SECTION A.II. WELL CONSTRUCTION DETAILS
40 CFR 146.82(a)(9), (12), and 40 CFR 146.86

MONTEZUMA NORCAL CARBON SEQUESTRATION HUB

Facility Information

Facility name:	Montezuma NorCal Carbon Sequestration Hub IW-A1
Facility contact:	Jim Levine, Managing Partner 2000 Powell Street, Suite 920 Emeryville, CA 94608 Phone: (510) 409-1765 Email: jim.levine@upstream.us.com
Well location:	Collinsville, Solano County, California Lat: 38º5’7.334” N Long: -121º51’30.914” W NAVD 88 Sec 22 T 3 N R 1 E

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List of Acronyms and Abbreviations

API = American Petroleum Institute	MC = Montezuma Carbon, LLC
BTU/(hr ft °F) = British Thermal Units per (hour foot degree Fahrenheit)	PISC = Post-Injection Site Care
CO_2 = carbon dioxide	ppmv = parts per million by volume
CR = Chrome	psi = pounds per square inch
ft = feet	psig = pounds per square inch, gauged
ft MSL = feet below mean sea level	TBD = to be determined
lbs = pounds (weight)	UIC = Underground Injection Control
Lbs = pounds (force)	US EPA = United States Environmental Protection Agency
lb/ft = pounds per foot	USDW = Underground Source of Drinking Water

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A.II.1 SUMMARY

Montezuma Carbon, LLC (MC) will utilize the following wells to meet the requirements of the United States Environmental Protection Agency (US EPA) Underground Injection Control (UIC) Class VI rule:

IW-A1: IW-A1 is designed and will be drilled, tested, and completed as a carbon dioxide (CO_2) injection well under a Class VI permit issued to MC by the US EPA. This well is to collect and obtain the necessary field data to support a US EPA UIC Class VI permit application. Following the Injection period, the plan is for IW-A1 to be re-completed as a Class VI injection zone monitoring well during the Post-Injection Site Care (PISC) period.

IZMW-A1 (proposed): This well is designed as a monitoring well that penetrates the confining zone with injection zone perforations to allow the ability to directly monitor the CO_2 plume and pressure front. The well is designed to the standards of 40 CFR 146.86 even though this regulation does not strictly apply to a monitoring well. MC may drill and initially complete this well as a stratigraphic test well within the next year to collect some additional and relevant subsurface information.

A.II.2 PROPOSED CONSTRUCTION OF IW-A1

IW-A1 was designed and will be drilled, tested, and completed as a CO_2 injection well under a Class VI permit issued to MC by the US EPA. The plan is for IW-A1 to be completed as a Class VI injection well for the Injection period, and later re-completed as a Class VI injection zone monitoring well during the PISC period. Additional basic information about IW-A1 is provided in Table A.II-1.

TABLE A.II-1. BASIC INFORMATION FOR IW-A1

Parameter	Value
Well Name	IW-A1
Operator	Montezuma Carbon, LLC
API Number	*TBD*
Location	Near Collinsville, Solano County, CA
GPS Coordinates (NAVD 88)	Lat: 38°5'7.334" N Long: 121°51'30.914" W
Section, Township, Range	SEC 22, T 3 N, R 1 E

API = American Petroleum Institute

A.II.2.1 PROPOSED STIMULATION PROGRAM [40 CFR 146.82(A)(9)]

No stimulation program is proposed for IW-A1 at this time since the target injection formation is already highly permeable. If MC later determines that stimulation techniques are needed, a stimulation plan will be developed and submitted for review and approval by the Program Director prior to plan implementation. Such a plan will conform to the requirements of 40 CFR 146.82(a)(9) by providing a description of stimulation fluids to be used and a determination that stimulation will not interfere with containment.

A.II.2.2 PROPOSED CONSTRUCTION PROCEDURES [40 CFR 146.82(A)(12)]

The proposed construction procedures for IW-A1 service as a completion as a Class VI injection well are described in the following sections of this document. The planned re-completion of this well as a Class VI monitoring well are be described in the PISC portion of this Class VI application.

A.II.2.2.1 DESIGN, DRILLING, CASING AND CEMENTING OF IW-A1 AS A CO_2 INJECTION WELL

IW-A1 is designed and will be constructed to conform to the general requirements of 40 CFR 146.86(a) and the casing and cementing requirements of 40 CFR 146.86(b) to allow its future used by MC for CO_2 injection and/or future monitoring services in accordance with the US EPA UIC Class VI rule.

The anticipated initial conditions for the top of the Anderson Sandstone are as follows: reservoir temperature at 96.46^{o}C (205.6^{o}F), reservoir pressure at 33.82 MPa (4,906 psi); and salinity at 16,658 ppm, and fluid density at 987.27 kg/m^3 (61.6lbs/ft^3).

Table A.II-2 provides information on the proposed open hole diameters and depth intervals for IW-A1.
Table A.II-3 provides the planned casing specifications for IW-A1.

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TABLE A.II-2. OPEN HOLE DIAMETERS AND INTERVALS FOR IW-A1

Name	Depth Interval (feet)	Open Hole Diameter (inches)	Comment
Surface	0 – 3,500	17 1/2	1,550 below USDW
Intermediate	0 – 7,900	12 1/4	Nortonville
Long	0 – 13,000	8 3/4	To Total Depth

USDW = Underground Source of Drinking Water

TABLE A.II-3. CASING SPECIFICATIONS FOR IW-A1

String	Depth Interval [ft]	Outside Diameter [inches]	Inside Diameter [inches]	Weight [lb/ft]	Grade [API]	Coupling	Thermal Conductivity [BTU/(hr ft °F)]	Burst Rating [psig]	Collapse Resistance [psig]
Conductor	0 - 80	20	19.124	94	H-40	STC	31	1530	520
Surface	0 – 3,500	13 3/8	12.415	68	J-55	STC	31	5020	2260
Intermediate	0 – 7,850	9 5/8	8.681	47	N-80	Long	31	6870	4760
Production (Upper)	0 – 7,850	5 1/ 2	4.670	23	N-80	Long	31	9880	11160
Production (Lower)	7,850 – 13,000	5 1/ 2	4.670	23	13CR-80	Vam	9.1	10560	11160

13 Chrome (CR) -80

ft = feet

lb/ft = pounds per foot

BTU/(hr ft °F) = British Thermal Units per (hour foot degree Fahrenheit)

psig = pounds per square inch, gauged

The casing strings for IW-A1 will be subject to different stresses during the different phases of construction, operation, and closure. To estimate the maximum axial loading on the casing strings, it is conservatively assumed that the casing strings are "hanging in air" with no buoyant force exerted by the drilling fluids, formation fluids, or cement in the borehole. For any other condition, the stresses on the component will be less. Nevertheless, this unrealistic condition is used here for a worst possible case condition. The resulting equation is given by:

Max Tension Load = Weight of Casing (lb/ft) * Depth of Casing (ft)

The maximum axial (tension) loading calculations for the five different casing strings at IW-A1 are provided below:

- Max Tension Load$_{conductor}$ = 94 lb/ft *80 ft. = 7,520 lbs
- Max Tension Load$_{surface}$ = 48 lb/ft * 3,500 ft. = 168,000 lbs
- Max Tension Load$_{Intermed}$ = 43.5 lb/ft * 7,850 ft. = 341,475 lbs
- Max Tension Load$_{Prod-Top}$ = 23 lb/ft *7,850 ft. = 180,550 lbs
- Max Tension Load$_{Prod-low}$ = 23 lb/ft *5,150 ft. = 115,450 lbs

lbs = pounds (weight)

These casing specific tension loading estimates are substantially less than the joint strength and yield strength for these respective casings, as presented in Table A.II-4 below.

TABLE A.II-4. CASING JOINT AND YIELD STRENGTH FOR IW-A1

Casing	Weight [lb/ft]	Grade [API]	Coupling	Joint Strength (lbs)	Yield Strength (lbs)
Conductor	94	H-40	STC	581,000	1,077,000
Surface	54.5	J-55	STC	514,000	853,000
Intermediate	43.5	N-80	LTC	905,000	1,086,000
Production-Top	23	N-80	LTC	530,000	502,000
Production-Low	23	13CR-80	VAM	530,000	95,000 (psi)

Lbs = pounds (force)
psi = pounds per square inch

CO_2 is an acid gas that forms carbonic acid when mixed with water. There is potential risk of accelerated corrosion of metal casing should it contact formation fluids or annulus fluid containing CO_2 and water. The conductor casing will be constructed from H-40 steel, which is standard for this service, and it has sufficient internal yield and external collapse ratings to prevent failures. There is no need for special CO_2 corrosion resistant metals since the conductor casing is not expected to contact CO_2/water mixtures. The surface casing will be constructed from J-55 steel, which is standard for this service, and it has sufficient internal yield and external collapse ratings to prevent failures. In addition, the joint yield strength is sufficient to prevent the surface casing from failing during operations. There is no need for special CO_2 corrosion resistant metals since the surface casing is not expected to contact CO_2/water mixtures. The intermediate casing will be constructed from N-80 steel, which is standard for this service, and it has sufficient internal yield and external collapse ratings to prevent failures. In addition, the joint yield strength is sufficient to prevent the surface casing from failing during operations. There is no need for special CO_2 corrosion resistant metals since the surface casing is not expected to contact CO_2/water mixtures. The upper portion of the production (Production-Top) casing, which will be isolated from the CO_2 stream with a packer, will be constructed from N-80 steel with internal yield, external collapse, joint yield strength, and body yield strength to prevent failure during operations. The lower portion of the production (Production-Low) string casing will be constructed from 13CR-80 steel with internal yield, external collapse, joint yield strength, and body yield strength to prevent failure during operations. 13CR-80 was selected to provide corrosion resistance to CO_2/water mixtures, based upon its history of successful use in similar service for other Class VI wells.

Likewise, there is potential risk for carbonic acid attack of the cement should it contact formation fluids containing CO_2 and water. The conductor casing will be cemented in place with approximately 228 sacks (sx) of cement. There is no need to use a CO_2 resistant formulation since the cement for the conductor casing is not expected to contact CO_2/water mixtures. The surface casing will be cemented in place using Class G cement. The cement will be pumped as a lead and tail slurry with an estimated 2,536 sacks of cement including 20% excess. The cement on the surface string provides a secondary barrier to protect the base of the USDW; it should not come in contact with CO_2/water mixtures and thus the cement formulation does not require CO_2 resistance. The intermediate casing will be cemented in place using Class G cement. The cement will be pumped as a lead and tail slurry with an estimated 2,581 sacks of cement including 20% excess. The cement on the intermediate casing string provides yet another barrier of protection for the USDW; it should not come in contact with CO_2/water mixtures and thus the cement formulation does not require CO_2 resistance.

The production string casing will be cemented in place in two stages. The upper portion of the production casing will not come in contact with CO_2/water mixture and will be cemented in place using an estimated 2,030 sacks (20% excess) of Class G cement. The lower portion of the production string casing will utilize an estimated 1,400 sacks (20% excess) of CO_2 resistant cement to prevent deterioration from contact with

CO_2/water mixtures. Both of these primary cementing stages for the production casing will be pumped as a lead and tail slurry.

The completion and cementing of the injection well casing as described above will provide at least three layers of cement and two steel casing strings to protect the lowermost USDW, the Tehama Formation, within this portion of Solano County, California. Therefore, the USDW will be isolated from the proposed CO_2 injection activities, horizontally by the fluid-filled annulus, multiple steel well casings and cement layers and vertically by thousands of feet and numerous confining layers.

Following completion of the cement job for the production string casing, the casing for IW-A1 is planned to be perforated at depths prescribed by the various open and cased hole logs in the Anderson sandstone between the depths of roughly 11,300 to 12,600 feet below mean sea level (ft MSL), and subsequently, some of these intervals may be acidized with a volume and composition of acid to be determined by reservoir conditions.

A.II.2.2.2 COMPLETION OF IW-A1 AS AN INJECTION WELL

Completion of IW-A1 as an injection well requires the design and installation of tubing, a packer, a wellhead, safety devices, an annulus fluid management system, and various additional testing and monitoring equipment. Section A.7.1 of the Application Narrative provides the quantity, flow rate, and pressure design basis for sizing these internals. Addition design basis information for sizing the internals includes an internal pressure of the tubing equal to the injection pressure, an external pressure of the tubing or internal pressure on the casing of 100 psig at the surface, and external pressure on the casing of less than 8,400 psi. Assuming the annular fluid and the injected supercritical CO_2 both have densities of 1 gram per cc, and 30,000 lb is placed on the packer, the axial load of the vertical tubing string will be roughly 135,000 lb. Expected chemical composition of the CO_2 stream is described in Section A.7.2 of the Application Narrative. Estimated values for current design purposes for the CO_2 stream include supercritical CO_2 composed of 100% CO_2, at 10^oC and roughly 2,000 psi at the surface. As CO_2 source data becomes available, these estimates may change.

Engineering design for the associated with the CO_2 pipeline transportation, compression, and dehydration systems are ongoing and under development. Similarly, the also injection tubing design is ongoing, with current estimates in Table A.II-5. The design for subsurface safety valves and packer (e.g., material, specific depths) are also ongoing and will be incorporate to future versions of Table A.II-5.

It is expected that the CO_2 stream will be dehydrated, nonetheless the stream is still potentially corrosive to metals used in the internals that come into direct contact with the stream. The US EPA Class VI Well Construction Guidance document discourages the use of carbon steel as a material of construction for well components that come into direct contact with the CO_2 stream if the water content of the CO_2 is greater than 50 ppmv (EPA 2012). Selection of the materials of construction for the internals of IW-A1 in injection well service is ongoing and will be informed by completion of the aboveground equipment and well design.

TABLE A.II-5. INJECTION TUBING AND SUBSURFACE SAFETY VALVE SPECIFICATIONS FOR IW-A1

Name	Depth Interval [ft]	Outside Diameter [inches]	Inside Diameter [inches]	Weight [lb/ft]	Grade [API]	Coupling	Tensile Strength [lb]	Burst Strength [psi]	Collapse Strength [psi]
Injection Tubing	0 – 11,300	3 1/2	2.75	12.95	13CR-110	VAM TOP	365,570	20,630	17,450

The tubing will be constructed from 13CR-110 – a CO_2 corrosion resistant metal. The minimum collapse and burst pressures for the tubing string and the tensile strength provided in Table A.II-5 and are based on the current version of the injection well design.

The permanent down-hole equipment consists of a packer for landing the tubing constructed from CO_2 resistant materials and set in the production casing at a depth of approximately 11,300 ft MSL. The packer will have a back pressure valve to prevent back flow of fluids from the formation. Further, prior to landing the tubing in the permanent packer, design calculations will be made to ensure the tubing and packer element can withstand the forces created by cooling during the injection process.

Figure A.II-1 provides a well schematic. The anticipated site-specific stratigraphic column is also illustrated on this figure. See the Site Characterization attachment to the Application Narrative to tie lithology of the injection and confining zones to the specific locations within of the stratigraphic column and depth of the well casings. Figure A.II-1 illustrates the casing and the right side of the figure summarizes construction details for hole sizes, casing sizes, and depths.

See Section E.2 of the Testing and Monitoring Plan for additional discussion on the characteristics of the CO_2 stream.

Formation fluids will be characterized following Section D.2 of the Pre-Operational Testing Program.

Figure A.II-2 provides a schematic of the above ground equipment with continuous recording devices and automatic shutoff devices to monitor injection pressure; the rate, volume, mass, and temperature of the CO_2 stream; and the pressure of the annulus between the tubing and long string casing and annulus fluid volume.

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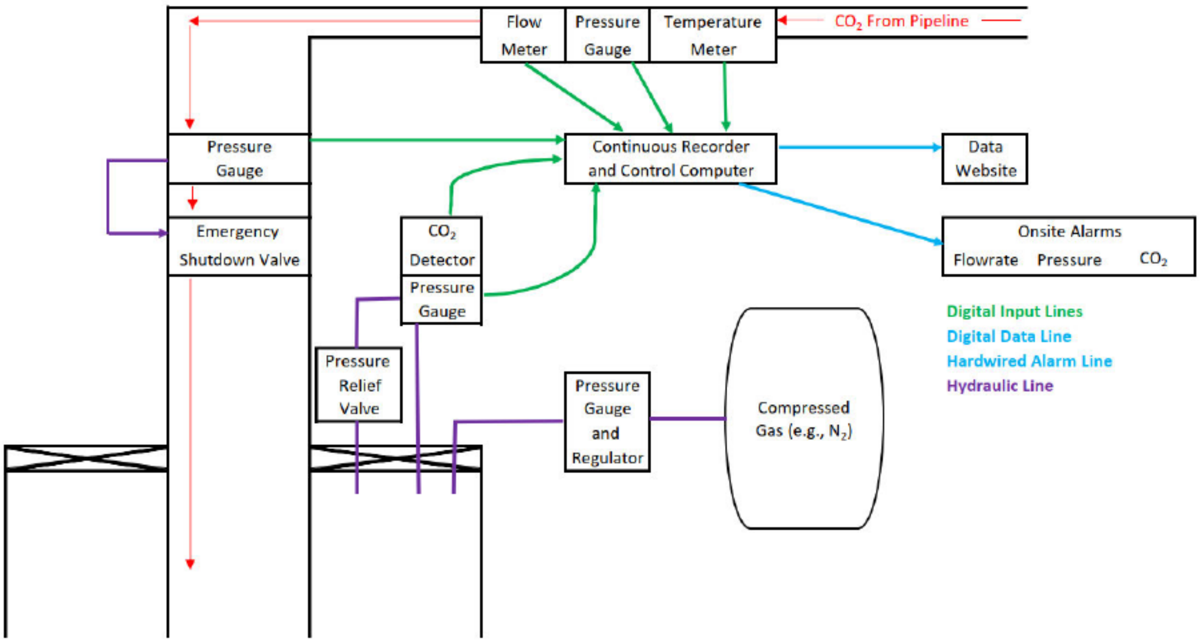
FIGURE A.II-1. SCHEMATIC OF IW-A1 IN INJECTION WELL SERVICE

FIGURE A.II-2 SCHEMATIC OF ABOVE GROUND EQUIPMENT CONTROLS FOR IW-A1



A.II.3 CONSTRUCTION OF IZMW-A1

The stratigraphic test well is planned to be completed as IZMW-A1. This well is designed as a monitoring well that penetrates the confining zone with injection zone perforations to provide the ability to directly monitor the CO_2 plume and pressure front. The well is designed to the standards of 40 CFR 146.86 even though this regulation does not strictly apply to a monitoring well. Basic information about IZMW-A1 is provided in Table A.II-7.

TABLE A.II-7. BASIC INFORMATION FOR IZMW-A1

Parameter	Value
Well Name	IZMW-A1
Operator	Montezuma Carbon, LLC
API	TBD
Location	Near Collinsville, Solano County, CA
GPS Coordinates (NAVD 88)	Lat: 38.083146 Long: -121.862816
Section, Township, Range	SEC 22, T 3 N, R 1 E

Figure A.II-3 provides a well schematic. The anticipated site-specific stratigraphic column and anticipated core sampling locations (as described in Section D.2 of the Pre-Operational Testing Program) are also illustrated on this figure.

A.II.3.1 CONSTRUCTION PROCEDURES

The proposed construction of IZMW-A1 follows the general design and construction as IW-A1. Corrosion resistant metals and cement will be utilized as in the construction of IW-A1. Additional detail on construction procedures for IZMW-A1 is TBD, pending completion of system design.

FIGURE A.II-3. DRAFT SCHEMATIC OF IZMW-A1

A.II.7 REFERENCES

EPA 2012, Geologic Sequestration of Carbon Dioxide: Underground Injection Control (UIC) Program Class VI Well Construction Guidance, EPA 816-R-11-020, May 2012. Available at: https://www.epa.gov/sites/default/files/2015-07/documents/epa816r11020.pdf.