotted HDPE pipes double-wrapped with a heavy non-woven geosynthetic fabric The outfalls of the new subdrains will be constructed with in-line trap to inhibit the flow of atmospheric oxygen up the drains By



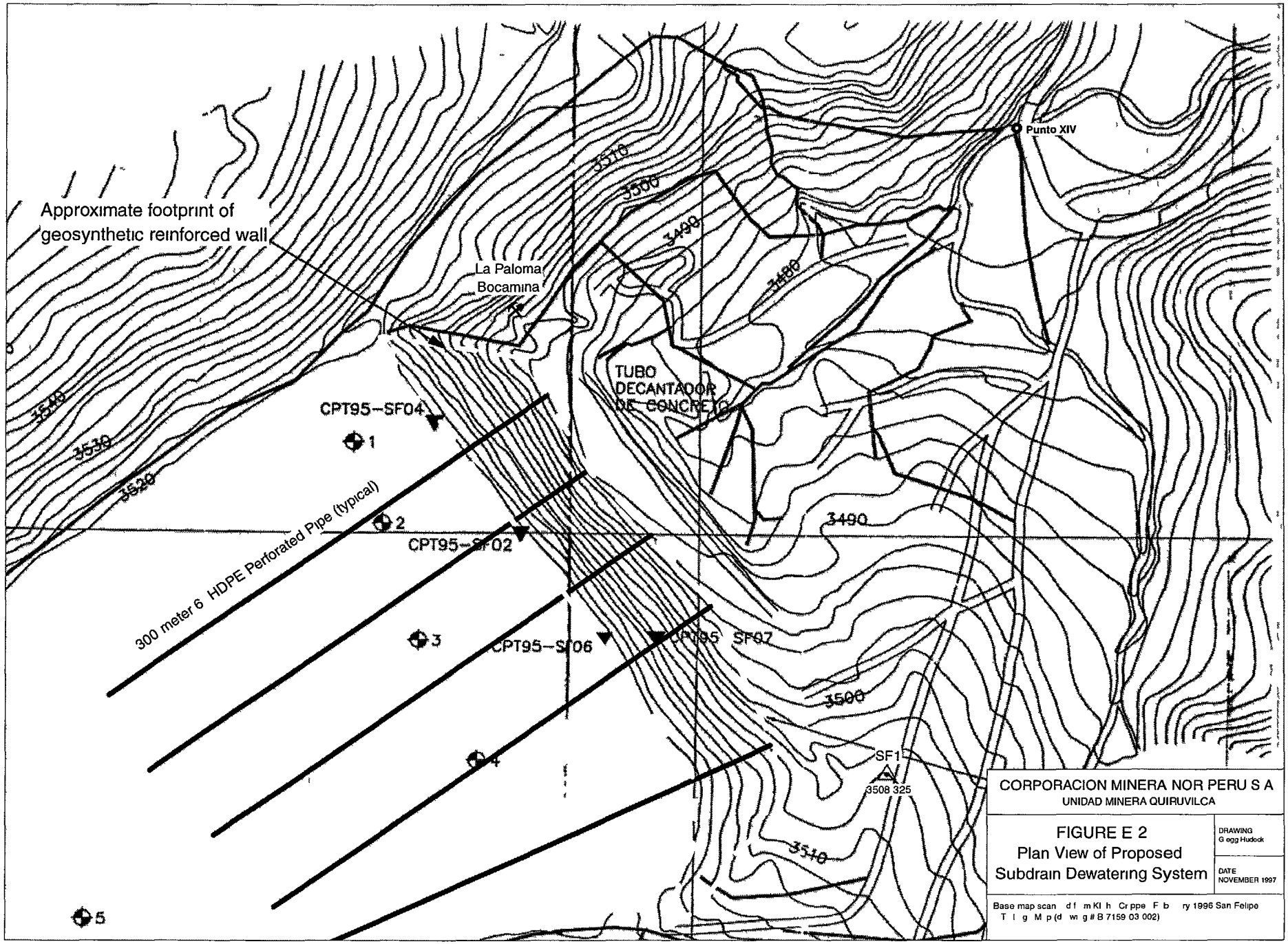
CORPORACION MINERA NOR PERU S A
UNIDAD MINERA QUIRUVILCA

FIGURE E-1
Profiles of Proposed
San Felipe Stabilization

DRAWING
G ogg Hudock

DATE
NOVEMBER 1997

Base map canned from Klohn Crippen February 1996 San Felipe Tailings Map (drawing # B 7159 03-004)


Approximate footprint of geosynthetic reinforced wall
La Paloma Bocamina
Punto XIV
TUBO DECANTADOR DE CONCRETO
CPT95-SF04
CPT95-SF02
CPT95-SF06
CPT95-SF07
1
2
3
4
5
300 meter 6 HDPE Perforated Pipe (typical)
3510
3500
3490
3480
3530
3520
SF1
3508 325
CORPORACION MINERA NOR PERU S A
UNIDAD MINERA QUIRUVILCA
FIGURE E 2
Plan View of Proposed
Subdrain Dewatering System
DRAWING
G egg Hudock
DATE
NOVEMBER 1997
Base map scan d f m Kl h Cr ppe F b ry 1996 San Felipe
T l g M p (d wi g # B 7159 03 002)

creating an anaerobic condition for the full length of the subdrain system internal oxidation and acidification of the tailings should be minimized The new drains will be installed at the same elevation of the base of the proposed geosynthetic wall This initial configuration has been chosen because it maximizes the horizontal reach of the new subdrain system on a unit cost basis and avoids having to bore through (and subsequently compromise) the existing granular starter berm However a detailed analysis may eventually reveal that drilling through the starter berm is the best option In either case it is likely that the subdrains will not completely eliminate flow in the existing subdrain system but the corresponding reduction in hydraulic head should lead to a reduction in the piping of tailings into the existing subdrain system

The groundwater profile shown in Figure E-1 divides the tailings into two main regions The southwestern end is wetlands area having a high water saturation The northeastern zone is a drier, unsaturated region In essence, the new subdrain system creates a dam within a dam, as the drier and stronger downstream block of tailings adjacent to the geosynthetic reinforced wall retains the wetter upstream block In this way, the wetlands is preserved while at the same time the long term erosional and geotechnical stability of the dam is attained The proposed alternative also satisfies the other constraints on the environmental management in the San Felipe valley The valley floor remains available for the implementation of passive environmental schemes grazing of livestock can continue unhindered without impacting the geotechnical improvements, and there is no infrastructure (fences pumps etc) to be stolen

Preliminary Cost Estimate

There are two main components to the system the geosynthetic wall and the subdrain system The estimates provided here are based on US market prices and do not include international taxes and duties (i e SUNAT) It is felt that these costs are somewhat conservative since the price of labor in Peru is considerable less than in the United States

Geosynthetic Reinforced Wall

The geosynthetic wall shown in Figure E-1 is anticipated to be 30 meters tall with a width of 180 and 380 meters at the bottom and top, respectively Five lifts per meter of wall height are required and a bench width of 5 meters with a 1 meter wrap is planned Accordingly, approximately 252,000 m^2 of geosynthetic will be required, but 275,000 m^2 will be used as for planning purposes Even if the final wall geometry changes somewhat this estimate is representative of the overall geosynthetics requirement The current price for Hoescht-Celanese 16-oz non-woven continuous filament fabric shipped F O B from Charleston, South Carolina, is approximately \$1 34/m^2 For such a large order, it may be possible to negotiate a price as low as approximately \$1 25/m^2, however, a price of \$1 30/m^2 is more realistic Based on a \$1 30/m^2 price, the material cost of the geosynthetic alone is anticipated to be approximately \$357,500 While it is currently recommended to use a 16-oz fabric, a detailed analysis should be conducted to see if a 12 oz fabric (\$1 02/m^2) will provide the same long-term performance The material cost for the 12-oz fabric is \$281,000, or a savings of \$76,500 Containerized shipping of either geosynthetic from South Carolina to Peru will be approximately \$98,000 based on a \$3 500/container charge with 25 rolls per container The cost of the geosynthetic plus shipping to Salaverry (or Lima) is conservatively estimated to be \$379,000 to \$455 500 depending on the fabric selected Since the geosynthetics can be classified either as a construction material or textile one should negotiate for the lower of the two import tariffs

An estimate of the construction cost would involve the geosynthetic transportation charges from Salaverry to Shorey Construction of the wall will require approximately 4-5 months based on unskilled labor (10 men) with two (max) backhoe operators, and several light-weight compactors The construction technique can be completed on a cut-and -cover basis at the face of the tailings dam A full-size John Deere 310A backhoe rents for less than \$2500/month in the Atlanta area The cost for two backhoes over a six-month period is approximately \$30,000 Therefore, if CMNP uses it own laborers currently on salary, it is not likely that the installation cost will exceed \$100,000

Subdrain system

This estimate assumes that a directional drilling rig and operators are available in Peru at a cost equal to or less than the US market price for comparable services The current installed price for directionally drilled pipes less than

0 33m-diameter (1 ft) is approximately $150/m ($40-50/ft) which includes mobilization/demobilization, materials, drilling etc Each of the five subdrains will be fabricated of 6-inch diameter slotted HDPE pipe double-wrapped with a heavy non-woven geosynthetic and will be approximately 300 meters long, for a total length of 1,500 meters The corresponding price estimate is $225,000

Overall Estimate

Less import tariffs, engineering design, construction and geosynthetic transportation costs between Salaverry and Shorey the installed cost of the geosynthetic wall and new subdrain system appears to be on the order of $704,000 to $780,500 Assuming the engineering design and construction monitoring are an additional 10%, the overall estimate approaches $774,400 to $858,550 excluding import tariffs and geosynthetic transportation costs between Salaverry and Shorey This is approximately $350,000 to $425,000 less than the quote provided by Klohn-Crippen ($1 2 million) for the rehabilitation and capping specified in the PAMA

Path Forward

Although incomplete the preliminary cost estimate for the geosynthetic wall and new subdrain system suggests that this option may fully price out at a total cost considerably less than the rehabilitation and capping option currently incorporated in the PAMA It is important to note that both alternatives are purely geotechnical and hydrological While the geotechnical and seismic stability of the San Felipe tailings dam are integral parts of the long-term care and management of the tailings dam, the PAMA makes the environmental issues primary In this regard, the geosynthetic wall and new subdrain system appears more consistent with the environmental issues and social constraints governing the San Felipe valley, while simultaneously allowing for the spatial needs of passive treatment technologies (i e , PGB), which, if implemented, must be located on the San Felipe valley floor immediately downstream of the dam By requiring less space and impacting only a small area of the existing tailings dam, the geosynthetic wall and subdrain system appears to provide CMNP with more management options and flexibility for long-term care

The proposed geosynthetic wall and new subdrain system is essentially untested although it draws on many principles used in analogous applications There are several success stories involving the use of geosynthetics to re-inforce poorly draining soils (similar to tailings) However the use of geosynthetics for tailings re-inforcement, let alone at high altitudes under high UV, acidic and de-oxygenated conditions, is relatively unheard of even by those very knowledgeable on geo-environmental applications of geosynthetics such as Drs John Bowders Jr , Robert M Koerner and James K Mitchell These researchers and others seemed to think the concept was interesting and held potential promise Such factors as the UV and chemical resistance of the geosynthetics geosynthetic pullout, geosynthetic-tailings interfacial shear behavior geosynthetic permittivity, etc, would need to be evaluated Coupled with the emphasis on wetlands and passive treatment techniques such as the porous geochemical barrier utilizing industrial byproducts, there are several aspects of the geosynthetic wall itself that are innovative and may lead to interesting research, design awards and good public relations

On an economics basis alone, sufficient motivation exists to more fully explore and evaluate the feasibility of the geosynthetic wall and subdrain system This will probably involve an experimental/empirical component to evaluate parameters such as pull out strengths and interfacial shear strengths between the geosynthetics and tailings Likewise, the longevity of the geosynthetics must be evaluated under the aggressive conditions associated with the San Felipe application If installed the geosynthetic wall should also be instrumented with inclinometers and settlement detection devices to monitor the wall movements

The focus of the current project between Georgia Tech and Corporacion Minera Nor Peru is to evaluate remediation technologies and the feasibility of a porous geochemical barrier to passively attenuate the acid waters at San Felipe While geotechnical and hydrological engineering issues in the valley ultimately affect the appropriateness of certain remedation technologies and the feasibility of the PGB, geotechnical and hydrological issues are not part of the formal agreement However, Georgia Tech and Drexel University are willing to help identify an engineering design company with geosynthetics experience in the event Klohn-Crippen / SVS Ingenieros is not able to assist Corporacion Minera Nor Peru in this matter

The Georgia Institute of Technology and Drexel University are well positioned to provide research facilities and expertise numerical modeling capabilities and technical oversight on the design construction and implementation of geosynthetics applications The Department of Civil and Environmental Engineering at the Georgia Institute of Technology was recently awarded the Middle Atlantic Earthquake Center (MAEC) by the National Science Foundation Many geosynthetics companies have large offices, headquarters, and/or manufacturing plants in the greater Atlanta area While considerable research at Georgia Tech involves geosynthetics, Drexel University is the home of the Geosynthetics Research Institute, one of the largest research facilities focused on geosynthetic applications Because of the untested nature of this application, Georgia Tech is very interested in pursuing additional mechanisms for collaboration with Corporacion Minera Nor Peru on the geosynthetic reinforced wall and new subdrain system The determination of UV and chemical resistance of the geosynthetics, geosynthetic pullout resistance, geosynthetic-tailings interfacial shear behavior, geosynthetic permittivity, detailed analyses, modeling and instrumentation monitoring has the characteristics of a very interesting Ph D thesis As such, the role Georgia Tech envisions is that of a research arm and peer review/technical advisor on the construction and implementation phases

Appendix F

Literature Provided to Georgia Tech Team by CMNP, July - August, 1997

Corporacion Minera Nor Peru S A *Rehabilitacion Ambiental - La Mina Quiruvilca y El Medio Ambiente*

Corporacion Minera Nor Peru S A *Programa de Adecuacion y Manejo Ambiental Unidad Minera Quiruvilca*, August, 1996

H A Simmons Ltd *Quiruvilca Mine Water Treatment Project Basic Engineering Report*, July, 1996

H A Simmons Ltd Letter to Ing Jose Pacora detailing Quiruvilca Water Treatment Project dated 12 September, 1996 Report includes

1 Design Criteria Revision "N"
2 Mechanical Equipment List dated 9 September 1996
3 Drawings - Process Flowsheets, Process & Logic Diagram
4 Summary of major changes to the Capital Cost Estimate
5 Capital Cost Estimate
6 Operating Costs for SX/Crystallization and HDS

Klohn-Crippen *Corporacion Minera Nor Peru S A Rehabilitation de La Zona de Relaves del Almirvilca*, Contrato No CMNP-01-96, March, 1996

Klohn-Crippen *Corporacion Minera Nor Peru S A , Rehabilitation de La Zona de Relaves de Santa Catalina*, Contrato No CMNP-02-96, March, 1996

Klohn-Crippen *Corporacion Minera Nor Peru S A Quiruvilca Mine Santa Catalina Tailings Impoundment Stabilization of Main Dam and Feasibility of Expansion*, April, 1996

Water quality sampling results for San Felipe Valley

Table 01 - Point XIV Water Quality Control for San Felipe (January, 1996 - December, 1996)
Table 02 - Point XIV Water Quality Control for San Felipe (January, 1997 - July, 1997)
Table 03 - Point XIV Water Quality Control for San Felipe (September & November 1994, April & October, 1995, April & December, 1996, August, 1997)
Table 04 - Drainage Trench Water Quality Control for San Felipe (July, 1994, August, 1994 November, 1996)