DRILLING & GROUTING FOR SUBSIDENCE

1. SCOPE

The work shall consist of drilling a series of holes around and under the homes and filling all encountered voids and collapsed overburden with a grout/concrete mixture as shown on the Drawings or as directed by the ENGINEER.

2. GENERAL

2.1. Definitions:

2.1.1. Zone: The horizontal area influenced by grouting a hole to its final depth.

2.1.2. Void: Any subsurface opening resulting from the removal, collapse, or in-place burning of the coal seam.

2.1.3. Gob or Roof Fall Material: A mixture of roof shales and other materials, which have fallen from the roof area or have been placed in a void.

2.1.4. Coal Pillar: An unmined block of coal remaining in the coal seam.

2.1.5. Stage: A vertical subsurface interval that may include all or part of a grout column installation.

2.1.6. ASTM: American Society for Testing and Materials

2.1.7. AASHTO: American Association of State Highway and Transportation Officials

2.8. Gas Monitoring: The Contractor shall provide equipment to monitor the presence of mine gases. The equipment shall be provided with certification of it most recent inspections and testing. Mine gases include but are not limited to carbon monoxide (CO), carbon dioxide (CO_2), and methane (CH_4).

3. MATERIALS

3.1. Drilling Equipment: The drilling rig will be a low ground pressure rig with adjustable mast and/or articulating masts capable of drilling any compound angle off vertical between 0 and 90 degrees, with an on-board dust collection system, and pressure gauges to indicate drilling medium pressure and down pressure on the drill bit.

The use of percussion drilling equipment will not be permitted, excluding down the hole air hammers for very dense formations. The drill rig shall be capable of drilling boreholes having an inside diameter capable of placing all the specified grout mixtures within the slump ranges specified, with the cuttings removed by air or water to a vertical depth of approximately 200 feet. Auger type drill tools may be used if approved by the ENGINEER.

The **on-board dust suppression or collection system** will have all protective guards, locks, clamps, and other standard safety devices as originally installed by the manufacturer, or as required by OSHA.

3.2 **Casing**: The casing shall be Schedule 40 steel or PVC plastic casing for each hole of a sufficient length to case at a minimum through the soil zone. Schedule 40 Cellular Core or SDR Sewer pipe is an acceptable alternative. Provide airtight caps that fit securely on the casing and are made of the same material as the pipe for each casing. The pipes shall be capped with a cap made of the same material as the pipe. The caps shall fit snugly over the pipe. No type of taping to close the top of the pipes will be allowed.

3.3. **Grouting Equipment**: All equipment used for mixing and injecting grout shall be furnished by the Contractor and shall be maintained in first-class operating condition at all times. The equipment shall be specifically designed for grouting service, including the agitating, pumping, and injection of the cement; Flyash; sand; and aggregate grout mixes.

The power, equipment, and layout of the grouting equipment shall meet all applicable requirements of local, State, and Federal regulations and codes, both safety and otherwise. The minimum equipment furnished for each grouting unit shall include:

a) A positive displacement screw-type pump. Other types of pumping equipment that is equal or better may be used, provided that the use of that equipment is specifically approved by the ENGINEER. A piston drive concrete pump shall be used for placing aggregate grout mixtures.

b) A means of monitoring the level of grout in the borehole.

c) All metal pipe and fittings required for grouting shall be furnished, cut, threaded, fabricated, and placed by the Contractor. The Contractor shall take all necessary precautions to prevent any pipe from becoming clogged or obstructed from any cause, and any pipe, which becomes clogged, shall be cleaned out in a manner satisfactory to the ENGINEER, at the Contractor's expense.

d) Such valves, hoses, pressure gauges, pipefittings, and small tools necessary to provide a continuous supply of grout and accurate control of the volume and pressure of grout being injected, will be provided. The pressure gauge shall be placed at the head of the grout supply pipe so that the down hole grout pressure can be accurately measured to $\pm$ 1 psi. Payment shall not be made for excessive grout injected due to the inaccuracy of the Contractor's control.

e) No restriction in the grout line from the pump to and down the hole will be allowed. The size of the line will be the same size with no reducers or restrictions being used in the pipeline. The pressure gauge must be placed at the top of the hole**.** The Contractor is responsible for selecting a pipe size, that will allow him to accomplish the objectives of this contract, which includes filling all mine level voids, roof fall material, and mine gob

material with any of the grout mixes indicated in the Grout Mixes section of these specifications.

Any grout hole that is lost or damaged due to mechanical failure of equipment, or inadequacy of grout supply, shall be replaced by another hole drilled by the Contractor at the Contractor's expense. The Contractor shall also be responsible for any expenses that are incidental to replacement of the lost or damaged hole.

All of the above-listed equipment, powered by internal combustion engines, shall be equipped with spark-arrester-type mufflers capable of noise suppression for work in residential areas.

The Contractor shall take all necessary precautions to prevent any pipe from becoming clogged or obstructed from any cause, and any pipe that becomes clogged shall be cleaned out in a manner satisfactory to the ENGINEER, at the Contractor's expense.

Adequate valves will be required at the pump and at each hole to ensure control, by-pass and shut-off capabilities as required by the ENGINEER. The equipment and lines shall be prevented from becoming fouled by either constantly circulating the grout or periodically flushing out the system with water.

f) Mechanical or hydraulic packers specifically designed for use in pressure grouting operations.

3.4. <u>Grout Mix Materials</u>:

3.4.1. <u>Certifications</u>: Upon request, the Contractor shall supply the ENGINEER with letters of certification that all materials to be used meet the requirements of this technical specification prior to commencing grouting activities. The Contractor shall notify the ENGINEER a sufficient time in advance of the beginning of grout mixing so that the ENGINEER can take samples or run tests, as deemed necessary.

3.4.2. <u>Water</u>: The water used in the grout shall be furnished by the Contractor and shall be clean and free from injurious amounts of sewage, oil, acid, alkali, salts, organic matter, or other foreign solids deemed by the ENGINEER as deleterious to the grout mix.

3.4.3. <u>Cement</u>:

(1) Cement used in grout shall meet the requirements ASTM C150-84 Type I or II.

(2) The cement shall be free from lumps due to storage. In the event the cement is found to contain lumps or foreign matter in an amount the ENGINEER considers deleterious to the grouting operations, screening through U.S. Standard 100 mesh screen shall be required. No additional payment shall be made for such screening of old cement.

3.4.4. Sand: Sand shall be supplied and handled by the Contractor. The sand shall consist of hard, dense, durable, uncoated rock fragments obtained from a river or quarry with not more than 5% of any deleterious substances. Frack or eolian (windblown) sand is preferred. The fineness of the sand required for grouting shall be as follows: 100% passing #4 with 15% and 25% passing a No. 200 sieve.

3.4.5. Coarse Aggregate: Type "A" coarse aggregate shall be supplied by the Contractor. The aggregate shall consist of hard, dense, durable uncoated gravel or crushed stone and shall be free of harmful amounts of clay, silt, vegetation, or other substances determined to be deleterious. The grain size distribution of the aggregate shall be as follows (equivalent to ASTM#7):

% Finer by Weight	Sieve Size
100	3/4 in.
90-100	2 in.
40-70	3/8 in.
0-15	No. 4

An alternative gradation may be used subject to the approval of the ENGINEER. Prior to use of the alternative aggregate in a grout mix, the Contractor shall submit to the ENGINEER a gradation of the material to be used and receive written approval for its use from the ENGINEER. Crushed stone may be required by the ENGINEER upon request.

3.4.6. Flyash: **Flyash shall conform to mineral admixture Class F,** but is not required to meet the uniformity and moisture requirements of that specification. The moisture content shall not exceed 15%, unless the Contractor can provide test data to the ENGINEER from an independent, qualified laboratory, which documents that the increased moisture will not negatively influence the grout characteristics and/or strength. **The maximum Loss of Ignition will be 6%. Black or brown Fly ash will not be allowed unless certified lab results show the loss of ignition to be 6% or less. Testing methods and calculations used to determine percentage of loss of ignition shall be in accordance with ASTM C311, Subsections 13 and 14. The Contractor shall be solely responsible for any costs associated with these tests.**

The Fly ash shall be stored so that it will not deteriorate from moisture, weather, or other causes. If the Flyash is found to contain lumps that the ENGINEER considers deleterious to the grouting operation, screening through a U.S. Standard 100 mesh screen will be required. No additional payment shall be made for such screening.

3.4.7. Accelerator: Accelerator admixtures shall conform to ASTM C494-82 chemical admixtures for concrete; Type E - water reducing, accelerating, and admixtures shall be added to the grout mix only with the approval of the ENGINEER.

3.5. Grout Mixes:

The water-cement-Flyash ratio, as well as the ratio of other materials, shall be varied by the ENGINEER to meet the characteristics of each hole as revealed by the drilling and grouting

operation. The ENGINEER shall determine, on a per day basis, if the rate of placement of the specified grout mixture for a hole is acceptable. The Contractor will increase or decrease placement daily as requested by the ENGINEER. The following mixtures may be utilized in any borehole at any time upon request of the ENGINEER. ***No more than 2 truckloads of a mixture will be brought to the site for the ENGINEER'S approval before additional loads are ordered.***

3.5.1. Mine Backfill- Mix 1

Cement	180 pounds
Sand	1,450 pounds
Flyash	1,250 pounds
No.8 Agg.	650 pounds
Water	45 gallons

The minimum 28-day compressive strength shall be 500 psi, and the slump as delivered to the site shall be 8-inches. Adjust water to accommodate moisture conditions and to achieve the required minimum slump.

3.5.2. Mine Backfill- Mix 2

Cement	300 pounds
Sand	620 pounds
Flyash	2,200 pounds
Water	75 gallons

The minimum 28-day compressive strength shall be 500 psi, and the slump as delivered to the site shall be 10-inches. Adjust water to accommodate moisture conditions and to achieve the required minimum slump.

3.5.3. Mine Backfill- Mix 3

Cement	393 pounds
Flyash	2,190 pounds
Water	95 gallons

The minimum 28-day compressive strength is to be 500 psi, and the slump as delivered to the site shall be 10-inches to 11-inches. Adjust water to accommodate moisture conditions and to achieve the required minimum slump.

3.5.4. Mine Backfill- Mix 4

Cement	500 pounds
Sand	2,000 pounds
Water	81 gallons

Minimum 28-day compressive strength is to be 1,200 psi, and the slump as delivered to the site shall be 0- to 2-inches. Adjust water to accommodate moisture conditions and to achieve the required minimum slump.

3.6. Changes in Grout Mixture: All grout mixture changes must be ordered and/or approved by the ENGINEER prior to mixing of the grout. The Contractor shall discard any unauthorized grout mixtures with no compensation. Any unauthorized grout mixtures placed by the Contractor will not be measured or paid for.

The ENGINEER has the authority to change any grout mix by adjusting the ratios of cement, Fly ash, sand, aggregate, water, and accelerators to meet the characteristics of a grout mix needed for a particular set of conditions as revealed by the drilling and grouting operations. This includes the deletion of any component of the grout mix.

3.7. Use of Chemical Admixture: The use of or substitution use of chemical admixtures shall be according to conditions as determined in the field by the ENGINEER and in accordance with the manufacturer's recommendations. Any grout mixtures using chemical admixtures without authorization from the ENGINEER will not be accepted and shall be discarded at the Contractor's expense with no compensation.

3.8. Mixture Plant: Grout material will be delivered ready mixed to the site. Pre-approval from the ENGINEER must be obtained by the Contractor to use any offsite grout plant owned or operated by the contractor. Any offsite batch plant that is approved for use by the ENGINEER must have certified weight scales to provide accurate measurements of materials. The scales and any other measuring devices used on the plant to dispense and mix the materials, shall be checked and re-calibrated when requested by the ENGINEER.

4. CONSTRUCTION- DRILLING

During the course of the work, the site shall be neatly maintained, free of litter and other debris, with site cleanup performed daily.

4.1. Drill Hole Location: The ENGINEER shall layout the holes after project mobilization. **The ENGINEER will determine where drilling will begin on the project.** The ENGINEER may require additional grout holes. **The ENGINEER may require drilling of confirmation holes adjacent to completed grout holes.** Borehole locations may change because of utility locations with the approval of the ENGINEER.

4.2. Drilling of Holes: Drill the holes in an orderly sequence to one foot below the base of the mine. Perform drilling in such a manner as to minimize mine-roof collapse, such as by

reducing down pressure, etc., directly above the mine. The Contractor shall be responsible for drilling a plumb hole. Drill the holes with bits and stabilizers that will provide full-diameter, straight holes. Diameter of holes and casing shall be large enough allow the specified grout mixes to be properly placed.

4.3. **Water in Drill Holes**: Contain and filter water encountered in the drilling process and carried to the surface with cuttings by the use of straw bales. Discharge water in such a manner, subject to approval of the ENGINEER, with no water directed toward the residence. Cuttings and dust sludge shall be cleaned daily from the hole area after drilling. Water discharged from the immediate work area shall meet all applicable Federal and State effluent limitations.

4.4. **Casing Holes**: Protect each hole from caving and/or becoming clogged or obstructed. Grout holes drilled through soil overburden shall have a casing keyed into rock sufficient to exclude all overburden and to be watertight. Holes drilled thorough the soil zone shall be sized to allow casing placement without excessive force. The casing must fall freely down into the hole with only minimum pressure. This casing shall then be capped. Any hole that becomes clogged or obstructed, for any reason, before completion of operations, shall be cleaned out or replaced at the Contractor's expense. Further, any incidental expenses required for cleaning out a hole or providing a replacement hole shall be the responsibility of the Contractor.

The casing shall extend no more than two feet above the ground surface and shall be capped. Casing shall be left in the hole until the completion of grouting operations at that hole, and shall then be removed or left in place. Drill holes in the driveway shall be cut flush with the pavement and protected with a steel cap or other acceptable method, which will protect the hole from being damaged by vehicular traffic.

A borehole must be washed, within 24 hours of drilling, to remove mud and cuttings adhering to the boring sidewalls. The method and amount of water used to wash the boreholes will be determined by the ENGINEER. For example, washing may be done by using water from a hose directed into the top of the hole.

4.5. **Drilling Holes through Rock**: Plug or non-coring bits may be used. Upon completion of drilling a hole, the hole shall be temporarily capped with a secure cap and otherwise protected from entry of foreign material until grouting operations are initiated.

4.6. **Completion of Holes**: Cap and protect all drilled and cleaned holes from obstruction by debris until completion of the grouting of the hole. Any required cleaning of the hole after initial drilling and cleaning shall be at the Contractor's expense.

The pipe casing can be removed or left in place. Casing grouted into place shall be cut off at a minimum distance of one foot below the surrounding surface elevation per the ENGINEER's approval. No additional payment shall be made for casing grouted into place.

The Contractor on a daily basis shall remove all unsuitable material from the site. Unsuitable material shall include, but not be limited to, concrete, drill cuttings, old pavement, spilled grout,

aggregate, and soils designated by the ENGINEER as unsuitable for backfill. The compensation for this work shall be included in other bid items of the contract.

The top one foot shall be replaced with material the same as, or similar to, the surface material through which the borehole was drilled. Backfill materials, methods, and material substitutions shall be subject to approval of the ENGINEER.

4.7. Borehole Logs: The Contractor shall keep accurate logs of boreholes drilled. Each log shall include, at a minimum, the following information:

(1) Project name, contract number, boring location, boring number, diameter of hole, driller's name, date, time started, and time completed.

(2) Complete listing by depth recorded in feet and tenths of feet of each overburden strata and description of each void and broken zone in the overburden, height of mine void, thickness of coal, and total depth of hole.

(3) Size and depth of casing installed and whether casing was removed or left in place.

(4) Information regarding relevant events during the drilling, including depth where groundwater was encountered, where drill water or air was lost, and venting gases encountered, etc.

(5) If requested by the ENGINEER, the Contractor shall record accurate water levels, borehole depth, and methane concentrations in each borehole every day for the duration of the project.

The fact that an inspector shall be present and keeping a record of the drilling shall not relieve the Contractor from the requirements of keeping an accurate log as described above.

A legible, handwritten copy of the borehole logs shall be presented to the ENGINEER within 24 hours of the drilling of any borehole. Typewritten borehole logs shall be presented to the ENGINEER at the end of each week during which drilling has taken place.

5. CONSTRUCTION- GROUTING

5.1. Grout Placement: Placement of grout mixtures shall be in accordance with these specifications as to depth, rate, ratios, qualities and quantities, or any combination of these requirements as indicated or otherwise established by the ENGINEER.

Unless determined otherwise by the ENGINEER, all placements of grout mixtures within the boreholes shall be as follows for the particular conditions described. All grout mixtures shall be pumped through a grout injection pipe that has been placed at a place within the overburden as determined by the ENGINEER. Holes with grout takes in excess of 32 cubic yards per day will be grouted in stages, as approved by the ENGINEER. If the grout is being pumped into collapsed or gob material or if pressure is building within the hole than additional grouting above

the 32-yard stage will be allowed. The grout shall be allowed to set for 12 hours between stages. Daily grout placement shall be limited to 32 cubic yards per borehole, unless otherwise reduced or increased by the ENGINEER. On holes that are under pressure in collapsed material the 32 CY per hole will be waived. Limits on grout for these types of holes will be determined on a hole-by-hole basis by the ENGINEER.

Any borehole that had grout placed into it but was not filled, shall be flushed with water within 30 minutes, or a period acceptable to the ENGINEER, after grout placement. <u>The amount of water used, the time spent, and method of the flushing will be subject to approval by the ENGINEER</u>. In addition, a minimal amount of water, to be approved by the ENGINEER, can also be used to lubricate grout lines and to clear the grout injection pipe. The Contractor shall transport via pipeline the grout into the borehole in such a way as to not coat or foul the borehole until the mine level void, roof fall material, and/or mine gob is filled. The grout line from the pump to the hole shall not have any restrictions of any kind. For example, if a three-inch line is selected to transport the material from the pump the contractor must continue the three-inch pipe all the way to and down the hole to the discharge end.

Upon ENGINEER request, a measurement shall be taken to determine the depth to the top of the grout. Additional grout shall be injected if, in the opinion of the ENGINEER, the grout has dropped to a depth that may indicate that additional voids exist within the grout hole.

5.2. <u>Structure Monitoring</u>: The Contractor shall provide monitoring of structures within the project area, and other structures as determined by the ENGINEER, during all grouting activities. The purpose of the monitoring is to detect any potential for damages due to grout migration. **The Contractor shall be responsible for all damages that occur due to the Contractor's failure to comply with these contract specifications and/or failure to use due care.**

<u>The loss of packers for various reasons is anticipated</u> during the course of grouting procedure. The Contractor will not be reimbursed for packer loss during project activity.

5.3. <u>Grout Conditions</u>:

5.3.1. <u>Grouting Gob-Filled Voids and Roof Fall Material (RFM)</u>: A hole shall be drilled through the overburden, RFM and/or mine gob to a depth of one foot below the base of the mined coal seam. A grout supply pipe, equipped with a discharge tip (if requested by the ENGINEER) and a packer, shall be extended through the drilled hole to a point in the overburden as determined by the ENGINEER. A packer may be set at the ENGINEER's approved elevation above the roof of the mine. If intact bedrock is not present within 10 feet of the mine, the packer may be set within intact bedrock as close as possible to the roof of the mine. The depth of the packer setting must be approved by the ENGINEER prior to its placement in the hole. A volume of grout Mix No. 1 (determined by the ENGINEER) shall be then forced under pressure (determined by the ENGINEER) into the gob or RFM. If large takes are encountered, the mix shall be changed, thickened and, if the take persists, aggregate shall be added.

5.3.2. Grouting Open Voids (two feet or greater): If an open void two feet or greater is encountered (as determined by the ENGINEER), the grout supply pipe shall be placed down to an elevation determined by the ENGINEER. (Any gob and/or roof fall material underlying the void shall be grouted in accordance with Item No. 5.4.) A volume of Grout Mix No. 3 (or other mixture as determined by the ENGINEER) shall be introduced into the void via pressure, as determined by the ENGINEER. If the grout take is not excessive (as determined by the ENGINEER), the cavity shall be filled in stages with a maximum of 32 cubic yards per hole/day. The grout shall be allowed to set for 12 hours between each stage. If large takes are encountered, as determined by the ENGINEER, the mix shall be thickened. The ENGINEER is authorized to designate the use of Mix Nos. 2 and/or 4 for grouting if excessive takes persist. The amount of the mix injected will be determined by the ENGINEER on a hole-by-hole basis. .

5.3.3. Grouting In-Place Coal: If neither voids, mine gob, nor roof fall material are encountered, a grout pipe shall be inserted, and the borehole shall be backfilled using Grout Mix No. 1 to a level three feet above the coal seam. After the initial set of the grout (12 hours), the rock overburden shall be grouted in accordance with TS No. 5.8.

5.3.4. Grouting Open Voids (less than two feet): Open voids, less than two feet in height, shall be grouted in accordance with TS No. 5.4.

5.3.5. Grouting Rock Overburden: Upon ENGINEER request, the grout pipe shall be inserted and the borehole shall be backfilled with a volume of Grout Mix No. 1 to a level immediately above the roof of the mine. After the initial set of the grout occurs at mine level, a down hole packer may be placed above the set grout at an ENGINEER determined elevation. Nitrogen filled or equivalent packers shall be used to reduce the risk of explosion. Oxygen filled packers are not permitted. Grouting with Mix No. 1 shall be continued until determined necessary by the ENGINEER. In general, pressures at the ground surfaces shall not exceed 1/2 psi per foot overburden above the packer location. The borehole above the final packer set elevation may be filled by gravity flow. Another stage of gravity grouting may be necessary to refill the hole to its former level after the grout is allowed to set for 16 hours.

5.3.6. Lost Grout Hole: Any grout hole that is lost or damaged due to Contractor-related causes shall be replaced by the Contractor, at the Contractor's expense, in a manner and location acceptable to the ENGINEER. Any incidental expenses incurred in replacing the grout hole shall be borne by the Contractor.

5.3.7. Grout Sample Testing: Grout may be sampled on a periodic basis by DAML. Test for compressive strength and a petrographic analysis of the sampled components shall be done by a qualified laboratory secured by the government. The test samples shall be taken by the ENGINEER or the onsite inspector. These tests will be random with no warning given to the contractor prior to the samples being taken.

5.3.8. Records and Forms: During the progress of the work, the Contractor shall supply, upon the ENGINEER's request, two copies of all records and forms pertaining to the quantity and quality of material delivered to the site and grout sample test results. The Contractor shall submit to the ENGINEER daily labor and material records.

The Contractor and the DAML monitor shall confer daily regarding the quantity of materials delivered and/or placed in the course of the work. Any disagreement shall be brought to the attention of the ENGINEER within 24 hours. The Contractor shall sign off on the monitor's daily construction logs signifying agreement or disagreement daily.