APPENDIX C

Waste Isolation Pilot Plant, Review of Proposed Panel Closure Enhancements

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WASTE ISOLATION PILOT PLANT
REVIEW OF PROPOSED PANEL CLOSURE ENHANCEMENTS

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF APPENDICES

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EXECUTIVE SUMMARY

The panel closure system for the Waste Isolation Pilot Plant (WIPP) Project near Carlsbad, New Mexico, is comprised in part of a mass concrete plug, together with installation of a grout to fill any voids between the concrete plug and host halite rock. The specification for the project provided a prescription based formulation for the *Salado Mass Concrete* for the closure panel. The specification also required the use of a crushed quart aggregate. With respect to the grout, the specification required the use of a fresh-water based grout.

AMEC has been asked to review and comment on three proposed *Panel Enclosure Enhancements:*

(a) A change to the specifications to allow the use of a well-rounded carbonate-based coarse aggregate in lieu of the originally specified crushed quartz aggregate in the mass concrete.
(b) A change in the grout used from a fresh-water grout to a salt-based grout.
(c) A change for the mass concrete requirements from a prescription-based specification (which gives a recipe for the *Salado Mass Concrete*) to a performance-based specification which requires the Contractor to formulate the mass concrete mixture design and meet a prescribed set of performance specifications.

In brief, AMEC concurs in principle with the above-proposed *Panel Closure Enhancements* as detailed in the report, which follows. AMEC has, however, provided a number of recommendations as to issues which should be addressed by the specifiers with respect to the proposed changes. In particular, with respect to the proposed change to a *well-rounded carbonate-based rock*, it is recommended that it be demonstrated that:

- The carbonate-based rock is physically and chemically suitable for it's intended purpose, i.e. it should be shown to not be susceptible to deleterious alkali-carbonate reactivity, or salt-induced chemical degradation, and should display satisfactory thermal properties.
- The coarse aggregate should have suitable bonding characteristics to the past fraction (the use of particles with a partial *crush-count* should be considered).

With respect to the proposed use of a salt-based grout, AMEC concurs with this proposed conge, since it will counteract the tendency for dissolution (and hence void formation) of fresh-water based grouts. Also, review of the literature indicates enhanced long-term chemical stability of salt-saturated grouts placed in salt formations, compared to fresh-water grouts.

Finally, with respect to the proposal to change from a prescriptive *Saslado Mass Concrete* specification to a *Generic Salt-Based Concrete* specification for the closure panel concrete, AMEC concurs with this recommended change, since it gives the Contractor more freedom to adjust the mass concrete mixture properties to optimize the concrete construction process. Also, it places responsibility for performance of the concrete with the Contractor. This is contractually preferable for the Owner. The project specification should, however, then be written in rigorous performance-based specification language. In addition, more specifics should be provided in the specification regarding permissible constituents materials for the mass concrete for components such as the salt (type and saturation level required) and shrinkage compensating materials.

1.0 INTRODUCTION

AMEC Earth & Environmental Limited (AMEC), was retained by Mining and Environmental Services LLC (MES) to review certain proposed panel closure enhancements for the Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico USA. Specifically AMEC was provided with a *Panel Closure Enhancement* (1) report by MES and asked to:

(a) Review the proposed change to the specifications to allow the use of well-rounded carbonate coarse aggregate in the panel closure concrete, in lieu of the crushed quartz aggregate specified in the *detailed design report for an operational phase panel closure system.*
(b) Review the proposed change to the specifications to allow the use of a salt-based grout, in lieu of the fresh water grout specified in the initial design report.
(c) Comment briefly on the proposed change to the specification to permit the use of a generic salt-based concrete in the panel closure concrete in lieu of the Salado Mass Concrete specified in the initial design report. (This was an addition to the initial terms of reference)

In addition to reviewing the report detailing the proposed *Panel Closure Enhancements* (1) provided by MES, AMEC conducted a literature search on the subject and reviewed relevant papers including Sandia National Laboratories Reports provided to AMEC by the Environmental Evaluation Group in Albuquerque, New Mexico. AMEC also communicated with a grouting specialist, Alex Naudts of ECO Grouting Specialists Ltd. in Ontario, Canada, with experience in the use of salt-based cement grouts in potash mines and other salt formations.

The report, which follows, provides a brief review of the preceding proposed panel closure enhancements. This report is written by Dr. D. R. Morgan, P.Eng, a civil engineer with particular experience in concrete technology, including concrete and grout mixture designs and construction monitoring and testing for civil and mining projects. While Dr. Morgan is not a chemist, he has considerable experience with respect to the hydration and durability of portland cement based systems, as affected by the addition of chemical admixtures, supplementary cementing materials and ingress of external aggressive agents. He also has experience in the design and construction of mass concrete structures in civil and mining applications. This report is written from this perspective.

2.0 LITERATURE REVIEW

AMEC conducted a literature search using key words: brine + salt + concrete + grout + potash + Salado in various combinations. Cited references are listed in Appendix A. A general list of references is provided in Appendix B. Readers wanting more details regarding any of the technical issues discussed in this report are invited to examine the cited references and if necessary general references. This reference list should not be considered as all-inclusive. Many more references are contained in the cited and listed references. It does, however provide a listing of key publications on the subjects of interest.

With respect to the proposed use of salt-based grout and generic salt-based panel closure concrete, it should be recognized that the performance of such products is likely to be very *salt-specific.* Thus, while there is value in examining the results of test on salts and performance of concretes and grouts from locations other than the Waste Isolation Pilot Plant (WIPP), most emphasis should be placed on WIPP tests and observations. From review of the literature, it is apparent that the majority of the testing and evaluation for the WIPP project has been conducted by the Sandia National Laboratories in Albuquerque, New Mexico. Most emphasis should thus be placed on the findings of these reports.

3.0 CHANGE IN GENERAL AGGREGATE SPECIFICATIONS

3.1 General

A proposed enhancement to the panel closure is to expand the specification for the coarse aggregate to be used in the mass concrete to allow for the use of well-rounded natural carbonate materials in place of the specified crushed quartz aggregate. The main reason for this proposed change is to improve the workability of the concrete in general, and pumpability in particular. A second reason for the proposed change is the fact that crushed quartz is not available within a 50-mile radius of the WIPP site, whereas natural rounded carbonate aggregates are locally available.

It is reported that the carbonate aggregate mineralogy is such that it should not adversely affect properties. This should be verified by:

(a) Examination of a petrographic analysis of the aggregate (ASTM C295) (2)
(b) Examination of conformance of the aggregate to the ASTM C33-99a *Standard Specification for Concrete Aggregates* (3)

In particular, the aggregate should be demonstrated to conform to the requirements in ASTM C33-99a, Tables 2 and 3 for:

- Gradation, including percent passing the 75 μm (No. 200) sieve;
- Deleterious particles (e.g. clay clumps, friable particles, chert, coal, etc).
- Magnesium sulphate soundness loss.

3.2 Alkali Aggregate Reactivity

Evaluation of the alkali aggregate reactivity (AAR) susceptibility of the aggregate should be carried out. More specifically it is recommended that records be produced demonstrating that the carbonate aggregate is non-reactive when evaluated against the:

- ASTM C 586-99 *Standard Test Method for Potential Reactivity of Carbonate Rocks as Concrete Aggregates* (*Rock-Cylinder Method*) (4) ;
- ASTM C1105-95 *Standard Test Method for Length Change of Concrete Due to Alkali-Carbonate Rock Reaction* (5) (12 month prism test).

Additional guidance with respect to evaluation and testing of carbonate-based aggregates for AAR can be found in CSA A 23.1-00, *Concrete Materials and Methods of Concrete Construction, Appendix B Alkali Aggregate Reaction* (6) and CSA A 23.2-27A *Standard Practice to Identify Degree of Alkali-Reactivity of Aggregates and Measures to Avoid Deleterious Expansion in Concrete* (7).

3.3 Chemical Stability in Brine

It is reported by Nowak et al (8) and Wakeley et al (9) that a certain dolomitic aggregate near Carlsbad, NM, has shown vulnerability to chemical alteration by reaction with brines in concrete. (Note: Dolomite, $MgO.CO_3.CaO.CO_3$.). It should be demonstrated that the carbonate aggregate selected for use is not susceptible to such deterioration.

3.4 Thermal Considerations

In addition to the above-recommended tests to demonstrate the suitability of the carbonate-based aggregate for it's intended use in the mass concrete closure panels, consideration should be given to the differences in thermal properties of the carbonate-based aggregates compared to the previously approved quartz-based aggregates. There are three thermal properties of aggregate that may be significant in the performance of the mass concrete: coefficient of thermal expansion, specific heat and conductivity. It is recommended that these thermal properties of the carbonate-based aggregate be determined and compared against those of the original crushed quartz aggregate specified. The design engineers for the closure panels should then evaluate the significance of any differences between the thermal properties of the two aggregate types on the expected behaviour of the mass concrete closure panels.

It is not proposed in this brief review report to elaborate on the test methods for the determination of thermal properties of the aggregates (or concrete) and the significance of these thermal properties with respect to the short and long term performance of the mass concrete closure panels. Good guidance in this regard can however, be found in publications such as: Cook, *Thermal Properties* (10,11) and Neville, *Properties of Concrete* (12).

A few thermal considerations are nevertheless worth pointing out:

- The coefficient of thermal expansion of the aggregate influences the coefficient of thermal expansion of the concrete containing such aggregate.
- It is desirable to have a coefficient of thermal expansion in the coarse aggregate which does not differ too much from the coefficient of thermal expansion of the hydrated portland cement paste in the concrete. Serious differences in the coefficients of thermal expansion have been reported to occur with aggregates with very low expansion, such as certain granites, limestones, and marbles (12). In such concretes, a large change in temperature (e.g. such as induced by the heat of hydration of the concrete) may introduce differential movement between the aggregate particles and paste, sufficient to break bond. This could result in microcracking, sufficient to impact on the durability of the concrete.

Thus for the carbonate aggregates proposed for use in the mass concrete closure panels at WIPP, it is recommended that the coefficient of thermal expansion of the aggregate be determined, to verify that it is suitable for use in it's intended application.

3.5 Workability/Pumpability

The prime reason for the proposed change from crushed quartz aggregate to a well-rounded carbonate-based rock is to enable production of a concrete with enhanced *workability* (mixing, pumping, placing, and consolidation characteristics) for the mass concrete closure panels. While quarried crushed rock is used to produce concrete with acceptable *workability* in several parts of North America (particularly the Eastern USA and Eastern Canada), natural rounded fluvial or glaciofluvial gravels typically produce concretes with superior *workability*, which are easier to mix, pump, place, consolidate and finish.

It should, however, be noted that most gravels used in concrete production are usually partially crushed, i.e. have a certain *crush-count*. There are certain advantages to having partially fractured faces in a sufficient percentage of the aggregate particles, including enhanced compressive, flexural and tensile strength development in the concrete made with such particles, compared to concrete made with natural rounded particles only. This observation, however, only applies if the particle crushing process produces aggregate particles with suitable shape i.e. particles that are more *equant* (cubical to round), as opposed to excessive quantities of particles that are flat, platy or elongated.

With respect to the proposed change to the use of natural rounded aggregates it should be cautioned that aggregate particles with very dense, smooth (polished) surfaces will typically have lower bond strengths than aggregates with rougher surface texture. Partial crushing of natural rounded aggregates is beneficial in that fracture faces on the aggregate particles typically have greater surface roughness. This enhances bond strength to the paste and consequently improves compressive, flexural and tensile strength development in the concrete.

To summarize, the proposed enhancement to use natural well-rounded aggregates to improve *workability* (including pumpability) of the closure panel concrete is considered appropriate. Consideration should, however, be given to producing an aggregate with a partial *crush-count*, to enhance paste to aggregate bond and consequent physical concrete properties.

4.0 SALT-BASED GROUT

It is understood that the *Environmental Protection Agency (EPA) Certified Closure* for the panel closure design approved the use of a *fresh water grout*. The proposed enhancement is to use a salt saturated grout instead. The purpose of the grout is to fill any voids that develop at the *back* (overlying roof) between the panel closure concrete, and the host halite formation as a result of sedimentation and bleeding, etc. in the mass concrete.

The concern with respect to using a *fresh water grout* is twofold:

(a) The liquid grout has the potential to dissolve the host halite material during placement, which is counterproductive to it's intended void sealing function;
(b) There is potential for a reduction in the long term stability and durability for the hardened grout because of the *chemical gradient* developed between the fresh water grout and the host halite formation; i.e. magnesium and other ions moving from the halite formation into the grout can result in calcium dissolution and depletion, which in turn can cause a loss of strength and degradation of the grout. Details regarding this dissolution mechanism can be found in publications by Wakeley and Burkes (13), Tumidajski and Chan (14), Wakeley et al, (15), Lambert et al (16) and Pool et al, (17).

Thus the proposed enhancement to use a salt-based grout is intended to negate the above concerns with using a *fresh water grout*. The use of a suitable salt solution (typically sodium chloride) as a mixing fluid in the grout minimizes the potential for the fresh grout to dissolve the host halite formation during placement and reduces the chemical gradient between the host halite formation, hardened grout, and proposed salt-based concrete (13, 14, 15, 16,17). In addition, Wakeley et al (15) report that salt-free grouts, when placed in contact with halite form no bond with the host rock. By contrast, a salt-saturated cementitious material bonds well with the halite.

There is precedence for the use of salt-saturated mixing water in cement-based grouts for void sealing of salt formations. Details can be found in publications such as Eyermann et al (18), Al-Manaseer et al (13) and others.

In addition to a review of the literature on this subject, Dr. Morgan of AMEC spoke with Alex Naudts at ECO Grouting Specialists Ltd., in Ontario, Canada, who has considerable experience in grouting in potash and salt mines. At AMEC's request, he provided a brief *capability statement* (20) of his experience in this regard. A copy of this statement is attached in Appendix B.

Notable examples of the use of salt-saturated grouts for void sealing purposes in salt formations include:

- Rocanville, Potash Mine, Saskatchewan, 1985 (19, 20)
- Esterhazy (K2) Mine, Saskatchewan, 1986 (19,20)
  (The writer was involved in the design and construction of one of the four bulkheads constructed on this project).
- Kali & Salz Potash Mine, Kassel, Germany (20)
- Potocan Potash Mine, New Brunswick (20)

Naudts (20) drew the conclusion that: *Most parties agree that it is not appropriate to use fresh water in grouts in contact with salt or potash ore (halite, carnalite, etc.) because of the migration of sodium, calcium or magnesium ions into the gelling grout, leaving a porous matrix near and at the contact zone.*

Review of the literature indicates that great care should be exercised in formulating salt-based portland cement grouts. Sodium chloride typically acts as a set retarder and water reducer. Chemical admixtures which work well in conventional portland cement-based grouts (without salt addition) may however, not be compatible with salt-based portland cement grouts. For example, certain water reducers and retarders are reported to not be suitable for use in salt-based grouts because of problems such as very high air contents, foaming, excessively rapid rate of slump loss and excess set retardation (9, 20, 21, 22). Also, bentonite is reported to not be compatible with salt-based grouts (20).

By contrast, supplementary cementing materials, such as fly ash (type F or type C) are reported to be beneficial with respect to improving both the plastic and hardened properties of the grout. The addition of fly ash results in a stable suspension, with reduced bleeding and hence provides a more homogenous grout. Similarly, silica fume is reported to have been beneficially used for such purposes (20, 22). In addition, it is reported that hardened grouts with fly ash addition displayed enhanced bond to halite (13) and superior *long term* performance, compared to grouts with no fly ash, with respect to parameters such as compressive and flexural strength and modulus of elasticity, when the grouts were submerged in containers with brine at various confining pressures (21).

An argument can thus be made that the salt-based grouts should be formulated with a supplementary cementing material, such as fly ash (and / or silica fume) for the WIPP project.

An example of a formulation for a salt-based grout with fly ash addition, is the Grout BCT-1F described below, which is given in the *WIPP Project Specification Section 02722 Section 2.1* (23).

Table 1: Salt-Saturated Grout (BCT-1F)

Component	**Percent of total Mass (wt.)**
Class H cement	48.3
Class C fly ash	16.2
Cal Seal (plaster – from Halliburton)	5.7
Sodium Chloride	7.9
Dispersant	0.78
Defoamer	0.02
Water	21.1

The specification states: *The following formulation is suggested to the contractor as an initiation point for selection of the grout mix.* The specification does, however, not provide any performance requirements for the grout. As such, the specification is likely to be interpreted as a *prescription specification* by the contractor. This creates potential contractual conflicts if the contractor simply adopts the BCT-1F formulation and the grout does not perform as intended. It is thus recommended that WIPP develop a set of *performance specifications* for the grout, and require the contractor to demonstrate conformance of the grout to these *performance specifications.*

Parameters of interest with respect to *performance specifications* for the grout could include:

- Chloride saturation, including a statement on what type of salt is permissible. Note: While halite is comprised mainly of sodium chloride, it can contain lesser amounts of salts such as calcium sulphate, calcium chloride and magnesium chloride (28);
- Water /cementing materials ratio (likely variable, depending on size of voids to be filled and distance grout has to travel);
- Viscosity, as measured by the Marsh Flow Cone Test e.g. API RP 13B-1;
- Early age volume change e.g. ASTM C 287-95a *Standard Test Method for Change in Height at Early Ages of Cylindrical Specimens for Cementitious Mixtures* (24).
- Volume change at later ages (1, 14, 28 days) as measured by CRD C 621 (25).
- Bleeding and Expansion e.g. ASTM C 940-98a, *Standard Test Method for Expansion and Bleeding of Freshly Mixed Grouts for Preplaced-Aggregate Concrete in the Laboratory* (26).
- Setting time e.g. ASTM C953 *Standard Test Method for Time of Setting of Grouts for Preplaced-Aggregate Concrete in the Laboratory* (27).
- Specific Gravity e.g. API RP 13B-1.

It is recommended that appropriate testing methodologies be selected and a set of performance requirements be established for the salt-based grout(s). This approach would be consistent with the proposed *Panel Closure Enhancement* (1) for the *Generic Salt-Based Concrete*, which represents a change from a prescription to a performance-based specification.

Finally the Panel Closure Enhancement (1) Section 3.6 statement that: *No strength specifications for grout is appropriate, since any grout injected would serve in a lithostatic stress state and not compromise a structural element of the barrier*, is noted. This reviewer concurs with this statement and so setting compressive strength performance requirements for the grout would not appear to be warranted.

5.0 SALT-BASED CONCRETE

AMEC has been asked to comment briefly on the proposed *Panel Closure Enhancement* (1) to permit the use of a generic salt-based concrete in the panel closure concrete in lieu of the Salado Mass Concrete specified in the initial design report. This was an additional item to the original terms of reference, and while we have conducted a literature search on the subject (and done pertinent background reading on the subject) this review is brief, because of time and budget constraints.

In principle, AMEC concurs with this proposed change to the specifications. It is recognized that considerable research has been conducted by the Sandia National Laboratories (8, 9, 15, 16, 17, 18) and others in developing the Salado Mass Concrete for the WIPP Project.

The Panel Closure Cast-in-Place Concrete Specification, Section 03300, provides a list of so-called *Target Properties of the Concrete Mix*, in clause 2.5. For convenience of referral, this clause is produced below.

2.5 Target Properties of the Concrete Mix

The Contractor shall develop and proportion a salt-saturated mix for use in constructing the concrete barrier. The Contractor shall demonstrate by trial mix that the proposed concrete meets the following properties:

Table 2: Target properties for Barrier Concrete

Property	*Comment*
4-hr working time	*Indicated by 8-inch slump (ASTM C 142) after 3-hr intermittent mixing, or an appropriate measure of pumpability.*
Less that 25°F heat rise prior to placement	*Difference between initial condition and temperature after 4 hr.*
4,000 psi compressive strength (f'_c)	*At 56 days after casting (ASTM C 39)*
Volume stability	*Length change between +0.05 percent and-0.02 percent (ASTM C 490)*
Minimal entrained air	*2 percent to 3 percent air*

The Contractor shall provide certified copies of test data from an approved laboratory demonstrating compliance with the above target properties.

In addition to the target properties the Contractor shall provide certified test data for the trial mix for the following properties:

- *Heat of hydration* — *ASTM C-186*
- *Concrete set* — *ASTM C-403*
- *Thermal Diffusivity* — *USACE CRD-C36*
- *Water Permeability* — *USACE CRD-C43*

The specifications then provide what amounts to a *prescription* formulation for the Salado Mass Concrete, as detailed below.

An example of initial proportioning for the concrete is the salt-saturated concrete shown below:

Table 3 : Salt-Based Concrete Mixture Proportions

Component	*Percent of Total Mass*
Class H cement (API 10)	*4.93*
Chem Comp III (ASTM C-845 Type K)	*2.85*
Class F fly ash (ASTM C-618)	*6.82*
Fine aggregate	*33.58*
Coarse aggregate	*43.02*
Sodium chloride	*2.18*
Defoaming agent	*0.15*
Sodium citrate	*.009*
Water	*6.38*

The specification then goes on to say: The Contractor shall prepare a trial mix and provide certified test data from an approved testing laboratory for slump, compressive strength, heat rise, heat of hydration, concrete set time, thermal diffusivity, and water permeability.

Despite the wording in the specifications, the above approach is tantamount to a *Prescription Specification*, i.e. the Contactor is being told what mass concrete mixture proportions to use. There are potential contractual concerns with this approach, since if the concrete supplied failed to meet the required performance parameters, the Contractor could argue, with some justification that it is not his responsibility, but that if the specifying authority.

In AMEC's view, it is preferable to write the specification as *a Performance-Based Specification*, with the responsibility for the concrete mixture proportioning residing with the Contractor. The specifier should write a rigorous performance-based specification, including provision of specifics regarding all constituent materials permitted to be used in the *generic salt-based concrete*. In particular, specifics should be provided regarding the salt that is permitted to be added to the concrete, and which shrinkage compensative materials will be permitted to be added.

The Specifier should make available to the Contractor pertinent material regarding *Salado Mass Concrete* developed for the WIPP Project. This material can then provide the Contractor with a starting point for his *generic salt-based mixture proportioning*. In this way, the Contractor can adjust the mixture design, if required during construction, to facilitate the construction process. The responsibility for performance of the concrete would however, reside with the Contractor.

6.0 Limitations and Closure

This report has been prepared for the exclusive use of Mining and Environmental Services LLC for the purpose described in the report. Any use which a third party makes of this report, or any reliance on or decisions made based on it, are the responsibility of such third parties. AMEC accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report. It has been prepared in accordance with generally accepted materials engineering practices. No other warranty, expressed or implied, is made.

AMEC thanks you for this opportunity to have been of service. We trust that this report satisfies your current requirements. Should you have any questions, please contact this office.

Yours Truly,

AMEC Earth & Environmental

Original signed by

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APPENDIX A :

CITED REFERENCES

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(5) ASTM C1105-95, *Standard Test Method for Length Change of Concrete due to Alkali – Carbonate Rock Reaction.*

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(23) Specification for Panel closure Construction at WIPP. (Cover sheet not provided; thus date of preparation of document not known)

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APPENDIX B :

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APPENDIX C :

PRIVATE COMMUNICATION FROM A. NAUDTS

ECO
ECO GROUTING SPECIALISTS LTD
293199 8th Line, RR 1, Grand Valley, ON, Canada L0N 1G0 Phone: (519) 928-5949 Fax: (519) 928-5968
e-mail: ecogrout@ecogrout.com Home Page Internet Address: ecogrout.com

July 3, 2001

ATTN: Dr. Rusty Morgan
AMEC Earth and Environmental Ltd.
2227 Douglas Road
Burnaby, BC
V5C 5A9

Dear Dr. Morgan:

Re : Capability statement regarding cement based suspension grouts using saturated brines as carrier for the particles, to be used in salty environments

This note is further to our conversation of this afternoon. It was good to hear from you after all those years.

ECO has done extensive work developing and testing cement based suspension grouts to be used in saline environments using brine as carrier for the particles.

Most parties agree that it is not appropriate to use fresh water in grouts in contact with salt or potash ore (halite, carnalite, etc), because of migration of sodium, calcium or magnesium ions into the gelling grout, leaving a porous salt matrix near and at the contact zone.

The following is an oversight of some of the work we did in potash and salt mines (formulating and testing):

1. We first developed cement based suspension grouts for Kali & Salz in Germany for a potash mine near Kassel during the late seventies. We established basic fluid and set characteristics. The use of additives and admixtures such as styrene butadieen, clay-phyllosilicates and first generation superplasticisers were novelties at the time. We used a saturated locally found mine brine as the carrier.

We were aiming at low matrix permeability and high strength with the highest fluidity possible. From our on-going relationship with this client, we have learned that the performance of this type of grouts has been satisfactory over the life time. The tests involved bleed-tests, viscosity tests (marsh) and specific gravity test (Mud balance) as well as unconfined compressive strength tests and I believe we also did bond-strength tests from grout to the potash ore.

2. During the eighties we performed lab testing for PCS during the Rocanville flooding. Our design for the plug was implemented. The plug is still standing up under a pressure of 1200 psi (since March 1985). We formulated both regular cement based grouts, microfine cement based grouts and solution grouts using the brine from the mine as carrier. We found that some of the water reducing agents were not compatible with the brine or some of the additives and admixtures. We predominantly used the following additives and admixtures to the brine: super plasticiser, type F-flyash, silica fume (first time we used this) and slag. We found out that bentonite was not compatible with brine. (we should have pre-hydrated the bentonite in fresh water and added this to the mix). We also made samples of grouts and bubbled hydrogen sulphide through the suspension and let the suspension grouts cure in this saturated environment. Three years ago a sealed jar with this smelly gas and cured grout broke when we moved to our present lab-location. The (slag based microfine cement) grout looked "perfect" after 13 years. I remember that some grouts never reached final set and only made it to "somewhere between initial and final set" (Vicat needle).

3. During the IMC potash inflow-crisis in 1986, ECO was asked by this organisation to perform a series of tests to develop "durable cement based grout formulations" for a variety of applications. The tests were actually conducted in the lab of BBT in Saskatoon.

We used similar admixtures as during the tests in Rocanville, but included a portland cement based microfine cement based grout. We also used type C fly-ash (not aware at the time of the critical maximum contents BWOC) and kiln dust. A series of formulations were developed and reports were made. Some of the formulations were used in various phases of the project.

4. ECO performed lab-testing for the grouting around shaft plugs in an abandoned salt mine in Dearborn (Michigan). The actual grouting was never performed because the permitting to use this abandoned mine as a landfill site was never approved.

5. During 1992 ECO performed extensive lab-testing for the installation of a pilot grout-curtain in an abandoned limestone mine in Acron (Ohio), which was to be deepened to be used for the power house for a power generating system (pump storage). The water bearing zones in the limestone were saturated with hydrogen sulphide and brine. A variety of grouts were developed with different rheology, viscosity, cohesion, resistance against pressure filtration, thixotropy, gel times, set times etc.

At the time we used much more sophisticated mixes, using admixtures and additives such as metha glycol cellullose to curtail run-away situations, F-fly-ash, de-airing agents, super plasticisers, slag, pumice and bentonite slurries. The tests were also more sophisticated and included resistance against pressure filtration tests, initial and final gelation and set tests, cohesion tests etc.

6. In 1997, for Potocan (and its German part-owner, Kali & Salz) ECO performed a substantial grout formulation and testing program for one of the biggest grouting ever performed. From over 200 formulations, six formulations were retained with distinctive fluid and set characteristics. The formulations contained in addition to most of the

aforementioned admixtures and additives also modern day bio-polymers and the third generation of super plasiticisers and for the first time we used iso-propyl alcohol to delay the curing of the grout. Brine from this New Brunswick potash mine was used as the carrier of the particles.

7. ECO is involved in an elaborate seal-grouting project for the Werra potash mine in the former East Germany for its owner Kali & Salz. This is a group effort involving an international panel of specialists, all with different expertise. We established grout formulations and test procedures both for regular and microfine cement based grouts. This project is ongoing.

8. ECO has done several grout test programs for manufacturers of microfine cement based grouts. Some of these formulations were made for use in saline environments. Brine saturated solutions were typically used for these tests.

After all those years of testing and evaluating performance of grouts, I must admit that there is still a lot to be learned about the application of suspension grouts in saline environments, especially if magnesium brines are present.

We would be very interested to participate in testing programs or review information by others. You can find more information about our firm on our site: www.ecogrout.com. We are completely independent and have no links or ties with manufacturers nor contractors nor distributors. Thank you for contacting us. We look forward to contribute to this project

Regards,

Alex Naudts, P.Eng.

APPENDIX D

September 4, 2001 letter, Triay to Marcinowski

Department of Energy
Carlsbad Field Office
P. O. Box 3090
Carlsbad, New Mexico 88221

September 4, 2001

Mr. Frank Marcinowski
Office of Radiation and Indoor Air
U.S. Environmental Protection Agency
401 M. Street, S. W.
Washington, DC 20460

Dear Mr. Marcinowski:

On April 17, 2001 we submitted a request to you seeking approval of several proposed enhancements to the WIPP panel closure system. Based on communications with your staff during our recent working meetings, we respectfully withdraw our request for approval of those modifications. In view of the approval of our panel 1 utilization request and our current and projected throughput rates, we wish to re-evaluate our panel closure strategy.

At the conclusion of our evaluation, we expect to revisit this topic with the EPA. We appreciate the effort already expended by your staff in the review of our April submittal. If you or your staff have any questions regarding this matter, please contact Mr. Daryl Mercer at (505) 234-7452.

Sincerely,

Inés Triay

Dr. Inés R. Triay
Manager

cc:
D. Huizenga, EM
S. Monroe, EPA
S. Ghose, EPA
C. Byrum, EPA
N. Stone, EPA
S. Zappe, NMED
M. Silva, EEG

CBFO:ORC:DMM:VW:01-1340:UFC:5400

APPENDIX E
LIST OF EEG REPORTS

LIST OF EEG REPORTS

EEG-1 Goad, Donna, A Compilation of Site Selection Criteria Considerations and Concerns Appearing in the Literature on the Deep Disposal of Radioactive Wastes, June 1979.

EEG-2 Review Comments on Geological Characterization Report, Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico SAND 78-1596, Volume I and II, December 1978.

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EEG-6 Geotechnical Considerations for Radiological Hazard Assessment of WIPP. A Report of a Meeting Held on January 17-18, 1980, April 1980.

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