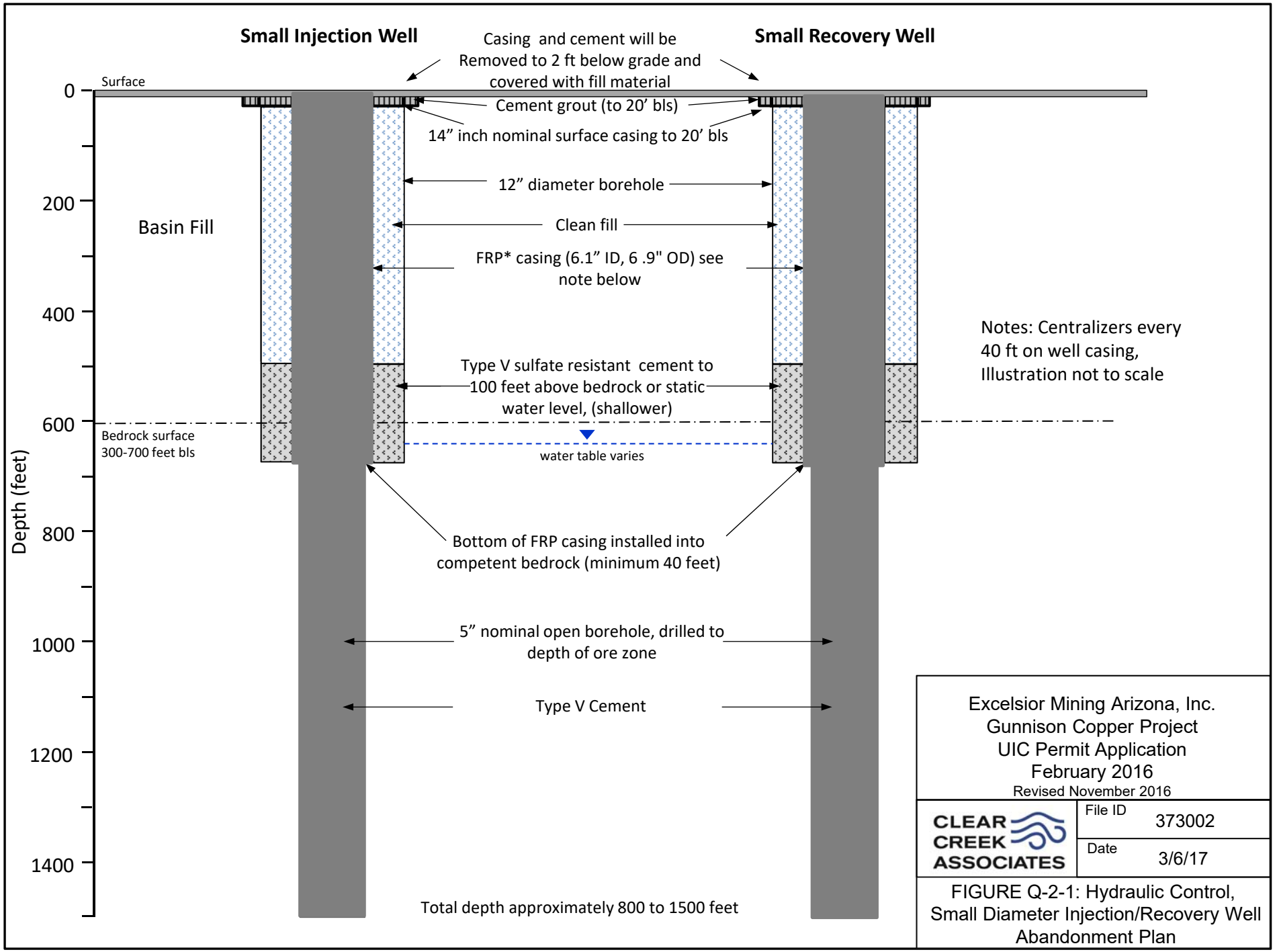
ATTACHMENT Q-2

ADWR WELL ABANDONMENT HANDBOOK AND EXAMPLE ADWR NOTICE OF INTENT TO ABANDON FORM

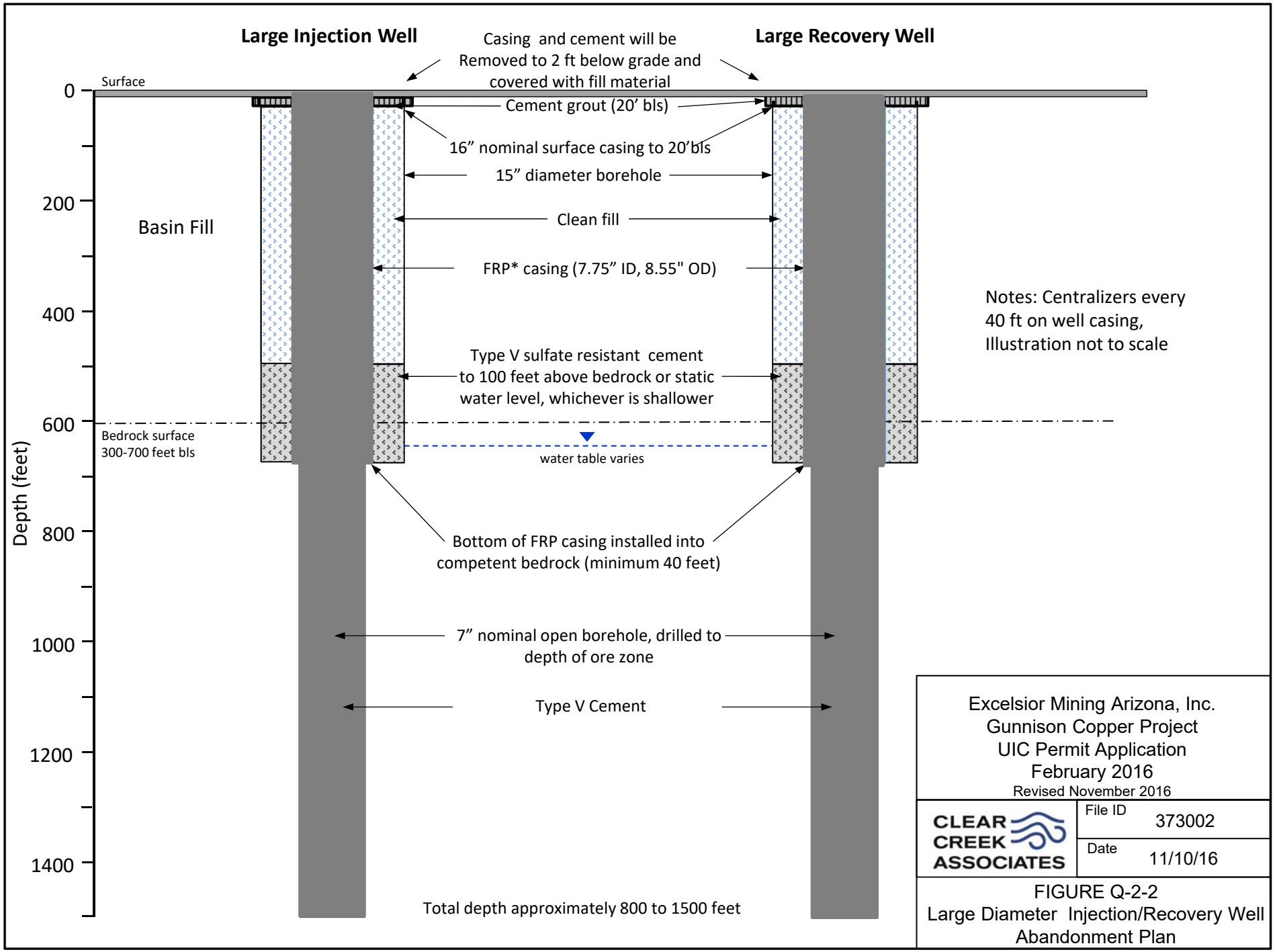


Excelsior Mining Arizona, Inc.
Gunnison Copper Project
UIC Permit Application
February 2016
Revised November 2016

CLEAR CREEK ASSOCIATES

File ID	373002
Date	3/6/17

FIGURE Q-2-1: Hydraulic Control, Small Diameter Injection/Recovery Well Abandonment Plan

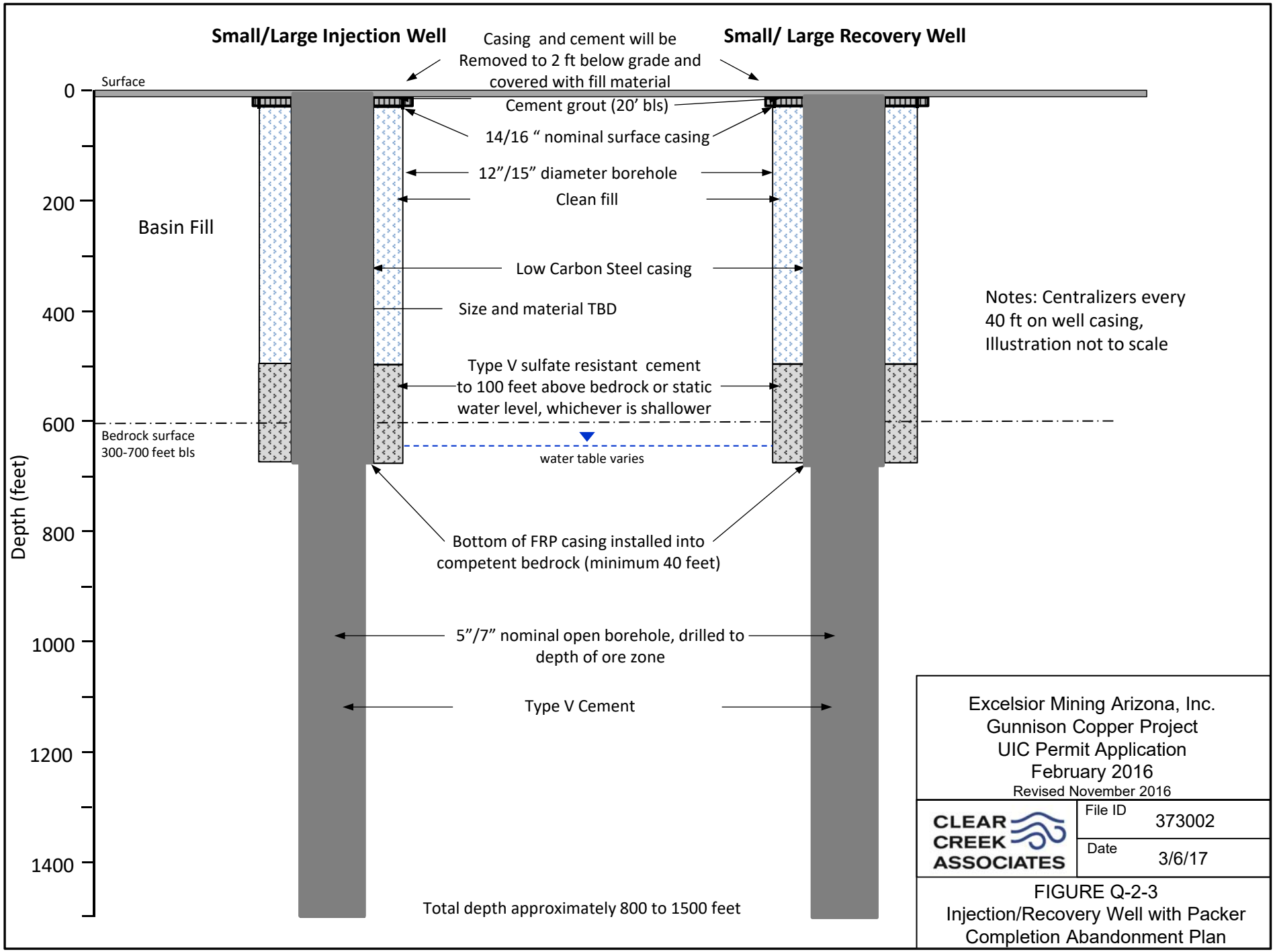


Excelsior Mining Arizona, Inc.
Gunnison Copper Project
UIC Permit Application
February 2016
Revised November 2016

CLEAR CREEK ASSOCIATES

File ID	373002
Date	11/10/16

FIGURE Q-2-2
Large Diameter Injection/Recovery Well Abandonment Plan

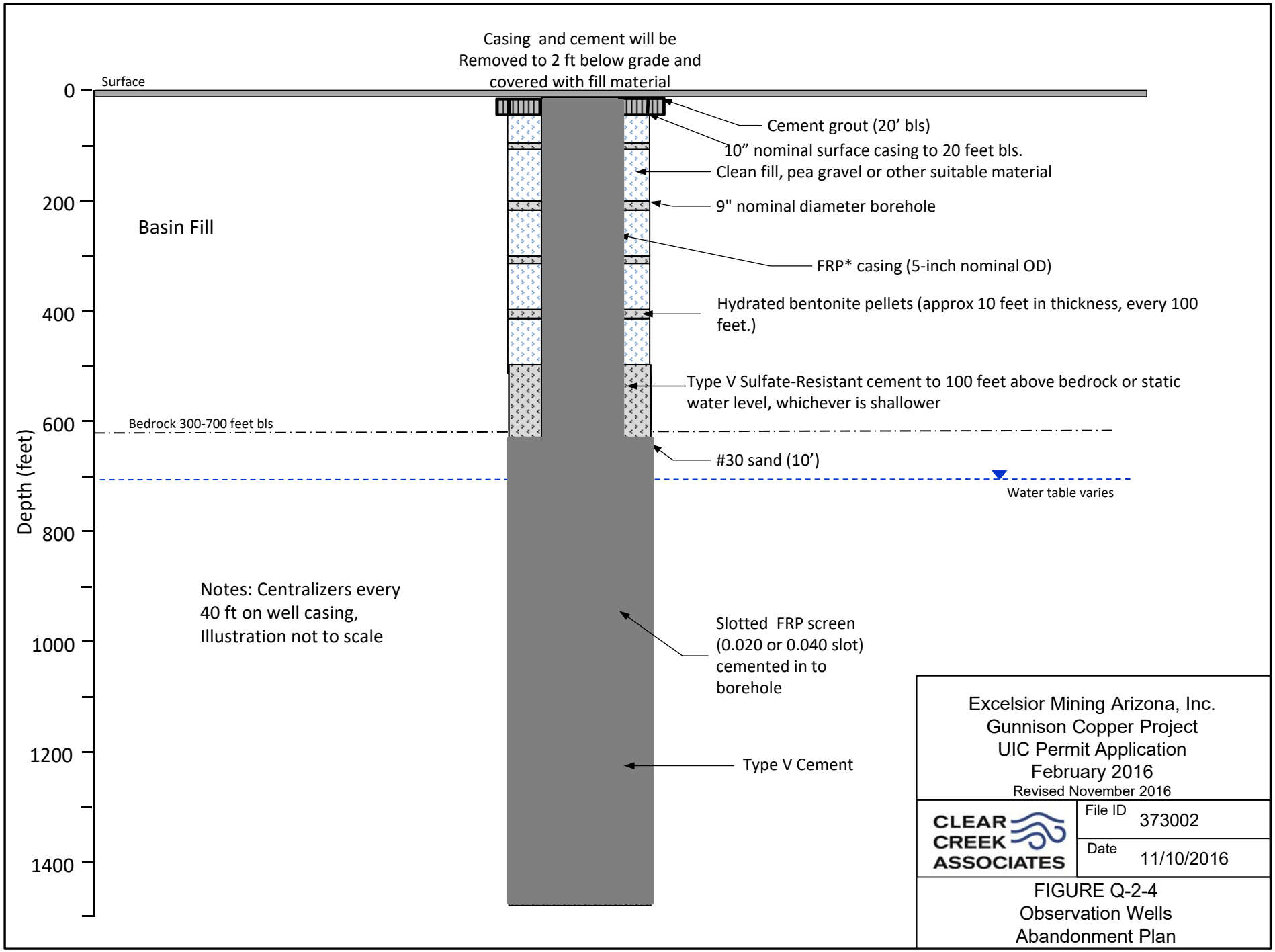


Excelsior Mining Arizona, Inc.
Gunnison Copper Project
UIC Permit Application
February 2016
Revised November 2016

CLEAR CREEK ASSOCIATES

File ID	373002
Date	3/6/17

FIGURE Q-2-3
Injection/Recovery Well with Packer
Completion Abandonment Plan



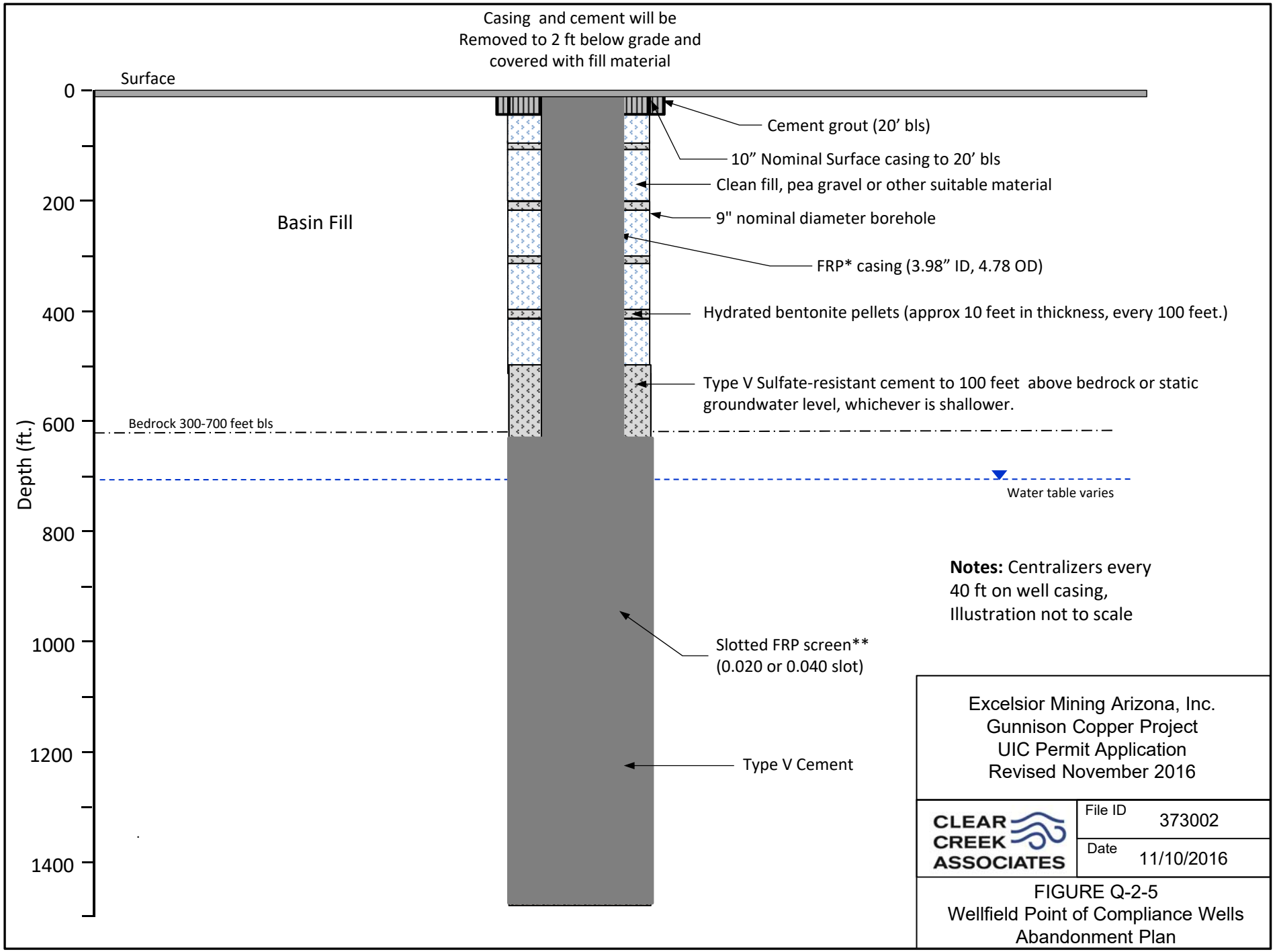
Excelsior Mining Arizona, Inc.
Gunnison Copper Project
UIC Permit Application
February 2016
Revised November 2016

CLEAR CREEK ASSOCIATES

File ID 373002

Date 11/10/2016

FIGURE Q-2-4
Observation Wells
Abandonment Plan


Casing and cement will be
Removed to 2 ft below grade and
covered with fill material
Surface
0
200
400
600
800
1000
1200
1400
Depth (ft.)
Basin Fill
Bedrock 300-700 feet bls
Cement grout (20' bls)
10" Nominal Surface casing to 20' bls
Clean fill, pea gravel or other suitable material
9" nominal diameter borehole
FRP* casing (3.98" ID, 4.78 OD)
Hydrated bentonite pellets (approx 10 feet in thickness, every 100 feet.)
Type V Sulfate-resistant cement to 100 feet above bedrock or static groundwater level, whichever is shallower.
Water table varies
Notes: Centralizers every 40 ft on well casing, Illustration not to scale
Slotted FRP screen**
(0.020 or 0.040 slot)
Type V Cement
Excelsior Mining Arizona, Inc.
Gunnison Copper Project
UIC Permit Application
Revised November 2016
CLEAR CREEK ASSOCIATES
File ID 373002
Date 11/10/2016
FIGURE Q-2-5
Wellfield Point of Compliance Wells
Abandonment Plan

Sample 7520-14 form for hydraulic control wells--A completed form will be provided to EPA prior to abandonment

OMB No. 2040-0042 Approval Expires 11/30/2014

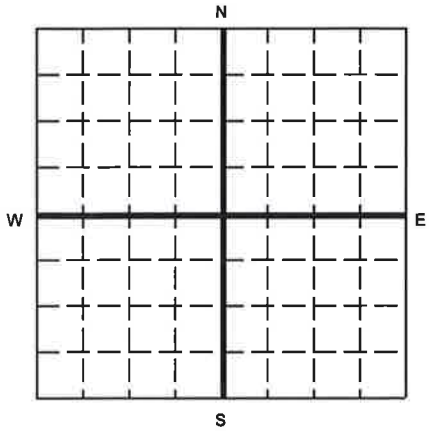
EPA

United States Environmental Protection Agency
Washington, DC 20460

PLUGGING AND ABANDONMENT PLAN

Name and Address of Facility	Name and Address of Owner/Operator
EXCELSIOR MINING CORP GUNNISON PROJECT	EXCELSIOR MINING CORP CONCORD PL, 2999 N 44TH ST, STE 300, PHOENIX, AZ 85018

Locate Well and Outline Unit on Section Plat - 640 Acres



State	County	Permit Number
AZ	Cochise	TBD

Surface Location Description

___ 1/4 of ___ 1/4 of ___ 1/4 of ___ 1/4 of Section 36 Township 15S Range 22E OR
Section 31 Township 15S Range 23E

Locate well in two directions from nearest lines of quarter section and drilling unit

Surface Location ___ ft. frm (N/S) ___ Line of quarter section
and ___ ft. from (E/W) ___ Line of quarter section.

TYPE OF AUTHORIZATION

- [ ] Individual Permit
- [x] Area Permit
- [ ] Rule

Number of Wells TBD

Lease Name

WELL ACTIVITY

- [ ] CLASS I
- [ ] CLASS II
  - [ ] Brine Disposal
  - [ ] Enhanced Recovery
  - [ ] Hydrocarbon Storage
- [x] CLASS III

Well Number Hydraulic Control Wells

CASING AND TUBING RECORD AFTER PLUGGING

SIZE	WT (LB/FT)	TO BE PUT IN WELL (FT)	TO BE LEFT IN WELL (FT)	HOLE SIZE
6.1	Unknown	0	Unknown: ~300-700	6.1

METHOD OF EMPLACEMENT OF CEMENT PLUGS

- [x] The Balance Method
- [ ] The Dump Bailer Method
- [ ] The Two-Plug Method
- [ ] Other

CEMENTING TO PLUG AND ABANDON DATA:	PLUG #1	PLUG #2	PLUG #3	PLUG #4	PLUG #5	PLUG #6	PLUG #7
Size of Hole or Pipe in which Plug Will Be Placed (inche	6.1	5.0					
Depth to Bottom of Tubing or Drill Pipe (ft.	TBD	TBD					
Sacks of Cement To Be Used (each plug)	TBD	TBD					
Slurry Volume To Be Pumped (cu. ft.)	TBD	TBD					
Calculated Top of Plug (ft.)	2	TBD					
Measured Top of Plug (if tagged ft.)							
Slurry Wt. (Lb./Gal.)	15.6	15.6					
Type Cement or Other Material (Class III)	V	V					

LIST ALL OPEN HOLE AND/OR PERFORATED INTERVALS AND INTERVALS WHERE CASING WILL BE VARIED (if any)

From	To	From	To
TBD	TBD		

Estimated Cost to Plug Wells

$10,300

Certification

I certify under the penalty of law that I have personally examined and am familiar with the information submitted in this document and all attachments and that, based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the information is true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment. (Ref. 40 CFR 144.32)

Name and Official Title *(Please type or print)*	Signature	Date Signed
Roland Goodgame, Executive Vice President		3-16-17

EPA Form 7520-14 (Rev. 12-11)

Sample 7520-14 form for large diameter injection/recovery wells

OMB No. 2040-0042 Approval Expires 11/30/2014

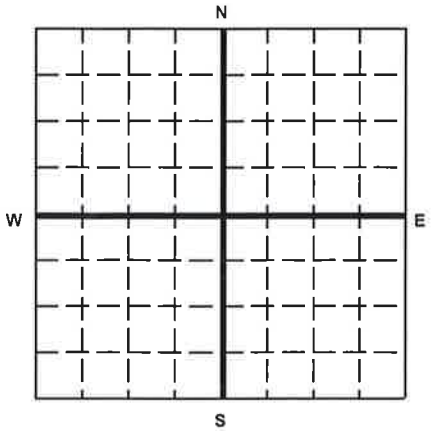
EPA

United States Environmental Protection Agency
Washington, DC 20460

PLUGGING AND ABANDONMENT PLAN

Name and Address of Facility	Name and Address of Owner/Operator
EXCELSIOR MINING CORP GUNNISON PROJECT	EXCELSIOR MINING CORP CONCORD PL, 2999 N 44TH ST, STE 300, PHOENIX, AZ 85018

Locate Well and Outline Unit on Section Plat - 640 Acres



State	County	Permit Number
AZ	Cochise	TBD

Surface Location Description

___ 1/4 of ___ 1/4 of ___ 1/4 of ___ 1/4 of Section 36 Township 15S Range 22E **OR**
Section 31 Township 15S Range 23E

Locate well in two directions from nearest lines of quarter section and drilling unit

Surface Location ___ ft. frm (N/S) ___ Line of quarter section
and ___ ft. from (E/W) ___ Line of quarter section.

TYPE OF AUTHORIZATION

- [ ] Individual Permit
- [x] Area Permit
- [ ] Rule

Number of Wells TBD

Lease Name

WELL ACTIVITY

- [ ] CLASS I
- [ ] CLASS II
  - [ ] Brine Disposal
  - [ ] Enhanced Recovery
  - [ ] Hydrocarbon Storage
- [x] CLASS III

Well Number Large Injection/Recovery

CASING AND TUBING RECORD AFTER PLUGGING

SIZE	WT (LB/FT)	TO BE PUT IN WELL (FT)	TO BE LEFT IN WELL (FT)	HOLE SIZE
7.75	Unknown	0	Unknown: ~300-700	7.75

METHOD OF EMPLACEMENT OF CEMENT PLUGS

- [x] The Balance Method
- [ ] The Dump Bailer Method
- [ ] The Two-Plug Method
- [ ] Other

CEMENTING TO PLUG AND ABANDON DATA:	PLUG #1	PLUG #2	PLUG #3	PLUG #4	PLUG #5	PLUG #6	PLUG #7
Size of Hole or Pipe in which Plug Will Be Placed (inche	7.75	7.0					
Depth to Bottom of Tubing or Drill Pipe (ft	TBD	TBD					
Sacks of Cement To Be Used (each plug)	TBD	TBD					
Slurry Volume To Be Pumped (cu. ft.)	TBD	TBD					
Calculated Top of Plug (ft.)	2	TBD					
Measured Top of Plug (if tagged ft.)							
Slurry Wt. (Lb./Gal.)	15.6	15.6					
Type Cement or Other Material (Class III)	V	V					

LIST ALL OPEN HOLE AND/OR PERFORATED INTERVALS AND INTERVALS WHERE CASING WILL BE VARIED (if any)

From	To	From	To
TBD	TBD		

Estimated Cost to Plug Wells

$17,000

Certification

I certify under the penalty of law that I have personally examined and am familiar with the information submitted in this document and all attachments and that, based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the information is true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibliity of fine and imprisonment. (Ref. 40 CFR 144.32)

Name and Official Title *(Please type or print)*	Signature	Date Signed
Roland Goodgame, Executive Vice President		3-16-17

EPA Form 7520-14 (Rev. 12-11)

Sample 7520-14 form for observation wells

OMB No. 2040-0042 Approval Expires 11/30/2014

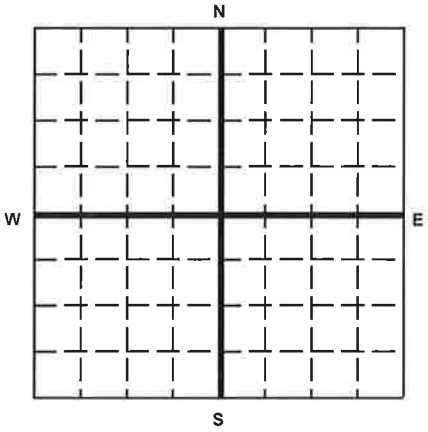
EPA

United States Environmental Protection Agency
Washington, DC 20460

PLUGGING AND ABANDONMENT PLAN

Name and Address of Facility	Name and Address of Owner/Operator
EXCELSIOR MINING CORP GUNNISON PROJECT	EXCELSIOR MINING CORP CONCORD PL, 2999 N 44TH ST, STE 300, PHOENIX, AZ 85018

Locate Well and Outline Unit on Section Plat - 640 Acres



State	County	Permit Number
AZ	Cochise	TBD

Surface Location Description

Section 36 Township 15S Range 22E OR

1/4 of ____ 1/4 of ____ 1/4 of ____ 1/4 of Section 31 Township 15S Range 23E

Locate well in two directions from nearest lines of quarter section and drilling unit

Surface Location ____ ft. frm (N/S) ____ Line of quarter section and ____ ft. from (E/W) ____ Line of quarter section.

TYPE OF AUTHORIZATION

- [ ] Individual Permit
- [x] Area Permit
- [ ] Rule

Number of Wells TBD

Lease Name

WELL ACTIVITY

- [ ] CLASS I
- [ ] CLASS II
  - [ ] Brine Disposal
  - [ ] Enhanced Recovery
  - [ ] Hydrocarbon Storage
- [x] CLASS III

Well Number Observation Well

CASING AND TUBING RECORD AFTER PLUGGING

SIZE	WT (LB/FT)	TO BE PUT IN WELL (FT)	TO BE LEFT IN WELL (FT)	HOLE SIZE
3.98	Unknown	0	Unknown: ~1400-1500	3.98

METHOD OF EMPLACEMENT OF CEMENT PLUGS

- [x] The Balance Method
- [ ] The Dump Bailer Method
- [ ] The Two-Plug Method
- [ ] Other

CEMENTING TO PLUG AND ABANDON DATA:	PLUG #1	PLUG #2	PLUG #3	PLUG #4	PLUG #5	PLUG #6	PLUG #7
Size of Hole or Pipe in which Plug Will Be Placed (inche	3.98						
Depth to Bottom of Tubing or Drill Pipe (ft.	TBD						
Sacks of Cement To Be Used (each plug)	TBD						
Slurry Volume To Be Pumped (cu. ft.)	TBD						
Calculated Top of Plug (ft.)	2						
Measured Top of Plug (if tagged ft.)							
Slurry Wt. (Lb./Gal.)	15.6						
Type Cement or Other Material (Class III)	V						

LIST ALL OPEN HOLE AND/OR PERFORATED INTERVALS AND INTERVALS WHERE CASING WILL BE VARIED (if any)

From	To	From	To
TBD	TBD		

Estimated Cost to Plug Wells

$25,000

Certification

I certify under the penalty of law that I have personally examined and am familiar with the information submitted in this document and all attachments and that, based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the information is true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment. (Ref. 40 CFR 144.32)

Name and Official Title *(Please type or print)*	Signature	Date Signed
Roland Goodgame, Executive Vice President		3-16-17

EPA Form 7520-14 (Rev. 12-11)

Sample 7520-14 form for POC Wells

OMB No. 2040-0042 Approval Expires 11/30/2014

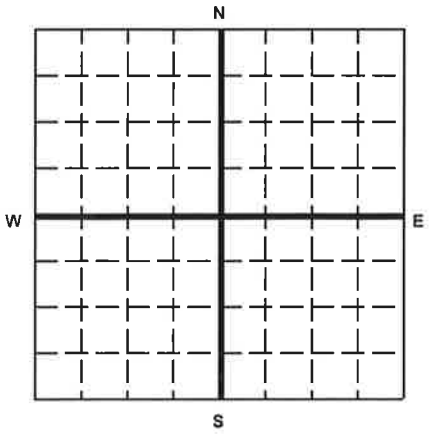
EPA

United States Environmental Protection Agency
Washington, DC 20460

PLUGGING AND ABANDONMENT PLAN

Name and Address of Facility	Name and Address of Owner/Operator
EXCELSIOR MINING CORP GUNNISON PROJECT	EXCELSIOR MINING CORP CONCORD PL, 2999 N 44TH ST, STE 300, PHOENIX, AZ 85018

Locate Well and Outline Unit on Section Plat - 640 Acres



State	County	Permit Number
AZ	Cochise	TBD

Surface Location Description

___ 1/4 of ___ 1/4 of ___ 1/4 of ___ 1/4 of Section 36 Township 15S Range 22E **OR**
Section 31 Township 15S Range 23E

Locate well in two directions from nearest lines of quarter section and drilling unit

Surface Location ___ ft. frm (N/S) ___ Line of quarter section
and ___ ft. from (E/W) ___ Line of quarter section.

TYPE OF AUTHORIZATION

- [ ] Individual Permit
- [x] Area Permit
- [ ] Rule

Number of Wells TBD

Lease Name

WELL ACTIVITY

- [ ] CLASS I
- [ ] CLASS II
  - [ ] Brine Disposal
  - [ ] Enhanced Recovery
  - [ ] Hydrocarbon Storage
- [x] CLASS III

Well Number POC

CASING AND TUBING RECORD AFTER PLUGGING

SIZE	WT (LB/FT)	TO BE PUT IN WELL (FT)	TO BE LEFT IN WELL (FT)	HOLE SIZE
4	Unknown	0	Unknown: ~300-700	9

METHOD OF EMPLACEMENT OF CEMENT PLUGS

- [x] The Balance Method
- [ ] The Dump Bailer Method
- [ ] The Two-Plug Method
- [ ] Other

CEMENTING TO PLUG AND ABANDON DATA:	PLUG #1	PLUG #2	PLUG #3	PLUG #4	PLUG #5	PLUG #6	PLUG #7
Size of Hole or Pipe in which Plug Will Be Placed (inche	4	9					
Depth to Bottom of Tubing or Drill Pipe (ft.	TBD	TBD					
Sacks of Cement To Be Used (each plug)	TBD	TBD					
Slurry Volume To Be Pumped (cu. ft.)	TBD	TBD					
Calculated Top of Plug (ft.)	2	TBD					
Measured Top of Plug (if tagged ft.)							
Slurry Wt. (Lb./Gal.)	15.6	15.6					
Type Cement or Other Material (Class III)	V	V					

LIST ALL OPEN HOLE AND/OR PERFORATED INTERVALS AND INTERVALS WHERE CASING WILL BE VARIED (if any)

From	To	From	To
TBD	TBD		

Estimated Cost to Plug Wells

$25,000

Certification

I certify under the penalty of law that I have personally examined and am familiar with the information submitted in this document and all attachments and that, based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the information is true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment. (Ref. 40 CFR 144.32)

Name and Official Title *(Please type or print)*	Signature	Date Signed
Roland Goodgame, Executive Vice President		3-16-17

EPA Form 7520-14 (Rev. 12-11)

Sample 7520-14 form for small diameter injection/recovery wells

OMB No. 2040-0042 Approval Expires 11/30/2014

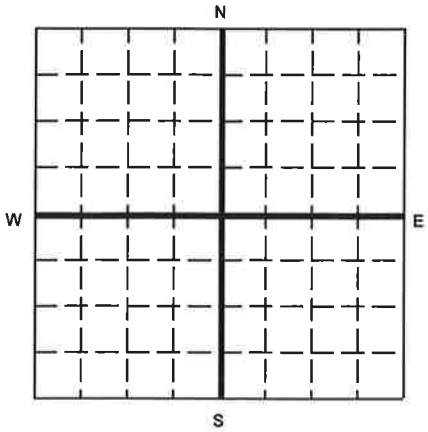
EPA

United States Environmental Protection Agency
Washington, DC 20460

PLUGGING AND ABANDONMENT PLAN

Name and Address of Facility	Name and Address of Owner/Operator
EXCELSIOR MINING CORP GUNNISON PROJECT	EXCELSIOR MINING CORP CONCORD PL, 2999 N 44TH ST, STE 300, PHOENIX, AZ 85018

Locate Well and Outline Unit on Section Plat - 640 Acres



State	County	Permit Number
AZ	Cochise	TBD

Surface Location Description

Section 36 Township 15S Range 22E OR

___ 1/4 of ___ 1/4 of ___ 1/4 of ___ 1/4 of Section 31 Township 15S Range 23E

Locate well in two directions from nearest lines of quarter section and drilling unit

Surface Location ___ ft. frm (N/S) ___ Line of quarter section and ___ ft. from (E/W) ___ Line of quarter section.

TYPE OF AUTHORIZATION

- [ ] Individual Permit
- [x] Area Permit
- [ ] Rule

Number of Wells TBD

Lease Name

WELL ACTIVITY

- [ ] CLASS I
- [ ] CLASS II
  - [ ] Brine Disposal
  - [ ] Enhanced Recovery
  - [ ] Hydrocarbon Storage
- [x] CLASS III

Well Number Small Injection/Recovery

CASING AND TUBING RECORD AFTER PLUGGING

SIZE	WT (LB/FT)	TO BE PUT IN WELL (FT)	TO BE LEFT IN WELL (FT)	HOLE SIZE
6.1	Unknown	0	Unknown: ~300-700	6.1

METHOD OF EMPLACEMENT OF CEMENT PLUGS

- [x] The Balance Method
- [ ] The Dump Bailer Method
- [ ] The Two-Plug Method
- [ ] Other

CEMENTING TO PLUG AND ABANDON DATA:	PLUG #1	PLUG #2	PLUG #3	PLUG #4	PLUG #5	PLUG #6	PLUG #7
Size of Hole or Pipe in which Plug Will Be Placed (inche	6.1	5.0					
Depth to Bottom of Tubing or Drill Pipe (ft	TBD	TBD					
Sacks of Cement To Be Used (each plug)	TBD	TBD					
Slurry Volume To Be Pumped (cu. ft.)	TBD	TBD					
Calculated Top of Plug (ft.)	2	TBD					
Measured Top of Plug (if tagged ft.)							
Slurry Wt. (Lb./Gal.)	15.6	15.6					
Type Cement or Other Material (Class III)	V	V					

LIST ALL OPEN HOLE AND/OR PERFORATED INTERVALS AND INTERVALS WHERE CASING WILL BE VARIED (if any)

From	To	From	To
TBD	TBD		

Estimated Cost to Plug Wells

$10,300

Certification

I certify under the penalty of law that I have personally examined and am familiar with the information submitted in this document and all attachments and that, based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the information is true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibliity of fine and imprisonment. (Ref. 40 CFR 144.32)

Name and Official Title *(Please type or print)*	Signature	Date Signed
Roland Goodgame, Executive Vice President		3-16-17

EPA Form 7520-14 (Rev. 12-11)

SECURING ARIZONA'S WATER FUTURE

ADWR

ARIZONA DEPARTMENT OF WATER RESOURCES

WELL ABANDONMENT HANDBOOK

SEPTEMBER 2008

3550 NORTH CENTRAL AVENUE, SUITE #200
PHOENIX, ARIZONA 85012-2105

PHONE: 602-771-8500
1-800-352-8488

FAX: 602-771-8691

WEB SITE: HTTP://WWW.AZWATER.GOV

WELL ABANDONMENT HANDBOOK

September 2008

Janet Napolitano, Governor
State of Arizona

Herbert R. Guenther, Director
Arizona Department of Water Resources

Arizona Department of Water Resources
3550 North Central Avenue, Suite #200
Phoenix, Arizona 85012-2105
(602) 771-8500
(800) 352-8488

www.azwater.gov

Permission to quote from or reproduce materials from this publication is granted when due acknowledgement is made.

ARIZONA DEPARTMENT OF WATER RESOURCES
3550 N. Central Ave., Suite 200, Phoenix, Arizona 85012
Telephone 602 771-8500 • Fax 602 771-8691

September 25, 2008

Janet Napolitano
Governor

Herbert R. Guenther
Director

SUBSTANTIVE POLICY STATEMENT WELL ABANDONMENT HANDBOOK

I. BACKGROUND

The Arizona Department of Water Resources ("Department") is required by Arizona Revised Statute (A.R.S.) § 45-594(A) to adopt rules establishing construction standards for wells, including the abandonment of existing wells. The Department adopted such rules effective March 5, 1984, and amended the rules effective June 18, 1990. The well abandonment rule is set forth in Arizona Administrative Code ("A.A.C.") R12-15-816.

Pursuant to A.A.C. R12-15-816(G), the Department's well abandonment rule requires that the abandonment of a well be accomplished "through filling or sealing the well so as to prevent the well, including the annular space outside the casing, from being a channel allowing the vertical movement of water." Although the rule specifies the materials that must be used to fill or seal the well if it penetrates a single or multiple aquifer, the rule does not specify the materials that should be used if the well does not penetrate an aquifer or if groundwater or vadose zone contamination exists at or near the well site. Additionally, the rule does not prescribe a method for emplacing fill or seal materials in a well to ensure that water does not move vertically through the well after abandonment.

The Director has determined that the Department should provide additional written guidance to the public on well abandonment. The purpose of the written guidance is not to change any of the requirements in the Department's well abandonment rule or to impose any additional requirements. Instead the written guidance is intended to assist well owners and well drillers in complying with A.A.C. R12-15-816(G) by informing them of fill materials and emplacement methods the Department considers to be adequate to seal a well in a manner that will prevent the well from being a channel allowing the vertical movement of water under various aquifer and vadose zone conditions. By following the written guidance, a person will be assured of complying with A.A.C. R12-15-816(G).

II. WELL ABANDONMENT THAT CONFORMS WITH THE APPLICABLE PROCEDURES IN THE ATTACHED WELL ABANDONMENT HANDBOOK WILL BE DEEMED TO BE IN COMPLIANCE WITH A.A.C. R12-15-816(G)

To assist well owners and well drillers in complying with A.A.C. R12-15-816, the Director issues the attached Well Abandonment Handbook as a substantive policy statement. The Handbook sets forth procedures for abandoning a well under most aquifer and vadose zone conditions, including special conditions not addressed in the Department's well abandonment rule. A person who abandons a well in conformance with the applicable procedures outlined in the Handbook will be deemed to be in compliance with A.A.C. R12-15-816(G).

III. EFFECTIVE DATE

This substantive policy statement rescinds and replaces the previous substantive policy statement dated September 20, 2001, and shall become effective immediately. The Director may modify or revoke this policy at any time.

Dated this 3rd day of October, 2008.

Herbert R. Guenther
Director
Arizona Department of Water Resources

Printed on recycled paper. Each ton of recycled paper saves 7,000 gallons of water.

Table of Contents

I. Introduction 1

II. Overview of the Well Abandonment Process 2

III. Surface Seal Requirements Applicable to the Upper 20 Feet of All Wells to be Abandoned and Special Requirements for Debris-Filled or Obstructed Wells 5

A. Surface Seal Requirements 5

Surface Casing Removal Option 5

Surface Casing Non-Removal Option 5

B. Special Requirements for Debris Filled or Obstructed Wells 5

IV. Abandonment Methods 5

A. Standard Abandonment Method 5

B. Alternative Abandonment Methods 6

Alternative 1 – *Applies to wells that do not penetrate aquifers, including wells that have gone dry, and no vadose zone contamination issues exist* 6

Alternative 2 – *Applies to wells that do not penetrate aquifers, including wells that have gone dry, and vadose zone contamination issues exist* 6

Alternative 3 – *Applies to wells that penetrate single or multiple aquifers, and water quality contamination issues exist* 6

Alternative 4 – *Applies to wells that penetrate a single aquifer only without vertical flow components, and no water quality contamination issues exist* 8

Alternative 4 (Variance Option) 8

Alternative 5 – *Applies to wells that penetrate single or multiple aquifers with vertical flow components, and no water quality* 9

Alternative 5 (Variance Option 1) 9

Alternative 5 (Variance Option 2) 9

References 12

APPENDIX A – A.A.C. R12-15-816, The ADWR Well Abandonment Rule 13

APPENDIX B – Definitions 15

APPENDIX C – Questions and Answers about the Abandonment Handbook 19

Figure 1 Well Abandonment Process 4

Figure 2 Alternative Abandonment Methods Applicable to Five Commonly Occurring Vadose Zone and Aquifer Conditions 7

Table 1 Acceptable Well Abandonment Materials and Mixtures 11

I. Introduction

The Arizona Department of Water Resources ("ADWR") regulates the abandonment of wells in Arizona. ADWR adopted a rule setting forth requirements for well abandonment in 1984 and amended the rule in 1990. The amended rule is published in the Arizona Administrative Code ("A.A.C.") as Rule R12-15-816. A copy of the rule is attached to this Handbook as Appendix A.

ADWR's well abandonment rule requires that well abandonment be accomplished "through filling or sealing the well so as to prevent the well, including the annular space outside the casing, from being a channel allowing the vertical movement of water." A.A.C. R12-15-816(G). The rule prescribes the fill materials that must be used in certain aquifer conditions. A.A.C. R12-15-816(H). The rule also requires the filing of a pre-abandonment notice with ADWR (unless the well is a new well being abandoned in the course of drilling the well) and the filing of post-abandonment reports. A.A.C. R12-15-816(B), (E) and (F).

The purpose of this Handbook is to provide a step-by-step guide to the abandonment of a well in a manner that complies with ADWR's well abandonment rule. The Handbook describes the abandonment process from the filing of a Notice of Intention to Abandon with ADWR prior to commencing abandonment, to the filing of post-abandonment reports by the well owner and well driller. Most importantly, the Handbook describes procedures that may be used to adequately abandon a well, including fill materials and emplacement methods.

A standard abandonment method is described that may be used for any well, regardless of the aquifer and vadose zone conditions applicable to the well. Five alternative abandonment methods are also described for five different vadose zone and aquifer conditions. In most cases, the alternative abandonment method will be less expensive than the standard method. However, a well owner may need to demonstrate to ADWR that the well to be abandoned falls within the condition to which the alternative method applies before that method may be used. For that reason, the abandonment process may take longer if an alternative abandonment method is requested.

The well abandonment methods described in this Handbook are presented in much greater detail than in ADWR's well abandonment rule. However, the Handbook is not intended to change any of the requirements in the rule or to impose any additional requirements. The purpose of including the abandonment methods in the Handbook is to assist well owners and well drillers in complying with A.A.C. R12-15-816(G) by informing them of fill materials and emplacement methods ADWR considers to be adequate to seal a well in a manner that will prevent the well from being a channel allowing the vertical movement of water. A person who abandons a well in accordance with the applicable well abandonment method described in this Handbook will be assured of complying with A.A.C. R12-15-816(G).

The next section presents an overview of the abandonment process. Section III describes surface seal requirements for the upper 20 feet of all wells and special requirements for debris-filled or obstructed wells. Section IV describes the standard abandonment method and the five alternative methods. Appendix B contains definitions of terms used in this Handbook and Appendix C contains questions and answers regarding this Handbook.

II. Overview of the Well Abandonment Process

Legal authorization from the ADWR is required to abandon most types of wells in the State of Arizona. The types of wells for which abandonment authority from ADWR is required are described in the question and answer section of this Handbook (Appendix C).

The process that must be followed to obtain well abandonment authority starts with the filing of a notice of intention to abandon a well (NOIA) (see Figure 1). NOIA forms may be obtained from the ADWR Groundwater Management Support Section office in Phoenix, or at local ADWR offices located in Prescott, Casa Grande, Tucson and Nogales. The NOIA form must be signed and filed by the well owner. However, the licensed well driller or a consultant may assist the well owner in filling out and filing the NOIA.

Information that must be submitted in the NOIA form includes the following:

- A well construction diagram showing all existing well construction features and the proposed abandonment specifications.
- A description of the type and condition of the casing. Although this information may not be completely known prior to abandonment, this description should be a "best estimate" of the conditions.
- A description of the proposed method of abandonment. The casing removal techniques (such as pulling by hydraulic jacks, overdrilling, etc.), or casing non-removal techniques (such as casing perforations, brushing, sonar jetting, etc.) must be described. If the casing is to be perforated, the perforation method, size, and intervals to be perforated must be described.
- A description of the method of emplacing the sealing or fill materials (such as "tremie pumped" or "pressure grouting", etc.).
- The specific type and estimated amount of grout material to be used, and the ratios of water, cement, and/or other grout materials.

If the well owner or well driller has any questions during the abandonment planning stages prior to submittal of the NOIA, it is recommended that they contact the ADWR Hydrology Division. ADWR will gladly work with the well owner or well driller to answer any questions and conduct a preliminary review of the proposed abandonment plan. ADWR may be contacted at:

602-771-8500
(Phoenix metro area)

1-800-352-8488
(outside metro Phoenix)

After the NOIA is filed, ADWR performs a completeness review of the notice (See Figure 1). The completeness review entails the examination of the NOIA to determine if all required information has been properly submitted. After the ADWR determines that the NOIA is complete, a substantive review is performed to determine whether the proposed abandonment methods and materials meet the requirements of the ADWR well abandonment rule (See Figure 1). If the standard method of abandonment described on page 5 of this Handbook is selected, which may be used for any well regardless of the aquifer and vadose zone conditions applicable to the well, the NOIA will be approved without further review.

If an alternative abandonment method is selected, the NOIA will receive additional substantive review to determine whether the

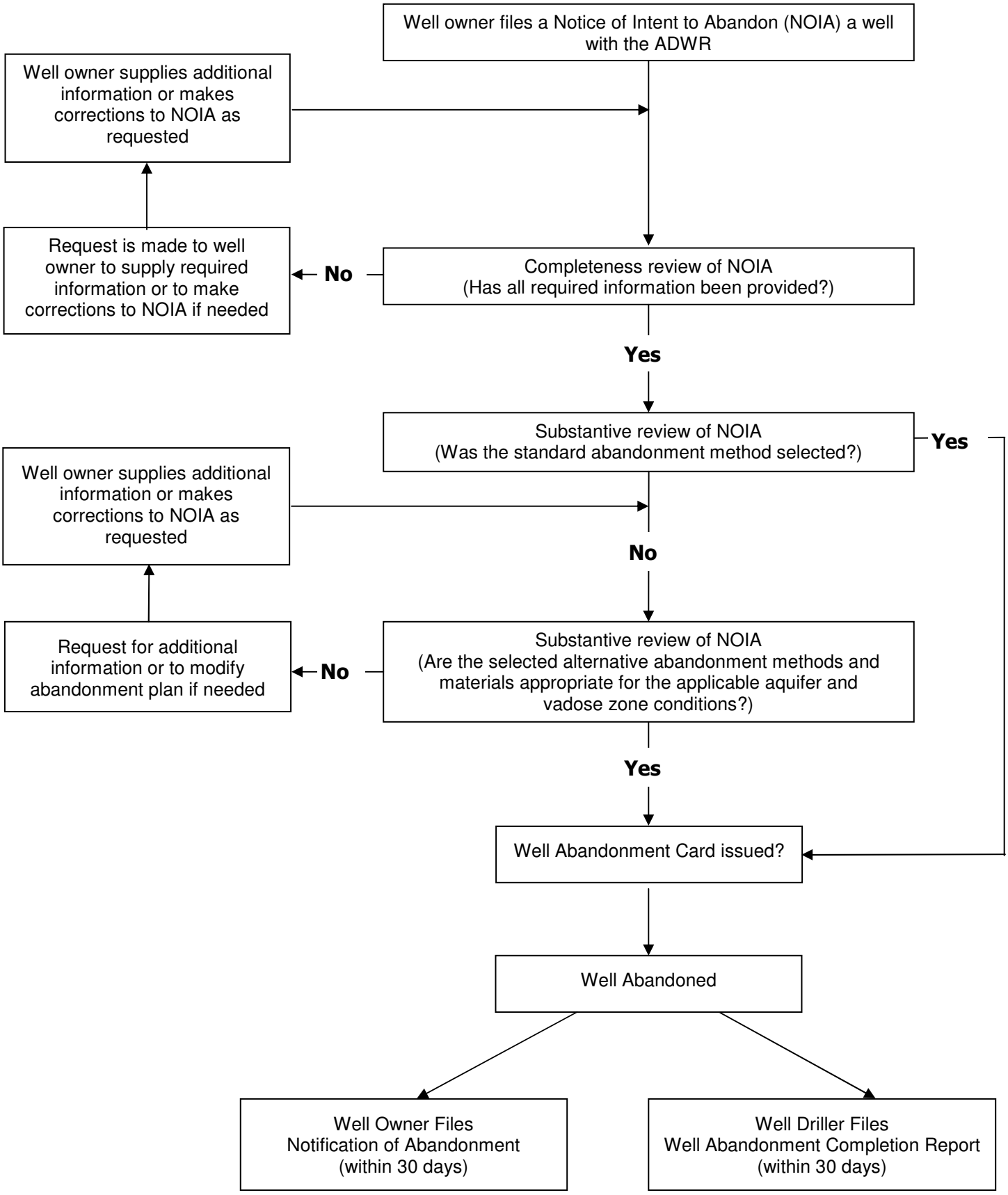
well falls within the condition to which the alternative method applies and whether appropriate fill materials were chosen. During the review process ADWR may contact the well owner to request additional information or discuss modifications to the proposed abandonment plan, if necessary.

Once the proposed well abandonment methods and materials meet the requirements of the abandonment rule, a well abandonment authorization card is mailed to the designated well driller and well abandonment operations may begin (See Figure 1).

Within 30 days after a well is abandoned, the well owner is required to file a Well Owner's Notification of Abandonment; and the well drilling contractor is required to file a Well Abandonment Completion Report with ADWR which describes the actual methods and materials used to abandon the well (See Figure 1). Information that must be submitted in the Well Abandonment Completion Report includes the following:

- The specific type and amount of grout and/or fill materials used as well as the mixing ratio of water, cement and/or other grout materials used.
- A description of the type and condition of the casing.
- A description of the actual method of abandonment. The casing removal techniques (such as pulling by hydraulic jacks, overdrilling, etc.), or casing non-removal techniques (such as casing perforations, brushing, sonar jetting, etc.) must be described. If the casing was perforated, the perforation method, size, and intervals must be described.
- A description of the method of emplacing the sealing or fill materials (such as "tremie pumped" or "pressure grouting", etc.).
- The latitude, longitude and well elevation of the abandoned well, and the method used to determine these data. Latitude and longitude coordinates determined from readily available Global Positioning System (GPS) equipment are preferred because of the high level of accuracy and comparative ease of measurement. If GPS equipment is used to determine these coordinates, the general grade of equipment should be specified (for example: survey grade or hand-held). Latitude, longitude and well elevation coordinates may also be obtained from conventional surveying methods or through estimation from a topographic map.

Figure 1
Well Abandonment Process



III. Surface Seal Requirements Applicable to the Upper 20 Feet of All Wells to be Abandoned and Special Requirements for Debris-Filled or Obstructed Wells

In addition to the well sealing and abandonment methods and materials that are discussed in the following section, ADWR's well abandonment rule requires a cement grout surface seal (plug) to be installed in the upper 20 feet of any well that is abandoned. Special requirements may also be necessary if casing obstructions and/or debris hamper the abandonment of a well. These requirements are described below:

A. Surface Seal Requirements

Surface Casing Removal Option

If the casing is removed from the top 20 feet of the well, a cement grout plug must be set extending from two feet below the land surface to a minimum of twenty feet below the land surface, and the well must be backfilled above the top of the cement grout plug to the original land surface.

Surface Casing Non-Removal Option

If the casing is not removed from the top 20 feet of the well, a cement grout plug must be set extending from the top of the casing to a minimum of twenty feet below the land surface, and the annular space outside the casing must be filled with cement from the land surface to a minimum of twenty feet below the land surface.

B. Special Requirements for Debris Filled or Obstructed Wells

In situations where casing obstructions and/or debris hamper well abandonment, the problems should be indicated on the NOIA form. In most instances a reasonable attempt to clear debris and obstructions from the well will be required. However, site-specific conditions will determine the actual method of abandonment.

IV. Abandonment Methods

A. Standard Abandonment Method

The ADWR standard abandonment method meets the requirements of ADWR's well abandonment rule under any given combination of aquifer and vadose zone conditions. The standard abandonment method may be followed to obtain expedited processing of an NOIA and issuance of a well abandonment authority.

Under the standard abandonment method, the entire length of well casing must be removed or the entire length of the casing must be reperforated (from 20 feet above the highest historic water level to the total depth of the well) with a minimum of two cuts per foot. If it is determined that the disturbance of the casing and/or gravel packed zones would negatively influence the sealing of the well, then an appropriate alternative abandonment method must be used (see Figure 2 for examples).

The well must be completely filled with neat cement, cement-bentonite grout or, except where free-product contamination is present, high-solids bentonite grout (granular or powder mixtures) with a minimum of 25% solids by weight. Materials or mixtures must be emplaced under sufficient pressure to fill all voids, including all annular space(s), and displace water from the well. A tremie pipe must be used to emplace the grout from the bottom up. The end of the tremie pipe must remain in close proximity to the rising grout surface, as the grout is pumped into the well.

In order to receive expedited processing, the NOIA should be filled out completely, and the "Standard method" should be selected in the proposed well abandonment method section of the NOIA form. The specific type

and estimated volume of grout material should be specified on the NOIA form. Any discrepancies between the estimated volume of grout to be used, and the actual amount of grout that was used for abandonment should be reported and explained on the Well Abandonment Completion Report.

B. Alternative Abandonment Methods

There are five alternatives to the standard abandonment method described above. Each alternative method is designed for a different vadose zone or aquifer condition, and only one alternative method is appropriate for a specific well. The conditions described at the beginning of each alternative and the depictions in Figure 2 should be carefully reviewed to determine the appropriate alternative method if the standard abandonment method is not selected. If an alternative method is selected, the method must be identified by number in the NOIA and the well owner may be required to submit information demonstrating that the applicable vadose zone or aquifer conditions exist for the well.

Alternative 1 – *Applies to wells that do not penetrate aquifers, including wells that have gone dry, and no vadose zone contamination issues exist.*

If the well does not penetrate an aquifer or has gone dry, and vadose zone contamination issues do not exist, the well must be filled with one or more of the following materials or mixtures: clean fine sand, cement grout (including neat cement grout, cement-bentonite grout and sand-cement grout), concrete grout, sand-bentonite grout, high-solids bentonite grout (granular or powder mixtures) with a minimum of 15% solids by weight, high-solids bentonite chips or high-solids bentonite pellets. See Table 1 for mixing ratios. High-solids bentonite chips and high-solids bentonite pellets must be hydrated to manufacturer's specifications. The materials or mixtures are recommended to exceed the casing volume by approximately 30 percent.

In the course of drilling a new well, the well may be abandoned using drill cuttings from the well being drilled if the well does not penetrate an aquifer, and no vadose zone contamination issues exist.

Alternative 2 – *Applies to wells that do not penetrate aquifers, including wells that have gone dry, and vadose zone contamination issues exist.*

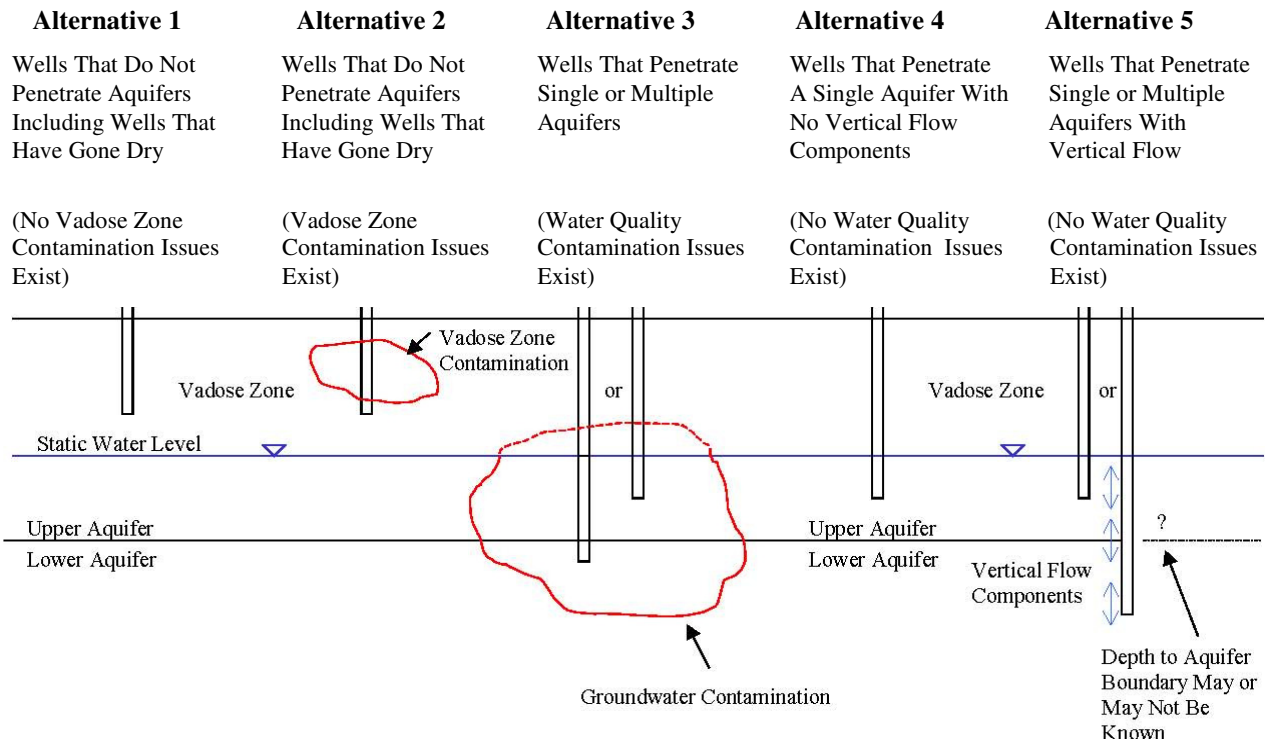
If the well does not penetrate an aquifer or has gone dry, and vadose zone contamination issues exist, but there is no free-product contamination, the well must be filled with one or more of the following materials or mixtures: cement grout (including neat cement grout, cement-bentonite grout and sand-cement grout), concrete grout, sand-bentonite grout, high-solids bentonite grout (granular or powder mixtures) with a minimum of 15% solids by weight, high-solids bentonite chips or high-solids bentonite pellets. See Table 1 for mixing ratios. High-solids bentonite chips and high-solids bentonite pellets must be hydrated to manufacturer's specifications. The materials or mixtures are recommended to exceed the casing volume by approximately 30 percent.

If free-product contamination issues exist, the entire well must be sealed with neat cement grout.

Alternative 3 – *Applies to wells that penetrate single or multiple aquifers, and water quality contamination issues exist.*

If the well penetrates a single or multiple aquifer system and water quality contamination issues exist, then site-specific conditions will determine the appropriate seal material and emplacement method. The seal material must be no more permeable than the formation being sealed. A target

Figure 2
Alternative Abandonment Methods Applicable to Five Commonly Occurring Vadose Zone and Aquifer Conditions



hydraulic conductivity of 10^{-7} cm/s may be used for sealant materials. The types of acceptable materials or mixtures are: cement grout (including neat cement grout and cement bentonite grout), high-solids bentonite grout (granular or powder mixtures) with a minimum of 15% solids by weight, high-solids bentonite chips or high-solids bentonite pellets. See Table 1 for mixing ratios. A minimum of 15% bentonite solids will be acceptable in most cases. However, a higher minimum of bentonite solids may be required in areas of high water quality contamination. Acid resistant cement (see definitions) may be required in certain areas where corrosive (low pH) groundwater conditions are encountered. The materials or mixtures are recommended to exceed the casing volume by approximately 30 percent.

If there is no free-product contamination at the well site, the vadose zone portion of the well may be sealed with the same material that is used to seal the well below the water level. High-solids bentonite chips and high-solids bentonite pellets must be hydrated to manufacturer's specifications if used in the vadose zone. If free-product contamination issues exist, the vadose zone portion of the well must be sealed with neat cement grout.

Materials or mixtures must be emplaced under sufficient pressure to fill all voids, including all annular space(s), and displace water from the well. A tremie pipe must be used to emplace the grout from the bottom up. The end of the tremie pipe shall remain in close proximity to the rising grout surface as the grout is pumped into the well.

Except as provided below for recently constructed monitor wells, if the casing is not removed, either the entire length of the casing must be reperforated (from 20 feet

above the highest historic water level to the total depth of the well), or the condition of the casing perforations must be determined by running a video log that must be submitted to the ADWR for review. If a video log demonstrates that the existing perforations are sufficiently open for grout to enter the annular space outside the casing, no additional perforations or casing treatments will be required. If the video log demonstrates that the existing perforations are not sufficiently open for grout to enter the annular space outside the casing, additional perforations and/or casing treatments such as mechanical brushing, scraping or sonic cleaning will be required, unless it is determined that disturbance of the casing and/or gravel packed zones would negatively influence the sealing of the well. Casing perforation and/or casing cleaning requirements for wells with water quality contamination issues will be made by ADWR on a case-by-case basis.

Wells requiring additional perforations must be perforated a minimum of two cuts per foot and sealed by pressure grouting. The intervals to be perforated must be determined based on site-specific information. However, if no vadose zone contamination issues exist, the perforations need only extend 20 feet above the static water level in the well.

Video logging and/or casing re-perforation may not be required in the case of the abandonment of recently constructed monitor wells. However, that determination must be made by ADWR on a case-by-case basis.

Alternative 4 – *Applies to wells that penetrate a single aquifer only without vertical flow components, and no water quality contamination issues exist.*

If the well penetrates an aquifer and hydrogeologic and stratigraphic information is available for the well at an acceptable level of confidence to determine that no aquifer boundaries and no vertical flow components exist within the length of the well, and if water quality contamination issues do not exist, the well must be filled with one or more of the following materials or mixtures: cement grout (including neat cement grout, cement-bentonite grout and sand-cement grout), concrete, high-solids bentonite grout (granular or powder mixtures) with a minimum of 15% solids by weight, high-solids bentonite chips, high-solids bentonite pellets, and sand-bentonite grout. See Table 1 for mixing ratios.

In the course of drilling a new well, the well may be abandoned using drill cuttings from the well being drilled if the well does not penetrate an aquifer, and no vadose zone contamination issues exist.

The vadose zone portion of these types of wells may be filled with any of the mixtures or materials described above or allowed in Alternative 1. High-solids bentonite chips and high-solids bentonite pellets must be hydrated to manufacturer's specifications if used in the vadose zone. The materials or mixtures are recommended to exceed the casing volume by approximately 30 percent.

Materials or mixtures must be emplaced under sufficient pressure to fill all voids, including all annular space(s), and displace water from the well. A tremie pipe must be used to emplace the grout from the bottom up. The end of the tremie pipe shall remain in close proximity to the rising grout surface as the grout is pumped into the well.

Alternative 4 (Variance Option)

A variance option is available to abandon wells that are 8 inches or greater in diameter and that fall under Alternative 4 aquifer conditions. Alternative 4 (Variance Option) allows the use of clean fine sand to fill the well.

Please note that anyone wishing to use this alternative abandonment method must first apply to ADWR for a variance from the well abandonment rule.

Alternative 5 – *Applies to wells that penetrate single or multiple aquifers with vertical flow components, and no water quality contamination issues exist.*

If the well penetrates a single or multiple aquifer system with vertical flow components, and if water quality contamination issues do not exist, the well must be sealed to prevent the vertical migration of fluids with cement grout (including neat cement grout, cement-bentonite grout and sand-cement grout), high-solids bentonite grout (granular or powder mixtures) with a minimum of 15% solids by weight, high-solids bentonite chips or high-solids bentonite pellets of sufficient volume, density, and viscosity to prevent fluid communication between aquifers. See Table 1 for mixing ratios.

The vadose zone portion of this type of well may be filled with any of the mixtures or materials described above or allowed in Alternative 1. High-solids bentonite chips and high-solids bentonite pellets must be hydrated to manufacturer's specifications if used in the vadose zone. The materials or mixtures are recommended to exceed the casing volume by approximately 30 percent.

Materials or mixtures must be emplaced under sufficient pressure to fill all voids, including all annular space(s), and displace water from the well. A tremie pipe must be used to emplace the grout from the bottom up. The end of the tremie pipe shall remain in close proximity to the rising grout surface as the grout is pumped into the well.

If the casing is not removed, it is recommended, but not required, that the condition of the casing perforations be determined by running a video log. If the video log demonstrates that the existing perforations are sufficiently open for grout to enter the annular space between the casing and the well bore, no additional perforations or casing treatments are necessary. If the video log demonstrates that the existing perforations are not sufficiently open for grout to enter the annular space outside the casing, additional perforations and/or casing treatments such as mechanical brushing, scraping or sonic cleaning are recommended, unless it is determined that disturbance of the casing and/or gravel packed zones would negatively influence the sealing of the well. A well requiring additional perforations should be perforated a minimum of two cuts per foot and sealed by pressure grouting.

Alternative 5 (Variance Option 1)

Alternative 5 (Variance Option 1) is available to abandon wells that are 8 inches or greater in diameter and that fall under Alternative 5 aquifer conditions. Alternative 5 (Variance option 1) allows the use of alternating layers of 50 feet of clean, fine sand and 10 feet of one of the approved Alternative 5 materials or mixtures mentioned above.

Please note that anyone wishing to use this alternative abandonment method must first apply to ADWR for a variance from ADWR's well abandonment rule.

Alternative 5 (Variance Option 2)

Alternative 5 (Variance Option 2) is available to abandon wells that are 8 inches or greater in diameter and that fall under Alternative 5 aquifer conditions. Alternative 5 (Variance Option 2) allows the installation of seals at aquifer boundaries if boundaries exist and if hydrogeologic and stratigraphic information is available for the well at an acceptable level of confidence to determine the depth(s) of aquifer boundaries. Aquifer boundary seals must be composed of one of the approved Alternative 5 materials or mixtures mentioned above.

Aquifer boundary seals must extend at least 50 feet above and 50 feet below aquifer boundaries to provide a reasonable level of confidence that the boundaries will be sealed. The intervals of the well above and below the seals must be filled with clean, fine sand or one of the approved Alternative 5 materials or mixtures mentioned above.

Please note that anyone wishing to use this alternative abandonment method must first apply to ADWR for a variance from ADWR's well abandonment rule.

Table 1
Acceptable Well Abandonment Materials and Mixtures

Category	Specific Material	Mixing Ratio		Permeability (cm/sec)	Applicable Abandonment Methods	Special Considerations
		Solids	Water			
Cement, Sand, Concrete & Bentonite Mixtures [1]	Neat Cement **or** Neat Cement Grout	One 94 pound sack of cement	Not more than six (6) gallons water	10^{-5} To 10^{-7}	Standard Method and Alts. 1-5	Must be pumped with tremie pipe. Not for use in low pH environments.
	Concrete **or** Concrete Grout	Cement, sand and aggregate with no less than seven (7) 94 lb. sacks of cement per cubic yard of concrete	Not more than seven (7) gallons water per sack of cement	—	Alts. 1,2,4,5	Cannot be used under Alternative 2 if free-product contamination issues exist.
	Sand-Cement Grout	One part cement and no more than one part sand by volume	Not more than six (6) gallons water	$2x10^{-5}$ to $5x10^{-8}$	Alts. 1,2,4,5	Cannot be used under Alternative 2 if free-product contamination issues exist.
	Cement-Bentonite Grout	One sack of cement (94 lb.) & 3-5 lbs. bentonite	Not more than six and one-half (6.5) gallons water	10^{-5} to 10^{-11}	Standard Method and Alts. 1-5	Cannot be used under Alternative 2 if free-product contamination issues exist. Also cannot be used in vadose zone portion of an Alternative 3 well if free-product contamination issues exist.
	Sand-Bentonite Grout	Equal parts sand and bentonite by volume	Slightly more than one (1) gallon water per pound of sand	—	Alts. 1,2,4	May be difficult to pump; the sand may be dumped into place while the bentonite slurry is pumped via tremie pipe. Cannot be used under Alternative 2 if free-product contamination issues exist.
	Acid Resistant Cement (Pozzolanic Cement)	One sack of cement (94 lb.) and seventy-four (74) lbs. pozzolans (fly-ash, perlites, etc.) 2% to 6% of bentonite by weight is needed if perlites are used	Not more than ten (10) gallons of water per sack of cement	—	See special considerations	Typically used in areas where low pH groundwater is encountered. If perlites are used bentonite is needed to keep perlites from floating. Chemical admixtures and plastizers may be used to reduce viscosity.
Well Cuttings	Clean cuttings from the well being drilled and abandoned	NA	NA	—	Alts. 1,4	Only permissible for wells that do not penetrate aquifers or wells that only penetrate a single aquifer with no vertical flow components. No vadose zone and no water quality contamination issues may exist.
Forms of Bentonite [1,2]	High-Solids Bentonite Grout (powder or granular mixture) with a minimum 15% solids by weight Minimum grout density = 9.2 lbs./gallon	Fifty (50) lbs. dry bentonite powder (powder mixture) **or** One hundred fifty (150) lbs. granular bentonite & 1 qt. Polymer (granular mixture)	Thirty–four (34) gallons (powder mixture) **or** One hundred (100) gallons (granular mixture)	10^{-7} to 10^{-8}	Alts. 1-5	A minimum of 15% solids bentonite will be acceptable in most cases. However, a higher minimum of bentonite solids may be required in areas of high water quality contamination. Cannot be used under Alternative 2 if free-product contamination issues exist. Also cannot be used in vadose zone portion of an Alternative 3 well if free-product contamination issues exist. Granular mixtures generally require the addition of polymers.
	High-Solids Bentonite Grout (powder or granular mixture) with a minimum 25% solids by weight Minimum grout density = 10.0 lbs./gallon	Fifty (50) lbs. dry bentonite powder (powder mixture) **or** One hundred fifty (150) lbs. granular bentonite & 1 qt. Polymer (granular mixture)	Eighteen (18) gallons (powder mixture) **or** Fifty-four (54) gallons (granular mixture)	10^{-8} to 10^{-9}	Standard Method	Cannot be used if free-product contamination issues exist. Granular mixtures generally require the addition of polymers.
	High-Solids Bentonite Chips and Pellets	NA	NA	—	Alts. 1-5	Rate of pour should not exceed 50 lbs. / 5 minutes. Must be hydrated to manufacturer's specifications if used in vadose zone. Cannot be used under Alternative 2 if free-product contamination issues exist. Also cannot be used in vadose zone portion of an Alternative 3 well if free-product contamination issues exist.

Notes: 1) Additives will be considered on a case by case basis (i.e., fly ash, CaCl, etc.).
2) Manufacturer's specifications should be followed to achieve a minimum 15% and 25% solids mixtures–mixing ratios listed in this table are approximate.

References

1. Alsay-Pippin Corporation, 1980, Handbook of Industrial Drilling Procedures and Techniques, 40 pp.

2. American Water Works Association, 1998, AWWA Standard for Water Wells, ANSI/AWWA A100-97, 73 pp.

3. Arizona Department of Water Resources, 2001, Statutes and Rules Governing Minimum Well Construction Standards and the Licensing of Well Drillers, 32 pp.

4. American Society for Testing and Materials (ASTM) Standard D5299-92, 1993, Standard Guide for Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes, and Other Devices for Environmental Activities, ASTM 1993 Annual Book of Standards, vol. 04-08, p. 1318-1333.

5. Baroid Drilling Fluids, Inc., 1999, Industrial Drilling Products Brochures, Houston, Texas.

6. Burgin, M. J., et. al., 1988, Grouting and Plugging of Domestic Water Wells in Georgia, Department of Natural Resources, Circular #13, 14 pp.

7. Driscoll, F.G., 1986, *Groundwater and Wells*. 2nd edition, Johnson Filtration Systems, St. Paul, Minnesota.

8. Eversoll, D.A., Hay, D. L., and Tremblay, R. J, September 15, 1995, Guidelines for Decommissioning Water Wells, How to Plug Water Wells, Nebraska Department of Health, Misc. Publ #37, 22 pp.

9. Kurt, C.E. and Johnson, R.C., Jr., 1982, Permeability of Grout Seals Surrounding Thermoplastic Well Casing: Ground Water, Vol. 20, no. 4, p. 415 - 419.

10. Lamb, B. and T. Kinney, 1989, Decommissioning Wells - Techniques and Pitfalls *in* Proceedings of the Third National Outdoor Action Conference on Aquifer Restoration, Ground Water Monitoring and Geophysical Methods, National Water Well Association, Dublin, Ohio, p.217 - 228.

11. Lutenegger, A. J., and DeGroot, D. J., 994, Hydraulic Conductivity of Borehole Sealants *in* D.E. Daniel and S.J. Trautwein (eds.), Hydraulic Conductivity and Waste Contaminant Transport in Soils, ASTM STP 1142, Philadelphia, Pennsylvania, p. 439-460.

12. Michigan Department of Public Health, Michigan Water Well Grouting Manual, 1988, 83 pp.

13. Portland Cement Association, 1988. Design and Control of Concrete Mixtures. 205 pp.

14. Smith, S.A., 1994. Well and Borehole Sealing: Importance, Materials, Methods, and Recommendations for Decommissioning. EPA - 542/K94/005. Wisconsin Water Well Association. 69 pp.

15. U.S. Environmental Protection Agency, 1975, Manual of Water Well Construction Practices, EPA - 570/9-75-001. 156 pp.

16. U.S. Environmental Protection Agency, March 1991, Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells, EPA- 600/4-89/034. 221 pp.

17. Wyo-Ben Inc., 1999, Groundwater & Mineral Exploration Products Brochure. Billings, Montana.

APPENDIX A – A.A.C. R12-15-816, The ADWR Well Abandonment Rule

R12-15-816. Abandonment

A. Well abandonment shall be performed only by a licensed well drilling contractor or single well licensee.

B. Except as provided in subsection (F) of this Section, the owner of a well shall file a notice of intent to abandon the well prior to abandonment, on a form prescribed and furnished by the Director, which shall include:

1. The name and mailing address of the person filing the notice.

2. The legal description of the land upon which the proposed well to be abandoned is located and the name and mailing address of the owner of the land.

3. The legal description of the location of the well on the land.

4. The depth, diameter and type of casing of the well.

5. The well registration number.

6. The materials and methods to be used to abandon the well.

7. When abandonment is to begin.

8. The name and well drilling license of the well drilling contractor or single well licensee who is to abandon the well.

9. The reason for abandonment.

10. Such other information as the Director may require.

C. The Director shall, upon receipt of a proper notice of intent to abandon, mail a well abandonment authorization card to the designated well drilling contractor or single well licensee.

D. Except as described in subsection (F) of this section, a well drilling contractor or a single well licensee may commence abandoning a well only if the driller has possession of an abandonment card at the well site, issued by the Director in the name of the driller, authorizing the abandonment of that specific well or wells in that specific location.

E. Within 30 days after a well is abandoned pursuant to this Section, the well drilling contractor or single well licensee shall file with the Director a Well Abandonment Completion Report on a form prescribed and furnished by the Director which shall include the date the abandonment of the well was completed and such other information as the Director may require.

F. In the course of drilling a new well, the well may be abandoned without first filing a notice of intent to abandon and without an abandonment card. If the well is abandoned pursuant to this subsection without first filing a notice of intent to abandon and without an abandonment card, the well drilling contractor or single well licensee shall provide the following information in the Well Abandonment Completion Report:

1. The legal description of the land upon which the well was abandoned and the name and the mailing address of the owner of the land.

2. The legal description of the location of the well on the land.

3. The depth, diameter and type of casing prior to abandonment.

4. The well registration number.

5. The materials and methods used to abandon the well.

6. The name and well drilling license number of the well drilling contractor or single well licensee who abandoned the well.

7. The date of completion of the abandonment of the well.

8. The reason for abandonment.

9. Such other information as the Director may require.

G. The abandonment of a well shall be accomplished through filing or sealing the well so as to prevent the well, including the annular space outside the casing, from being a channel allowing the vertical movement of water.

H. A well not penetrating an aquifer shall include a surface seal which shall be accomplished as follows:

1. If the casing is removed from the top 20 feet of the well, a cement grout plug shall be set extending from two feet below the land surface to a minimum of twenty feet below the land surface, and the well shall be backfilled above the top of the cement grout plug to the original land surface.

2. If the casing is not removed from the top ten feet of the well, a cement grout plug shall be set extending from the top of the casing to a minimum of twenty feet below the land surface, and the annular space outside the casing shall be filled with cement from the land surface to a minimum of twenty feet below the land surface.

I. In addition to the surface seal required in subsection (H):

1. A well penetrating a single aquifer system shall be filled with cement grout, concrete, bentonite drilling muds, clean sand with bentonite, or cuttings from the well.

2. A well penetrating a single or multiple aquifer system with vertical flow components shall be sealed with cement grout or a column of bentonite drilling mud of sufficient volume, density, and viscosity to prevent fluid communication between aquifers.

J. Materials containing organic or toxic matter shall not be used in the abandonment of a well.

K. The owner or operator of the well shall notify the Director in writing no later than 30 days after abandonment has been completed. The notification shall include the well owner's name, the location of the well, and the method of abandonment.

APPENDIX B – Definitions

For the purposes of this Handbook, the following terms have the following meanings:

Acid Resistant Cement (also known as Pozzolanic cement) (generic mixture): means a cement mixture that has improved resistance to corrosive fluids. Acid resistant cement is developed by adding silicious materials, pozzolans, to Portland cement. Pozzolans from both natural materials of volcanic origin such as perlites (volcanic ashes), heat treated clays, shales, tuffs, opaline cherts and diatomaceous earth, and artificial materials consisting of by-products from glass factories, furnace slag, and fly ash may be used. A common mixing ratio is 74 pounds of pozzolans per 94 pound sack of cement and not more than ten (10) gallons of water per sack of cement. If perlites are used, 2 to 6 percent of bentonite by weight is needed to keep the perlite from floating. Acid resistant cement is typically recommended for well abandonment material in areas where low pH groundwater is encountered (such as near some mine sites).

Aggregate (generic mixture): means sand or gravel with particle size up to ¼ inch.

Annular Space: "means the space between the outer well casing and the borehole wall. An annular space also means the space between an inner well casing and an outer well casing." **A.A.C. R12-15-801(1)**

Aquifer: "means an underground formation capable of yielding or transmitting usable quantities of water." **A.A.C. R12-15-801(2)**

Aquifer Boundary: means a vertical change in aquifer properties indicated by a difference in hydraulic conductivity between aquifer layers that is at least greater than two orders of magnitude (100 times greater).

Bentonite "means a colloidal clay composed mainly of sodium montmorillonite, a hydrated aluminum silicate." **A.A.C. R12-15-801(5)**

Cement Grout or Grout: "means cement mixed with no more than 50 percent sand by volume, and containing no more than six gallons of water per 94 pound sack of cement." **A.A.C. R12-15-801(15)**

Cement grout is sometimes referred to as "sand-cement grout", when sand is in the mixture.

Grout is often used as a synonym for slurry which is a generic term that means a thin mixture of liquid, commonly water, and any of several finely divided substances such as cement or clay particles.

Cement-Bentonite Grout (generic mixture): means a mixture of cement, bentonite and water at a ratio of 6.5 gallons of water per each 94 pound sack of cement with not more than 3 to 5 pounds of bentonite per sack of cement.

Concrete or Concrete Grout (generic mixture): means a mixture of cement, sand, coarse aggregate and water, with not less than seven (7) 94 pound sacks of cement per cubic yard of mixture and not more than seven (7) gallons of water per sack of cement.

Exploration Well: "means a well drilled in search of geophysical, mineralogical, or geotechnical data". **A.A.C. R12-15-801(13)**

Free-Product Contamination: means any known hazardous substance that is essentially immiscible (non-soluble) in water. Some typical examples of free-product contamination are gasoline and carbon tetrachloride.

Hazardous Substance: has the same meaning prescribed by A.R.S. § 49-201.

High-Solids Bentonite Grout (granular or powder mixture) with a minimum of 15% solids by weight: means a mixture of granular bentonite or powder bentonite that yields a grout that has a minimum 15% bentonite solids by weight.

High-solids bentonite grout with a minimum of 15% solids by weight can be prepared from a mixture of granular bentonite (nominal 8 to 20-mesh particle size), water and polymer at a ratio of one hundred-fifty (150) pounds of granular bentonite and one hundred (100) gallons of water premixed with one (1) quart of polymer.

High-solids bentonite grout with a minimum of 15% solids by weight can also be prepared from a mixture of bentonite powder (nominal 200-mesh particle size) and water at a ratio of fifty (50) pounds of dry bentonite powder and thirty-four (34) gallons of water.

High-Solids Bentonite Grout (granular or powder mixture) with a minimum of 25% solids by weight: means a mixture of granular bentonite or powder bentonite that yields a grout that has a minimum 25% bentonite solids by weight.

High-solids bentonite grout with a minimum of 25% solids by weight can be prepared from a mixture of granular bentonite (nominal 8 to 20-mesh particle size), water and polymer at a ratio of one hundred-fifty (150) pounds of granular bentonite and fifty-four (54) gallons of water premixed with one (1) quart of polymer.

High-solids bentonite grout with a minimum of 25% solids by weight can also be prepared from a mixture of bentonite powder (nominal 200-mesh particle size) and water at a ratio of fifty (50) pounds of dry bentonite powder and eighteen (18) gallons of water.

High-Solids Bentonite Chips: means chips of coarse bentonite ranging in size from 0.25 to 0.75 inch.

High-Solids Bentonite Pellets: means pellets of fine compressed bentonite (200-mesh) ranging in size from 0.25 to 0.50 inch.

Neat Cement or Neat Cement Grout (generic mixture): means a mixture of one (1) 94 pound sack of cement with not more than six (6) gallons of clean water.

Pressure Grouting "means a process by which a grout is confined within the borehole or casing of a well by the use of retaining plugs, packers, or a displacing fluid by which sufficient pressure is applied to drive the grout into and within the annular space or interval to be grouted." **A.A.C. R12-15-801(23)**

Sand-Bentonite Grout (generic mixture): means a mixture of equal parts sand and bentonite by volume with slightly more than one (1) gallon of water per pound of sand.

Sand-Cement Grout (generic mixture): means a mixture of one 94 pound sack of Portland cement, sand and water in the proportion of not more than one (1) part by volume of sand to one (1) part of cement with not more than six (6) gallons of water per 94 pound sack of cement.

Sealing: means the conscious effort to construct a positive permanent barrier within a well that restricts or prohibits the vertical movement of groundwater and/or any other fluids or materials.

Vadose Zone Well "means a well constructed in the interval between the land surface and the top of the static water level. **A.A.C. R12-15-801(26)**

Vadose Zone Contamination Issue: means any hazardous substance that is found in the vadose zone at or in the vicinity of the well at concentrations that exceed established state or federal standards.

Water Quality Contamination Issue: means any known hazardous substance that is found in groundwater at or in the vicinity of the well at concentrations that exceed established state or federal standards.

Well: means any man-made opening in the earth through which water may be withdrawn or obtained from beneath the surface of the earth including: 1) all water wells, monitor wells and piezometer wells; 2) geothermal wells for which the rules of the Arizona Oil and Gas Commission do not require the reinjection of all water associated with the geothermal resource to the producing strata; and 3) all exploration wells and grounding or cathodic protection holes, except those that are less than 100 feet in depth and do not encounter groundwater.

The question and answer section of this Handbook contains additional information concerning the types of wells that are subject to ADWR's well abandonment rule.

Well Abandonment "means the modification of the structure of a well by filling or sealing the borehole so that water may not be withdrawn or obtained from the well." **A.A.C. R12-15-801(28)**

APPENDIX C – Questions and Answers about the Abandonment Handbook

Why was it necessary to provide a separate well abandonment Handbook when there is an existing well abandonment rule?

ADWR has become aware of some misunderstanding among well owners and well drillers concerning the requirements of the well abandonment rule, A.C.C. R12-15-816. This Handbook is intended to provide guidance to well owners and well drillers on what is required by the rule.

In addition, this Handbook describes the procedures and materials that should be used to abandon wells not detailed in the rule. The well abandonment rule requires a person abandoning a well to fill or seal the well in order to prevent the well, including the annular space outside the casing, from being a channel allowing the vertical movement of water. Any well owner or well driller who abandons a well in compliance with this Handbook will be deemed to be in compliance with this requirement.

Q. ***What types of wells are subject to ADWR's well abandonment rule?***

A. The well abandonment rule applies to man-made openings in the earth through which water may be withdrawn or obtained from beneath the surface of the earth, including all water wells, monitor wells and piezometer wells.

The well abandonment rule also applies to geothermal wells for which the rules and regulations of the Arizona Oil and Gas Commission do not require the reinjection of all waters associated with the geothermal resource to the producing strata, as well as exploration wells and grounding or cathodic protection holes greater than 100 feet in depth (regardless of whether they intercept groundwater).

Q. ***What types of openings in the earth are not subject to ADWR's well abandonment rule?***

A. The well abandonment rule does not apply to:

1. man-made openings in the earth not commonly considered to be wells, such as construction and mining blast holes, underground mines and mine shafts, open pit mines, tunnels, septic tank systems, caissons, basements, and natural gas storage cavities;

2. an injection well or vadose zone well that is subject to regulation by the Arizona Department of Environmental Quality (ADEQ), provided that ADEQ has issued a letter or other document asserting explicit regulatory authority over the well;

3. oil, gas, and helium wells drilled pursuant to the provisions of Title 27, Arizona Revised Statutes (wells regulated by the Arizona Oil and Gas Commission); and

4. boreholes in the earth less than 100 feet in depth which are made for purposes other than withdrawing or encountering groundwater (such as exploration wells and grounding or cathodic protection holes less than 100 feet in depth), except that if groundwater is encountered in the drilling of the borehole, the well abandonment rule will apply.

Although the well abandonment rule does not apply to these types of wells and boreholes, it is nevertheless recommended that unused wells or

boreholes that are not regulated under ADWR's well abandonment rule be abandoned in a manner that will protect the aquifer.

Q. ***What is the benefit of abandoning an unused well, as opposed to capping the well (which is also allowed under ADWR's rules)?***

A. Proper well abandonment is favored over well capping for both environmental and safety reasons.

Unused and unabandoned wells constitute actual or potential environmental hazards because they can serve as vertical conduits for hazardous substances to cross-contaminate aquifers. For example, during the last several decades, serious and costly vertical cross-contamination of a multiple aquifer system has occurred through unabandoned conduit wells at the Indian Bend Wash Superfund site in Scottsdale, Arizona. Owners of unused, unabandoned wells should also realize that they may be held legally responsible for secondary contamination if it is demonstrated that their well served as a conduit for vertical cross-contamination of an aquifer system.

Public safety issues also favor well abandonment over well capping. Capped wells are often tampered with, and once the well cap is removed there is a real danger for humans or animals to fall into the well, or for the well to be used for the illegal disposal of hazardous materials.

Q. ***Why is it <u>generally required</u> to run a video log to determine the condition of the casing perforations in areas where water quality contamination exists if the casing is not ripped?***

A. Because significant conduit flow can occur through the annular space outside the casing, it is essential to seal this pathway to prevent potential vertical cross-contamination. Therefore, when water quality contamination issues exist, unless the well casing is removed or the casing is re-perforated over its entire length from 20 feet above the highest historic water level to the total depth of the well, the well owner must run a video log to determine whether the grout material can flow through the casing perforations and seal the annular space outside the casing.

Video logging and/or casing re-perforation may not be required in the case of the abandonment of recently constructed monitor wells. However, that determination must be made on a case-by-case basis.

In areas where water quality contamination issues do not exist, if the casing is not ripped, a video log is <u>recommended</u>, although not required, to determine perforation conditions. It is important to make sure that the well and the annular space outside the casing are properly abandoned even when there are no current water quality contamination issues. This is because the water could become contaminated in the future.

It should also be pointed out that additional benefits can be derived from running a video log. Those benefits may include: the determination of the structural integrity of the well casing, the presence of casing anomalies and obstructions, the presence of perched or cascading water, etc. This information can be very important in developing an effective abandonment design.

Q. ***Under what circumstances is it permissible to use drill cuttings to abandon a well?***

A. In the course of drilling a new well, the well may be abandoned using drill cuttings from the well being drilled only if the well does not penetrate an aquifer or the well penetrates a single aquifer only, with no vertical flow components. Drill cuttings may only be used to abandon the well from which they were originally removed. Drill cuttings may not be used to abandon wells or boreholes that have water quality and/or vadose zone contamination issues.

Q. ***How can it be determined whether vertical flow components exist in an aquifer or aquifer system?***

A. The determination of vertical flow conditions in an aquifer can be a challenging task. However, vertical flow conditions can be assessed by evaluating water level data collected in piezometers or monitor wells that are completed at different depths within an aquifer or aquifer system at the same location. Vertical fluid movement can also be evaluated in non-pumping wells using various geophysical logging techniques such as flowmeter logging, spinner logging or tracer logging. The observation of cascading water or water seeping into a non-pumping well below static level is a clear indication of vertical flow conditions within the well.

Because unit-specific water level data are typically unavailable, and geophysical logging may be impractical or too costly, it is best to assume that most aquifers or aquifer systems have some component of vertical flow, and well abandonment methods and materials should be chosen accordingly.

Q. ***What should I do if I have further questions concerning a well abandonment project?***

A. Contact ADWR Hydrology Division at:

602-771-8500
(Phoenix metro area)

1-800-352-8488
(outside metro Phoenix)

HYDROLOGY DIVISION

ADWR

ARIZONA DEPARTMENT OF WATER RESOURCES

SECURING ARIZONA'S WATER FUTURE

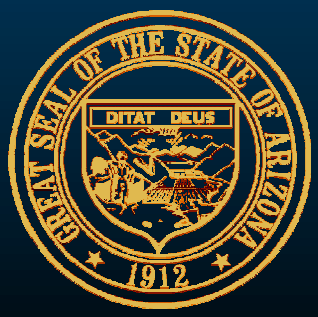
ADWR
ARIZONA DEPARTMENT OF WATER RESOURCES

3550 N CENTRAL AVENUE, SUITE 200
PHOENIX, ARIZONA
85012-2105

PHONE: 602-771-8500
1-800-352-8488

FAX: 602-771-8691

WEBSITE: http://www.azwater.gov



Arizona Department of Water Resources
Water Management Division
P.O. Box 36020 • Phoenix, AZ 85067-6020
(602) 771-8500 • (620) 771-8614 fax
· www.azwater.gov ·

Well Owner's Notification of Abandonment

NO FEE

- Review the instructions prior to completing the form in black or blue ink.
- The owner or operator of any well shall notify the Department, in writing, no later than 30 days after the abandonment has been completed. (A.R.S. § 45-594, A.A.C. R12-15-816(K))

FILE NUMBER
WELL REGISTRATION NUMBER
55 -

** PLEASE PRINT CLEARLY **

SECTION 1. DRILLING FIRM

NAME	
DWR LICENSE NUMBER	
TELEPHONE NUMBER	FAX
DATE ABANDONMENT COMPLETED	

SECTION 2. LOCATION OF WELL

WELL LOCATION ADDRESS (IF ANY)					
TOWNSHIP (N/S)	RANGE (E/W)	SECTION	160 ACRE ¼	40 ACRE ¼	10 ACRE ¼
COUNTY ASSESSOR'S PARCEL ID NUMBER					
BOOK	MAP	PARCEL			
COUNTY WHERE WELL IS LOCATED					

SECTION 3. OWNER INFORMATION

Well Owner		**Landowner** (if different from Well Owner)	
FULL NAME OF COMPANY, ORGANIZATION, OR INDIVIDUAL		FULL NAME OF COMPANY, GOVERNMENT AGENCY, OR INDIVIDUAL	
MAILING ADDRESS		MAILING ADDRESS	
CITY / STATE / ZIP CODE		CITY / STATE / ZIP CODE	
CONTACT PERSON NAME AND TITLE		CONTACT PERSON NAME AND TITLE	
TELEPHONE NUMBER	FAX	TELEPHONE NUMBER	FAX

I state that this notice is filed in compliance with A.R.S. § 45-594 and A.A.C. R12-15-816 and is complete and correct to the best of my knowledge and belief.

SIGNATURE OF WELL OWNER	DATE