STANDARD OPERATING PROCEDURE No. 5.0
MONITORING WELL INSTALLATION

R Squared Inc.
9034 E. Easter Place, Suite 201
Centennial, Colorado 80112

Approved by: _____ **Date:** _____

Attachment A

TABLE OF CONTENTS

List of Figures

1.0 PURPOSE AND SCOPE

The purpose of this document is to define the Standard Operating Procedure (SOP) for installing groundwater monitoring wells in unconsolidated geologic materials and bedrock at the Powertech, Inc. (hereafter referred to as Powertech) Mine Site and in surrounding areas. This SOP describes designs, procedures, and materials used to construct monitoring wells that will produce accurate groundwater level measurements and representative groundwater samples. Well construction and abandonment reports will be submitted to the Colorado State Engineer. The step-by-step procedures described herein are intended to be sufficiently detailed to allow field personnel to properly install monitoring wells.

2.0 RESPONSIBILITIES AND QUALIFICATIONS

The Project manager has the overall responsibility for implementing this SOP. He/she will be responsible for assigning appropriate environmental staff to implement this SOP and for ensuring that the procedures are followed accurately by all personnel.

All personnel performing these procedures are required to have the appropriate health and safety training. In addition, all personnel are required to have a complete understanding of the procedures described within this SOP and receive specific training regarding these procedures, if necessary.

All project staff are responsible for reporting deviations from this SOP to the Project Manager.

3.0 RELATED STANDARD OPERATING PROCEDURES

The procedure for monitoring well installation set forth in this SOP is intended for use with the following SOPs:

SOP No. 3.0	Borehole Logging
SOP No. 6.0	Water Elevation Measurements
SOP No. 10.0	Decontamination of Sampling Equipment
SOP No. 11.0	Sample Management
SOP No. 15.0	Well Development
SOP No. 22.0	Groundwater Sampling
SOP No. 35.0	Surveying (Land and GPS)

4.0 EQUIPMENT LIST

Equipment that will be used for installing groundwater monitoring wells includes (as per American Society for Testing and Materials [ASTM] 1996, U.S. Environmental Protection Agency [EPA] 1986, 1990):

- Well casing and well screen
- Bentonite pellets for the annular seal

- Filter pack sand [Field Determined]
- Cement and powdered bentonite for grouting
- Stainless-steel centralizers
- Protective steel well casing with locking cap
- Steel guard posts
- Decontamination equipment and supplies (See SOP 10.0, Decontamination of Sampling Equipment)
- Well location map
- Drill rig capable of installing wells to the desired depth in the expected formation materials and conditions (i.e., capable of hanging well casing, tremie pumping sand and grout, and accurate measurement of material in the annulus). (See SOP 37.0, Drilling and Sampling of Subsurface Materials.)
- Weighted tape measure
- Water level probe
- Disposable latex gloves
- Appropriate health and safety equipment
- Waterproof pens
- Weatherproof bound field logbook
- Powertech Database forms
- Calculator
- Well Completion Diagram (Figure 1)
- GPS set to correct coordinate system

5.0 GROUNDWATER MONITORING WELL INSTALLATION PROCEDURES

Well construction procedures will fulfill all applicable regulatory agency requirements for permit applications, material standards, and construction/completion protocols. Licensing and/or certification of the driller may be required. In order to maintain quality control and obtain accurate information, a field geologist or hydrogeologist will be on the site to supervise well construction and log details of the procedure. All activities will be conducted in conformance with the Project Health and Safety Plan.

5.1 MAINTENANCE OF DRILL RIG EQUIPMENT AND WELL MATERIALS

Decontamination procedures specified in SOP 10.0, Decontamination of Sampling Equipment, will be performed.

Drill rig injection and water pumps will be cleaned as necessary.

Any leaks from the drill rig occurring during well installation will be fixed or contained in such a way that they will not contaminate the borehole.

Care will be taken not to contaminate the well casing or the borehole with diesel fluid, hydraulic fluid, WD-40, oil, dirty tools, and so forth.

Drillers will use gloves when handling downhole equipment. Different gloves will be used for performing activities such as fueling, adding oil, and working on equipment.

As defined in 20.6.2 NMAC, pipe lubricants that are used should not introduce contaminants into the borehole. Lubricants that are environmentally acceptable include: Green Stuff®; King Stuff®; vegetable oil; Crisco™; and some Teflon™-based lubricants. Lubricants that are not acceptable include petroleum-based and most metal-based lubricants. The Project Manager, Field Geologist, or the Powertech Environmental Staff will pre-approve lubricants that will be used, and the Material Safety Data Sheets (MSDS) for these lubricants will be provided for reference.

All well casing and screen will be free of foreign material. Casing and screen will be stored off the ground in the original manufacturer's shipping containers until they are installed in the borehole. Before installation, well casing, screen, and centralizers will be certified clean from the manufacturer or will be decontaminated according to SOP 10.0, Decontamination of Sampling Equipment. Acid rinse solutions should not be used for PVC decontamination. Clean latex or nitrile gloves will be worn when handling the well materials.

5.2 MONITORING WELL DESIGN AND COMPLETION

Procedures for installing three types of monitoring wells are presented in this section: water table wells in unconsolidated materials; water table wells in bedrock; and deep bedrock wells below the water table. Installation of water table wells in unconsolidated material and bedrock is discussed in Section 5.2.2. Monitoring well installation in deeper bedrock borings is described in Section 5.2.3.

5.2.1 General Well Installation Procedures

Monitoring wells will be constructed in open boreholes or through the hollow stem augers or surface casing, depending on the stability of the borehole and materials encountered during drilling (ASTM 1996, EPA 1990).

For boreholes that may need to be backfilled to a certain depth before well installation, clean sand with a 3-foot bentonite seal will be added to fill the borehole to the depth desired for well installation. Wax coated pellets may be used if the saturated water column in the borehole is greater than 50 feet.

The annular space between the well string and the borehole wall will be filled with a filter pack (adjacent to the well screen), a bentonite seal, and casing grout. As the annular space is being filled, the well string will be centered and suspended such that it does not rest on the bottom of the hole. At least two stainless steel centralizers will be used if the well is deeper than 50 feet—one at the bottom of the well screen and one at the top of the well screen. For deep bedrock

wells, additional centralizers will be attached to the riser casing at 100 foot intervals and one near the top of the well string.

The Field Geologist will calculate and record the volume of the filter pack, bentonite seal, and grout required to fill the annular space based on the borehole size and casing size. The volume is calculated by subtracting the volume of the casing (based on the outer diameter) from the volume of the borehole using the equation:

$$V=\pi(r_b^2-r_c^2)h$$

where:

V = volume (in feet^3)

r_b = radius of borehole (in feet)

r_c = radius of casing (in feet)

h = height (in feet) between the top and bottom of the material (filter pack, bentonite, or grout).

π = p[1] (3.14)

Measurements made during filling of the annular space will be performed to the nearest 0.1 foot below ground surface (bgs) and will consist of the following:

- Total depth of borehole at the completion of drilling
- Total depth of the open borehole before the start of well construction
- Lengths of the end cap, screen sections, riser blank sections, and stickup of well above ground surface
- The depth to the top of the filter pack, top of the bentonite seal, and the top of each grout lift

Following well completion, the horizontal location of the monitoring well will be surveyed in accordance with SOP 34.0, Surveying (GPS). The elevation of the ground surface and top of the PVC casing (i.e., water level measuring point) will also be determined. A notch will be cut on the north side of the PVC casing that will be used as a measuring point for water levels.

5.2.1.1 Casing and Screen Requirements

The casing requirements will be as follows (EPA 1990):

- All casing will be new, unused, and decontaminated according to the specifications of Section 5.1.
- All PVC will conform to the ASTM Standard F-480-88A or the National Sanitation Foundation Standard 14 (Plastic Pipe System).
- The casing will be straight and plumb.

Well screen requirements include:

- All requirements for casing, except for strength requirements, apply to well screens.
- Well screens will be 15 feet to 20 feet in length or the length specified by the Field Geologist in specific cases.
- Screens shall be machine-slotted (No hack saw slotting), or installed with an approved manufactured screen.
- Screen slot openings shall be 0.010 inches or 0.020 inches depending on subsurface material sizes and groundwater flow rates. Screen slot sizes will be selected using methods recommended by the manufacturer.
- The bottom of the screen will be capped with a threaded cap.
- The top of the well screen will be placed at least 5 feet above the static water level, if possible (except for the deep bedrock wells).

5.2.1.2 Well Filter Pack

The purpose of the well filter pack is to provide lateral support for the well screen, increase yield by improving the hydraulic conductivity in the immediate vicinity of the well, and retain the formation to prevent natural materials from entering the well. The filter pack material will be clean, inert, and well rounded, and will contain less than 2 percent flat particles. The filter pack material will be certified free of contaminants by the vendor or contractor. The filter pack will consist of 12/20 or 20/40 mix or equivalent of clean silica sand and will be placed from the bottom of the hole to at least 2 feet, but not more than 4 feet, above the top of the well screen (5 to 7 feet in the bedrock water table wells). The size of the filter pack material used will be selected as appropriate for the well screen slot size installed so that no more than 10% of the filter pack material is smaller than the slot size (ASTM 1996, EPA 1990). For auger boreholes, the filter pack will be placed in the hole by pouring the sand through the augers and slowly raising the augers out of the hole. For bedrock monitoring wells installed in open boreholes (by air rotary drilling), the screen and riser casing will be suspended at least one foot above the bottom of the borehole as the filter pack is poured directly into the borehole. The volume of the filter pack placed in the well will be recorded.

After the filter pack is placed, the well will be surged with a surge block or bailer for 30 minutes to ensure that the filter pack is settled so that the grout in the annular seal does not come into contact with the well screen. The top of the sand pack will be sounded using a weighted tape during placement to verify its depth. Additional filter pack material will be placed as required to return the level of the pack to at least 2 feet above the screen and the well will be surged for an additional 5 minutes. Again, additional filter pack material will be placed, as required, to bring the level to at least 2 feet above the screen, or as specified by the Field Geologist.

5.2.1.3 Well Seal

The materials used to seal the annulus between the borehole wall and casing must: prevent potential contaminant migration from ground surface or intermediate zones; isolate a discrete monitoring zone; preserve confining conditions; prevent intrusion of the overlying grout into the filter pack; and prevent cross-contamination between strata. The bentonite seal will consist of at

least 3 feet, but not more than 5 feet, of bentonite pellets between the filter pack and the casing grout. A minimum of 20 feet of bentonite seal will be used in the deep bedrock wells. Wax-coated sodium bentonite pellets (delayed hydration) may be used to allow the bentonite to fall through the water column and prevent bridging if the saturated water column is greater than 50 feet. If the bentonite seal is placed above the water table, then the bentonite will be hydrated using deionized or distilled water.

5.2.1.4 Annulus Backfill/Grout

The annular space above the filter pack and seal will be grouted with a bentonite/cement mixture. Grouting is used to minimize the vertical migration of water to the screened interval and to increase the stability and integrity of the well casing.

The cement/bentonite grout mixture shall consist of 95 to 97 percent Type V or Type II-V Portland Cement and 3 to 5 percent bentonite powder by weight (equivalent to one 94-pound bag of cement and between 2.8 and 4.7 pounds of bentonite). Approximately 8.5 gallons of water shall be used for each cement/bentonite batch. The grout mixture shall be prepared by thoroughly mixing the bentonite powder with water first and then mixing in the cement (USEPA 1990).

The casing grout requirements are as follows:

- The bentonite seal will be allowed to hydrate for a minimum of 1/2 hour before the grout is placed.
- The annular grout will extend from the top of the bentonite seal to approximately 3 feet below ground surface (bgs).
- Grout shall be placed in the well annulus using a side-discharge tremie pipe located within approximately 10 feet of the top of the bentonite seal. The tremie pipe will be pulled up as the annular space is filled. The tremie pipe will have a minimum inner diameter of 1.25 inches and be composed of steel or PVC.
- No single lift of grout will exceed 100 feet and each lift will be allowed to set before the next lift is placed.
- Pumping will continue until undiluted grout has been returned to the surface.
- After grouting, the well shall not be disturbed or be developed for a minimum of 24 hours. Additional grout will be added if settling occurs.

Alternatively, the annular space can be backfilled with a bentonite slurry if the potential exists for cross-contamination of adjacent wells. This may occur when wells are installed in pairs, and the grouted interval in a deep well coincides with the water bearing zone to be screened in a shallow well.

5.2.1.5 Surface Seal Installation

Groundwater monitoring wells will be constructed with above-ground completions. A concrete surface seal will be placed around the annulus of the well to a minimum depth of one foot or to the top of the bentonite/cement grout, whichever is deeper. Twenty-four hours should elapse between grout emplacement and installation of the surface seal to allow the grout to cure and

shrink and prevent a cavity from forming between the two seals. The well casing will be extended 2 to 3 feet above land surface, and a reference point will be marked for future water level measurements on the north side of the casing using a decontaminated metal file. A casing cap for each well will be provided, and the extended casing will be shielded with a protective steel casing that has a locking cap placed over the PVC well casing. The steel casings will be cemented in place and will extend a minimum of 3 feet below ground surface and 3 feet above ground surface. Center the protective steel casing around the monitoring well casing and insert the steel casing approximately 3 feet into the cemented annulus. The protective casings will be a minimum of 6 inches larger in diameter than the PVC monitoring wells. The protective steel casing will be seated in a 4-foot by 4-foot by 6-inch concrete surface pad. The pad will be sloped away from the protective casing. The concrete pad surface will extend approximately 1 inch above ground surface with about 5 inches below grade. At least one small hole will be drilled at the base of the protective casing to allow water to drain from the casing. The well number or identification code will be indelibly marked on the protective casing and on the well cap. A lockable cap or lid will be installed on the protective casing. In high traffic areas near roads or parking areas, the steel protective casing will be protected by four, 4-inch-diameter, Schedule 40, steel guard posts. The guard posts will be 6 feet in total length, with 3 feet bgs and 3 feet above ground surface. The guard posts will be set in concrete, but will not be installed in the concrete pad placed at the well base (ASTM 1996, EPA 1990).

All wells will be secured as soon as possible after drilling. Corrosion-resistant locks will be provided for the steel protective casing. The locks must either have identical keys or be keyed for opening with one master key.

5.3 WELL TYPES

Four types of monitoring well or tensiometer completions could potentially be completed from the drill holes and they may be completed in clusters (SRT Drilling Plan, 2003). The wells and tensiometers will be located to most advantageously meet the data quality objectives (DQOs) as determined by the PIs. The Type 1 well will be a monitoring well completed within the narrowest drill hole available. This well would be completed with 2.0 inch PVC casing in a 6 5/8 inch drill hole (Becker) or 7 5/8 inch (Sonic) drill hole. The purpose of the Type 1 well is to collect a subsurface water sample, if water encountered and/or to provide access to the geophysical tools (SOP 23). The Type 2 well will be composed of nested monitoring wells completed in a 9 inch diameter drill hole (Becker) or 8 5/8 inch (Sonic) drill hole. The purpose of the Type 2 well is to obtain subsurface water samples of multiple water-bearing units and to determine if a vertical gradient is present. The Type 3, or wide well, consists of one or more tensiometers set within the larger diameter drill hole. The tensiometers will be installed to determine matric potential of damp strata. The Type 4 well will consist of a monitoring well and a tensiometer completed in the same large diameter drill hole. The Type 4 completion will be installed if both a water-bearing and damp strata are found in the same drill hole.

6.0 DOCUMENTATION

Documentation of observations and data acquired in the field will provide information on the activities concluded and also provide a permanent record of field activities. The observations and data will be recorded on the following database forms:

- Drillhole Form
- drill_log
- Field_Activity_Form
- Fieldphotos_Subform
- Screening_Subform
- Tailgate_Safety_Mtg_Form
- Waterlevel_Subform

Field forms will be entered into the electronic database on a daily basis.

6.1 DRILL LOG

A Field Geologist experienced in borehole drilling will be present at each operating drill rig. This geologist will be responsible for logging samples, monitoring drilling operations, recording water losses or gains and groundwater data, and preparing field boring logs. The procedures for lithologic logging of boreholes are contained in SOP 6, Borehole Logging. Boring log information will also be recorded on the Drillhole_form and Drill_Log form and subform.

6.2 MONITORING WELL COMPLETION INFORMATION

The well completion information will be recorded on the Screening and Waterlevel forms (Appendix 1). The forms will include the following information:

- Well identification (identical to the borehole identification)
- Drilling method
- Installation date(s)
- Total boring depth and total well depth
- Lengths and descriptions of the screen and casing
- Depths and descriptions of the filter pack, bentonite seal and casing grout
- Elevation of water surface before and immediately after well installation
- Summary of the material penetrated by the boring.
- GPS reading using correct coordinate system

7.0 REFERENCES

U.S. EPA. 1986. "RCRA Groundwater Monitoring Technical Enforcement Guidance Document (T.E.G.D.)." U.S. Environmental Protection Agency, Washington D.C., Document No. OSWER-9950.1

U.S. EPA. 1990. "Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells". U.S. Environmental Protection Agency, Washington D.C., Document No. EPA/600/4-89/034.

American Society for Testing and Materials (ASTM). 1996. "ASTM Standards on Groundwater and Vadose Zone Investigations: Drilling, Sampling, Well Installation and Abandonment Procedures." ASTM Standard F-480-88A or the National Sanitation Foundation Standard 14 (Plastic Pipe System)

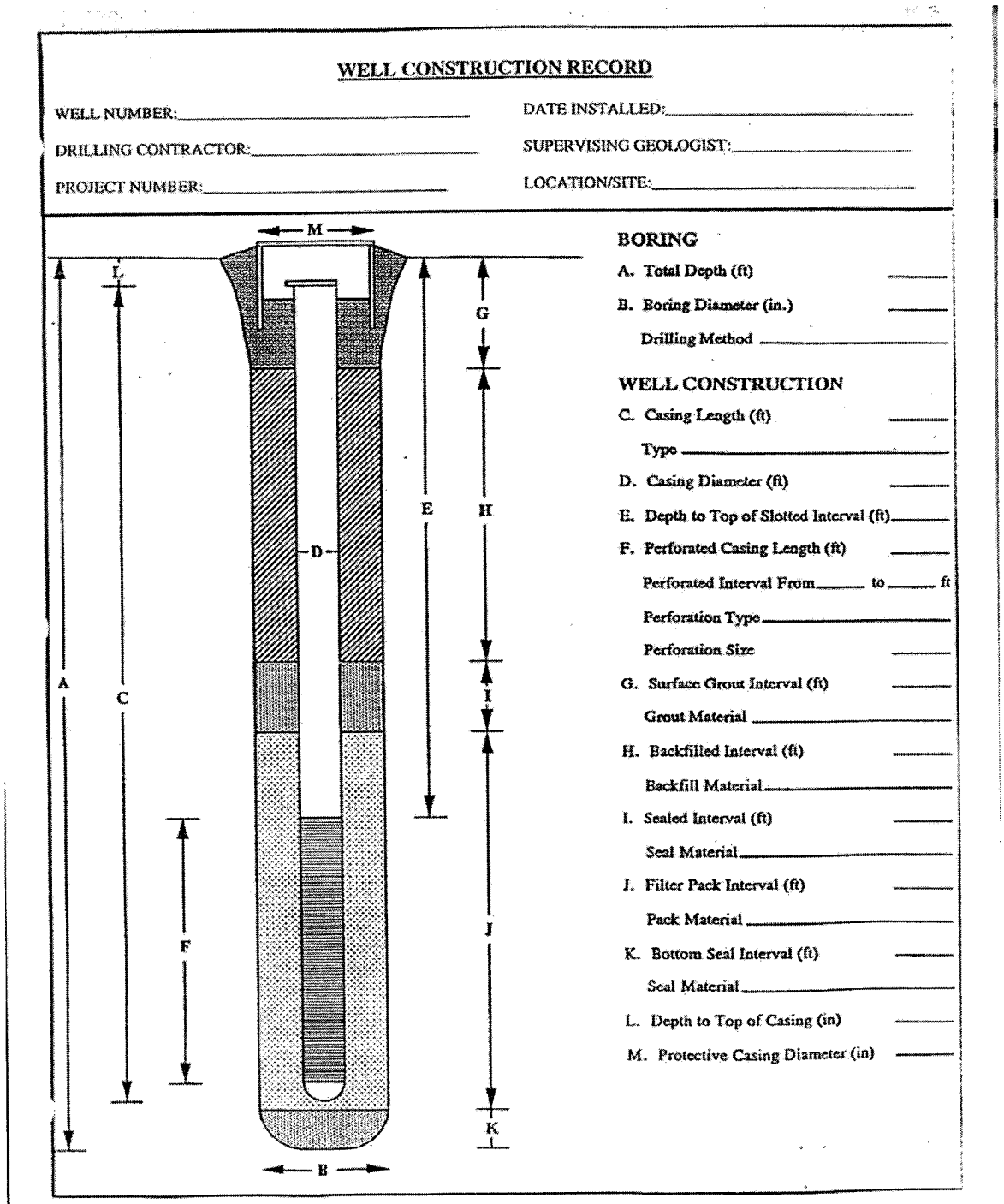

Figure 1: Monitoring Well Completion Diagram