



Oil & Gas, Environmental, Regulatory Compliance, and Training

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Re: Ohio Oil & Gas Well Construction (Casing and Cementing) Requirements

Per your request, I have reviewed the changes from Ohio Senate Bill 165 that were made last year to Ohio's Oil & Gas Law (Ohio Revised Code (O.R.C. 1509)); the existing Ohio Administrative Code (OAC), Chapter 1501:9, Division of Mineral Resources Management for Oil and Gas; and the example Ohio well permit stipulations you provided¹ to identify recommended changes to the OAC or well permit stipulations for well construction (casing and cementing).

This memo summarizes my initial recommendations to improve the OAC and well permit stipulations for well construction. Oil and gas well construction design includes many engineering, environmental and safety design elements. This memo addresses the primary design elements of properly casing and cementing a well. During my review, I noted other areas for improvement that are not covered in this memo. For instance, this memo does not address safety design requirements of wellhead control systems, blowout preventers, gas diverter systems or mud system design. Further, this memo does not include recommendations for surface facility design (e.g. pits, liners, tank systems, piping, and valve systems), nor does it address well stimulation issues, maintenance, repair, and ongoing monitoring requirements (e.g. corrosion, erosion, gas detection). Those topics could be the subject of additional memorandums in the future if Ohio is considering revisions to these aspects of their regulations or standard permit stipulations.

¹ Permit Conditions for Devonian Shale/Oriskany Sandstone Wells in Ashtabula and Lake Counties; Lake & Ashtabula Counties-North of Route 90 Permit Conditions for Fluid Rotary Rigs (Devonian Shale Wells); I. Lake Plain Region Permit Conditions for Air/Fluid Rotary Rigs (Oriskany or Deeper Wells); Permit Conditions for All Wells Drilled to the Trempealeau Dolomite; Permit Conditions Areas of Thin Glacial Till Overlying Fractured Bedrock Aquifers (Wells Drilled to the Knox Unconformity Play); Shallow Surface Casing Permit Conditions; Permit Conditions for All Wells Drilled Through the Knox Unconformity; Permit Conditions Oil and Gas Wells Drilled in A Municipal Wellhead Protection Areas (Wells Drilled to the Knox Unconformity Play); Permit Conditions Oil and Gas Wells Drilled in a Municipal Wellhead Protection Area (Wells Drilled no deeper than the Clinton Sandstone); Permit Conditions Oil and Gas Wells Drilled in the Lake Plain Region (Wells Drilled to the Utica or Deeper); and Hydrogen Sulfide Gas Permit Conditions.

1. Ohio Oil & Gas Law Changes to Well Construction

The Ohio Legislative Service Commission's June 2010 summary of the changes made to well construction law stated:

“The act requires a well to be constructed in a manner that is approved by the Chief as specified in the permit, using materials that comply with industry standards for the type and depth of the well and the anticipated fluid pressures that are associated with the well. In addition, a well must be constructed using sufficient steel or conductor casing in a manner that supports unconsolidated sediments, that protects and isolates all underground sources of drinking water as defined by the Safe Drinking Water Act, and that provides a base for a blowout preventer or other well control equipment that is necessary to control formation pressures and fluids during the drilling of the well and other operations to complete the well. An oil and gas reservoir must be isolated during well stimulation and during the productive life of the well using steel production casing with sufficient cement. In addition, sour gas zones and gas bearing zones that have sufficient pressure and volume to over-pressurize the surface production casing annulus resulting in annular overpressurization must be isolated using approved cementing, casing, and well construction practices. However, isolating an oil and gas reservoir cannot exclude open-hole completion. A well cannot be perforated for purposes of well stimulation in any zone that is located around casing that protects underground sources of drinking water without written authorization from the Chief as provided under the provisions discussed below. The act retains a provision of law that states that when the well penetrates the excavations of a mine, the casing must remain intact and be plugged and abandoned in accordance with the requirements of the Oil and Gas Law (R.C. 1509.17(A)) Rules.

The Chief may adopt rules in accordance with the Administrative Procedure Act, which are consistent with the standards for constructing a well discussed above, for evaluating the quality of well construction materials and for completing remedial cementing. In addition, the standards established in rules must consider local geology and various drilling conditions and must require the use of reasonable methods that are based on sound engineering principles (O.R.C. 1509.17(B)).”²

Therefore, the revised Ohio Oil & Gas Law only provides very general guidelines requiring wells to be constructed to unspecified industry standards and approved by the Ohio Chief, subject to rules and stipulations that may be added.

The revised Ohio Oil & Gas Law (O.R.C.) requires an operator to notify the state before cementing:

“An owner or an owner’s authorized representative must notify a mineral resources inspector each time that the owner or the authorized representative notifies a person to perform the cementing of the conductor casing, the surface casing, or the production casing. In addition, not later than 60 days after the completion of the cementing of the production casing, an owner must submit to the Chief a copy of the cement tickets for each cemented string of casing and a copy of all logs that were used to evaluate the quality of the cementing (O.R.C. 1509.17(C)).”³

² Ohio Legislative Service Commission, Final Analysis of Senate Bill 165, a summary of changes to Ohio’s Oil and Gas Law, June 30, 2010, p.38.

³ Ohio Legislative Service Commission, Final Analysis of Senate Bill 165, a summary of changes to Ohio’s Oil and Gas Law, June 30, 2010, p.38.

The O.R.C. allows the Chief to grant exemptions from well construction standards based on zonal isolation confirmed by a cement bond log:

“The Chief must grant an exemption from the standards for constructing a well if the Chief determines that a cement bond log confirms zonal isolation and there is a minimum of 500 feet between the uppermost perforation of the casing and the lowest depth of an underground source of drinking water (O.R.C. 1509.17(D)).”⁴

O.R.C. 1509.10 requires the operator to report information describing how the well was actually constructed within 60 days of completing the well (e.g. casing sizes, setting depths, drilling methods, cement volumes, etc.), but the law only requires reporting, and does not set specific construction standards for any of these well construction components.

Overall, the O.R.C. provides very general, limited guidance on oil and gas well construction, deferring more specific standard setting to Ohio rulemaking and well-specific permit stipulations.

In summary, Ohio’s Revised Code (O.R.C.) requires:

- **Casing.** Wells must be cased in a manner that supports unconsolidated sediments, protects and isolates drinking water sources, provides an anchor for the blowout preventer, isolates sour gas and over-pressure zones, and withstands well stimulation treatment pressures.
- **Open-hole.** Wells must be cased down to the hydrocarbon interval, but may be left open-hole across the hydrocarbon interval.
- **Surface Casing Perforation.** Perforation of surface casing is generally prohibited, but the Chief may approve exemptions if there a 500’ separation from the perforations to the base of the drinking water zone, and if proof of a cement bond log showing zonal isolation is provided.
- **Defective Casing or Construction.** Wells must either be immediately repaired or plugged and abandoned if defective casing or construction is discovered.

2. Ohio Administrative Code (OAC) Existing Well Construction Standards

The Ohio Administrative Code (OAC), Chapter 1501:9, sets forth the existing well construction regulations for oil and gas wells at:

- Chapter 1501:9-1 Oil Well Drilling; and
- Chapter 1501:9-9 Safety Regulations.

Lack of Gas Well Construction Standards. Chapter 1501:9-1 Oil Well Drilling defines the term “gas” but the term does not appear to apply specifically to gas wells because the title of the chapter is limited to “oil well drilling.” There is no equivalent chapter for gas wells; therefore, there appears to be a major gap in well construction standards because there are no gas well standards in Chapter 1501:9. Potentially, Ohio has used the oil well drilling standards for both oil and gas wells, but this is unclear.

Recommendation No. 1: Expand the OAC to include requirements for gas well construction.

⁴ Ohio Legislative Service Commission, Final Analysis of Senate Bill 165, a summary of changes to Ohio’s Oil and Gas Law, June 30, 2010, p.39.

Permit Required. Chapter 1501:9-1-02 requires an operator to obtain an approved oil well permit prior to drilling the well; however, the application only requires the applicant to submit information regarding the well name, location, and waste plan. No information is required on the well construction design (casing and cementing program). Ohio requires casing and cementing information to be submitted 60 days after the well is drilled and completed. It is difficult to repair or replaced a flawed design or implementation after the well is drilled and completed.

Due to the importance of properly installing casing and cementing to protect groundwater, casing and cementing plans should be submitted to Ohio as part of the well permit application. That way, Ohio can review, approve, and provide informed technical guidance to the operator in advance. Too often, regulators get involved at the end of the process, when the casing has been run and the cement job has failed. Efficient and economic corrections are difficult to achieve at this stage. Advance review and approval is appropriate.

Based on the example permit stipulations you provided me for Ohio, it appears that Ohio applies a wide variety of well construction permit stipulations based on location and formation type. However, based on the very cursory well application information submitted to Ohio at this time, it is not clear how an Ohio regulator could know whether or not the standard stipulations are appropriate for the proposed well plan. There is insufficient information in the application to know what the operator has proposed for a casing and cementing program.

It is recommended that Ohio require more information in the well permit application. The plan should include the anticipated depth and thickness of groundwater resources, confining barriers, and producing formations; expected pressures; wellbore diameter; casing type, depth, diameter, thickness and pressure rating; cement type, volume and additive plan; number and location of centralizers; cement integrity evaluation and testing program; blowout control system and safety plan.

The plan should, at a minimum, achieve safe operating conditions for the total measured depth proposed; confine fluids to the wellbore; prevent migration of hydrocarbons from one stratum to another; ensure control of well pressures encountered; prevent contamination of freshwater; and provide well control considering all factors relevant to well control including formation fracture gradients, formation pressures, casing setting depths and proposed total depth.

An as-built wellbore diagram should be prepared post well construction to accurately document the wellbore construction. This information will be critical to engineers for operation, workover, repair, stimulation and abandonment design.

Recommendation No. 2: Expand the OAC permit application process to:

- a. Require the permit operator to prepare and submit a casing and cementing plan for review and approval as part of the well permit application.
- b. Require Ohio to review and approve a complete well drilling and completion plan application, including a casing and cementing plan, as part of the well permitting process. This application will ensure that O.R.C. well construction objectives are met and will allow Ohio the opportunity to place appropriate permit stipulations in the permit.

Casing Types and Function. Casing is metal pipe that is installed in oil and gas wells to serve many structural and safety functions, it:

- Maintains wellbore structural integrity (so the hole does not cave in);
- Isolates water zones from oil and gas production zones;
- Contains well pressure during drilling, oil and gas production, and remedial well work (e.g. fractures, stimulations);
- Isolates formations that contain different pressures;
- Provides the structure and location to install blowout preventers, wellhead equipment, and hanging production tubing; and
- Serves an important environmental protection function by preventing aquifer contamination and containing well blowouts or leaks that could result in oil spills or gas venting.

Multiple sections of casing are attached to create longer pipe sections (commonly referred to as a “casing string,” or a “string of pipe”).

A typical well is constructed by installing conductor casing, surface casing, intermediate casing, and production casing, in that order. All wells include conductor, surface, and production casing. Intermediate casing may be installed depending on local conditions (e.g. to isolate a gas or water zone), future well utility, or stimulation treatment methods.

The conductor casing is the largest diameter, followed by the other types of casing, decreasing in size. Each successive casing type must fit inside the one previously installed (telescoping construction).

Conductor casing, surface casing, and intermediate casing (if used) are run from the surface of the well to its design depth. Production casing may be set from the surface of the well or may be hung off the bottom of the deepest casing string above it. Thus, a wellbore may have at least one, and maybe up to three, sets of casing covering a freshwater aquifer for protection.

The casing programs must be designed to meet the well conditions and formation depths anticipated. General guidelines and standards can be set in regulation for casing size, depth, cement, and testing, but the specific details of a casing program must be engineered to address local conditions and safety hazards. Thus, it is important for the operator to have a qualified petroleum engineer design a casing and cementing program for the unique conditions of each well that is drilled, and that design must be submitted for review and approval prior to drilling a well.

Recommendation No. 3: Expand OAC to require a qualified petroleum engineer to design the casing and cementing program to meet the unique conditions of each well drilled. The well design should be submitted and approved by Ohio, prior to drilling and completing the well.

Casing Quality. Chapter 1501:9 does not establish any casing quality requirements. Operators should be required to install new conductor, surface, and intermediate casing (if used). Operators should only be allowed to install recycled production casing if the casing is tested and meets quality standards required for production casing. It is strongly recommended that no recycled casing be allowed for surface casing or intermediate casing when the casing’s primary function is to protect groundwater. New casing should be used in these cases.

As part of the permit application, operators should be required to specify whether the casing is new or recycled. If the casing is recycled, the date, condition, and location of prior use, and its prior service

history, should be recorded along with an engineering assessment that the casing is in suitable condition for the well construction design planned.

As part of the permit application, operators should be required to provide information on the casing size, grade, and manufacturer specifications, including the casing's burst pressure rating, collapse resistance and tensile strength. To design a reliable casing string, you must know the strength of the pipe under different load conditions.⁵ All casing strings should be designed to withstand anticipated collapse, bursting, bending, buckling, corrosion, erosion and all other stresses expected during the entire lifetime of the well and shall have sufficient tensile strength.

All well construction materials should be design and installed to withstand the effects of corrosion and erosion, including use of coated piping, higher grade pipe, or thicker walled pipe with a higher corrosion allowance. A monitoring plan for corrosion and erosion should be developed and implemented.

Well monitoring should be completed on routine intervals to ensure production tubing, packers, and casing are remain in good condition and repair or replacement is completed when needed. Good operating and maintenance practices include replacing a failed packer, patching failed casing, or adding an additional string of casing inside the failed casing string.

Recommendation No. 4: Expand OAC to require operators to submit casing quality information:

- a. To show that the type and grade of casing proposed for the well meets the O.R.C. environmental protection and safety objectives;
- b. To verify that new casing will be used for conductor, surface, and intermediate casing, including information about the casing manufacturer;
- c. To provide the date, condition, location of prior use, and prior service history for any recycled casing that may be planned for the production interval, along with an engineering assessment that the casing is in suitable condition for the well construction design planned; and
- d. To provide the casing size, grade, and manufacturer specifications, with an engineering assessment that the selected casing is appropriate for the well temperature, pressure, formations, fluids, and conditions that may be encountered.

Conductor Casing. Chapter 1501:9 does not establish any conductor casing requirements. The conductor casing hole should be drilled⁶ using air, freshwater, or water-based mud. Oil-based mud, synthetic muds or other chemical lubricants should be prohibited to prevent contamination of surface or shallow groundwater.

The conductor casing should be made of new steel and should be cemented from top to bottom and firmly affixed in a central location in the wellbore with a continuous, equally thick layer of cement in the annulus around the pipe.

A cement seal, or other impermeable seal, should be installed at the surface to prevent surface water or fluids from contaminating the groundwater. This seal will prevent downward migration of surface pollutants that could originate from wellhead leaks or other remedial/operational activities at the wellhead area.

⁵ Petroleum Engineering Handbook, Volume II, Drilling Engineering, Society of Petroleum Engineers, 2006.

⁶ Alternatively, if surface geology allows, conductor casing can be driven by mechanical percussion methods into unconsolidated strata. In this case, there is no annulus, and the casing is not cemented. Also in this case, a mechanical or cement seal needs to be installed at the surface to prevent the downward migration of surface pollutants.

Conductor casing should be set to a sufficient depth to provide a solid structural anchor for a gas diverter system. Shallow gas is vented through a gas diverter system until the surface casing is set, and a BOP is installed.

Typically, the conductor casing setting depth is limited to 100' or less. The actual casing depth should be based on regional engineering and geologic data.

Recommendation No. 5: Expand OAC to require operators to design conductor casing to be:

- a. Set in a hole that is drilled using air, freshwater, or water-based mud;
- b. Made of new steel;
- c. Cemented from top to bottom and firmly affixed in a central location in the wellbore with a continuous, equally thick layer of cement in the annulus around the pipe;
- d. Installed with a cement seal, or other impermeable seal, at the surface to prevent surface water or fluids from contaminating the groundwater; and
- e. Set to a sufficient depth to provide a solid structural anchor for a gas diverter system, based on regional engineering and geologic data.

Surface Casing. Chapter 1501:9 does not establish any surface casing requirements. Surface casing is the second casing set in the wellbore. Surface casing is set to protect ground water aquifers, provide the structure to support blowout prevention equipment, and provide a conduit for drilling fluids while drilling the next section of the well. This section of the well can be hundreds to thousands of feet deep, depending on the well design and geologic formations. The drilling engineer will determine the depth of the surface casing with a two key factors in mind: (1) the surface casing should stop above any significant pressure zone or hydrocarbon zone to ensure the blowout preventer can be installed prior to drilling into these zones; and (2) the surface casing needs to be set to provide a protective barrier that prevents hydrocarbons from contaminating drinking water aquifers when the well is drilled deeper (below the surface casing) into hydrocarbon bearing zones.

Surface casing size is a site-specific, well-specific function and can vary. The surface casing pipe is set into the earthen hole and the annulus is filled with cement. It is important that the casing is centered in the hole so that an equal, continuous section of cement filling is placed from the bottom to the top of the annulus. Casing centralizers are installed on the outside of the pipe to keep it centered in the hole while cement is pumped into the annulus, setting the pipe in place. In high angle holes, casing centralizers are very important because the heavy casing pipe will lie on the low side of the hole unless casing centralizers are used to force the pipe into the center of the hole. Casing in a horizontal well that is not properly centralized will have little or no cement where the pipe is close to or comes in contact with the earth wall.

After the cement is allowed to harden, it must be integrity tested (e.g. hardness, continuity, and proper seal). There is no blowout preventer (BOP) equipment in place while the surface hole is drilled and the surface casing is installed because, until the surface casing is installed and cemented in place, there is insufficient casing or cement in the ground to anchor the BOP equipment. If shallow gas is encountered while drilling, the surface casing is vented to atmosphere through a diverter valve.

Once the surface casing is cemented in place, the blowout preventer is installed at the surface and is attached to the surface casing. The surface casing serves as a solid anchor in the ground, holding the blowout preventer in place in the event high pressures are encountered as the well is drilled deeper into hydrocarbon bearing zones.

The surface casing hole should be drilled using air, freshwater, or water-based mud. Oil-based mud, synthetic muds or use of other chemical lubricants should be prohibited to prevent contamination of surface or shallow groundwater.

Surface casing should be made of new steel and should be cemented from top to bottom and firmly affixed in a central location in the wellbore with a continuous, equally thick layer of cement in the annulus around the pipe.

Surface casing should be set to a sufficient depth to provide a solid structural anchor for the BOP. Surface casing should be new pipe, of sufficient quality, size, and pressure rating to allow the blowout preventer to contain any formation pressures that may be encountered when drilling deeper into hydrocarbon formations below the surface casing shoe.

The surface casing depth should be based on regional engineering and geologic data, but should be set at least 100' below the deepest freshwater zone and at least 100' into bedrock. Ohio's standard permit conditions only required surface casing to be set 50' below the deepest freshwater zone. The deeper the surface casing is set below the freshwater zone, the greater the freshwater protection. However, in areas where hydrocarbons occur at shallow depths, less than 100' from the base of the freshwater zone, the surface casing depth must be adjusted to ensure that the surface casing is set and cemented in place, and a BOP installed before drilling through the hydrocarbon zone. Therefore, where potential oil or gas zones are anticipated at depths within 100 feet below the deepest fresh groundwater, the operator should set and permanently cement surface casing prior to drilling into a stratum known to contain, or likely to contain, oil or gas.

Setting surface casing above the hydrocarbon zone will seal freshwater zones behind the surface casing and prevent hydrocarbon contamination of subsurface waters. This surface casing will also allow a BOP to be installed to control the well to prevent a well blowout that could result in surface water contamination.

Recommendation No. 6: Expand OAC to require operators to design surface casing to be:

- a. Set in a hole that is drilled using air, freshwater, or water-based mud;
- b. Made of new steel;
- c. Cemented from top to bottom and firmly affixed in a central location in the wellbore with a continuous, equally thick layer of cement in the annulus around the pipe;
- d. Set to a sufficient depth to protect ground water aquifers, provide the structure to support blowout prevention equipment, and provide a conduit for drilling fluids while drilling the next section of the well based on regional engineering and geologic data;
- e. Set to provide a protective barrier to prevent hydrocarbons from contaminating drinking water aquifers when the well is drilled deeper (below the surface casing) into hydrocarbon bearing zones;
- f. Set above any significant pressure zone or hydrocarbon zone;
- g. A solid anchor to attach the blowout preventer to prior to drilling into a deeper pressured zone or hydrocarbons;
- h. Of sufficient quality, size and pressure rating to allow the blowout preventer to contain any formation pressures that may be encountered when drilling deeper into hydrocarbon formations below the surface casing shoe; and
- i. Set at a depth based on regional engineering and geologic data, but at least 100' below the deepest freshwater zone and at least 100' into bedrock.

- j.** In areas where hydrocarbons occur at shallow depths, less than 100' from the base of the freshwater zone, the surface casing depth must be adjusted to ensure that the surface casing is set and cemented in place, and a BOP installed before drilling through the hydrocarbon zone.

Intermediate Casing. Chapter 1501:9 does not establish any intermediate casing requirements. Intermediate casing may be set if it is needed to provide a transition from the surface casing to the production casing. This casing may be required for protection of oil, gas, and freshwater zones, and to seal off anomalous pressure zones, lost circulation zones, and other drilling hazards. A drilling engineer may decide to set hundreds or thousands of feet of intermediate casing to isolate unstable hole sections (to prevent collapse), to isolate high or low pressure zones, or to isolate geologic “thief” zones that may be prone to robbing mud from the well bore (lost circulation). Intermediate casing is also used to put gas or saltwater zones behind pipe before drilling into the production zone, or to provide additional wellbore structure.

For example, if additional fresh groundwater is encountered when drilling below the first permanently cemented set of surface casing, an additional string of casing should be installed at least 100' below the additional fresh groundwater resources to completely isolate and protect fresh groundwater.

Recommendation No. 7: Expand OAC to require operators to require intermediate casing if:

- a.** Additional fresh groundwater is encountered when drilling below the first permanently cemented set of surface casing. In that case, an additional string of casing should be installed at least 100' below the additional fresh groundwater resources to completely isolate and protect fresh groundwater. Intermediate casing should be set at a depth based on regional engineering and geologic data, but at least 100' below the deepest freshwater zone and at least 100' into bedrock. However, in areas where hydrocarbons occur at shallow depths, less than 100' from the base of the freshwater zone, the intermediate casing depth must be adjusted to ensure that it is set and cemented in place before drilling through the hydrocarbon zone; and
- b.** It is needed to provide a transition from the surface casing to the production casing. Intermediate casing may be required for protection of oil, gas, and freshwater zones, and to seal off anomalous pressure zones, lost circulation zones, and other drilling hazards. If needed, the casing should be designed to isolate unstable hole sections (to prevent collapse), to isolate high or low pressure zones, or to isolate geologic “thief” zones that may be prone to robbing mud from the well bore (lost circulation). Intermediate casing is also used to put gas or saltwater zones behind pipe before drilling into the production zone, or to provide additional wellbore structure.

Intermediate casing will be smaller than the surface casing and will be lowered in the hole, and cemented in place.

Intermediate casing is typically set prior to drilling through the hydrocarbon bearing zone, and may be cemented behind the entire casing string from the top of the well to the bottom of the casing shoe if the intermediate casing depth is shallow enough. Intermediate casing provides a second protective barrier across a freshwater aquifer. However, it is not possible to cement the entire intermediate casing string if it is more than a few thousand feet deep. In this case, the intermediate casing strings are partially cemented in place to secure the lower section of the pipe in place. Then, intermediate casing should be cemented with sufficient cement to fill the annular space from the casing shoe to a minimum of 600 feet above all significant hydrocarbon zones and abnormally geo-pressured strata.

Recommendation No. 8: Expand OAC to require operators to design intermediate casing to be:

- a. Set in a hole that is drilled using air, freshwater, or water-based mud;
- b. Made of new steel;
- c. Set to provide a protective barrier to prevent hydrocarbons from contaminating drinking water aquifers when the well is drilled deeper (below the surface casing) into hydrocarbon bearing zones.
- d. Cemented behind the entire casing string from the top of the well to the bottom of the casing shoe if the intermediate casing depth is shallow enough. Casing should be cemented and firmly affixed in a central location in the wellbore with a continuous, equally thick layer of cement in the annulus around the pipe.
- e. If the casing string is more than a few thousand feet deep, it is not possible to cement the entire intermediate casing string. In that case, intermediate casing should be cemented with sufficient cement to fill the annular space from the casing shoe to a minimum of 600 feet above all significant hydrocarbon zones and abnormally geo-pressured strata; and
- f. Cemented and integrity tested before drilling deeper.

Production Casing. Chapter 1501:9 does not establish any production casing requirements. Production casing is the last string of casing set in the well. It is called “production casing” because it is typically set across the hydrocarbon producing zone, but alternatively could be set just above the production zone if the production zone is left as an open, uncased hole. Surface or intermediate casing should not be used as production casing.

If production casing is set across the hydrocarbon producing zone it is called a “cased hole” completion. In this scenario, production casing is lowered into the hole and cemented in place. Explosives are lowered inside the production casing (perforation guns) to perforate holes through the pipe/cement barrier to allow oil and/or gas to enter the wellbore. In some cases, a drilling engineer may elect not to set production casing. This is called an “open hole” completion. Ohio Oil & Gas Law allows for open-hole completions.

While open-hole completions are possible, typically, production casing is used to isolate hydrocarbon zones and contain formation pressure. Production casing pipe and cement integrity are very important because they are the piping/cement barrier that is exposed to fracture pressure, acid stimulation treatments, and other workover/stimulation methods used to increase hydrocarbon production.

Production casing size is a site-specific, well-specific function and can vary. However, regardless of the situation, the casing must be of sufficient strength to contain any expected formation or stimulation pressures. Production casing should be designed to withstand the effects of tension, and to prevent burst and collapse during its installation, cementing, and subsequent drilling and producing operations.

Production casing, preferably, should be new pipe. However, if recycled casing is considered in the well design, the production casing should be tested to verify that it meets quality standards required for production casing. As part of the permit application, operators should be required to specify whether the casing is new or recycled, and if recycled, the date, condition, and location of prior use and prior service history should be recorded, along with an engineering assessment that the casing is in suitable condition for the well construction design planned.

Production casing should be cemented by a pump-and-plug or displacement method. Enough cement should be used to circulate above the top of the completion zone to a height sufficient to prevent any movement of oil, gas or other fluids around the exterior of the production casing. More specifically,

production casing should be cemented with sufficient cement to fill the annular space from the casing shoe to a minimum of 600' above all significant hydrocarbon zones and abnormally geo-pressured strata.

If production casing is not run to the surface (a production liner is set) there should be at least 100' of overlap between the production liner and the next largest casing string, and the overlap should be tested with a fluid entry test to assure a competent seal. Production tubing and a packer system should be used to protect shallower casing strings from corrosion and erosion.

Production tubing and packers should be installed to provide a conduit for gas, gas liquids (condensate) and water to be produced to the surface, providing an additional protective barrier for the well casing that can more readily be replaced on a routine basis.

Recommendation No. 9: Expand OAC to require operators to design production casing to be:

- a. Made of new steel or pressure tested recycled steel of sufficient strength to contain any expected formation or stimulation pressures;
- b. Designed to withstand the effects of tension, and to prevent burst and collapse during its installation, cementing, and subsequent drilling and producing operations;
- c. Cemented by a pump-and-plug or displacement method with enough cement to circulate above the top of the completion zone to a height sufficient to prevent any movement of oil, gas, or other fluids around the exterior of the production casing; and
- d. Constructed with sufficient cement to fill the annular space from the casing shoe to a minimum of 600' above all significant hydrocarbon zones and abnormally geo-pressured strata.
- e. If production casing is not run to the surface (a production liner is set) there should be at least 100' of overlap between the production liner and the next largest casing string, and the overlap should be tested with a fluid entry test to assure a competent seal.
- f. Production tubing and packers should be installed to provide a conduit for gas, gas liquids (condensate) and water to be produced to the surface.

Cementing. Chapter 1501:9 does not establish any cementing requirements. Properly cementing casing in a wellbore is critical to protect freshwater zones and mitigate gas migration behind pipe. Proper cementing is also critical to seal off anomalous pressure zones, lost circulation zones, and other drilling hazards, and to isolate unstable hole sections and provide additional wellbore structure.

Casing is successfully cemented when a continuous, equally thick layer of cement is placed in the annulus around the pipe and the pipe is firmly affixed in a central location in the wellbore. Piping centralizers are necessary to center the casing in the hole and to ensure that a concentric cement ring is placed around the pipe, sealing the annular space between the earthen wellbore wall and the casing.

There are several important steps to achieving a successful cement job, including selecting the right type of cement for the wellbore conditions, selecting the correct type and number of casing centralizers, and calculating the correct amount of cement needed to fill the annulus plus at least 25% excess. Engineers must also design the cementing program to allow the cement to harden before disturbing the cement and test its integrity before drilling deeper.

Once the casing is set, there is still drilling fluid inside the casing and in the annular space between the casing and the earthen wellbore wall. Circulation should be established and the hole should be conditioned before the cement is pumped. All gas flows should be killed before cementing. Drilling mud

is displaced out of the hole by pumping cement down the inside of the casing and up the back side of the annulus. A flush, spacer or extra cement should be used to separate the cement from the bore hole fluids to prevent cement dilution. Cement must be mixed and pumped to manufacturer specifications or it will not set up properly in the annulus, and may not meet the desired pressure rating, or may have voids or channels that allow hydrocarbon movement in the annulus.

Casing should be rotated or reciprocated during mud conditioning and cementing, unless the well is very deep or directionally drilled and pipe rotation subjects the casing to unacceptable stresses

Poorly centralized casing will allow the cement to bypass the drilling fluid, following the path of least resistance (usually down the wide side of the annulus), leaving drilling fluid behind the casing on the narrow side of the annulus. If this happens, a section of the annulus is not properly cemented/sealed. Casing centralizers are installed on the outside of the pipe to keep it centered in the hole while cement is pumped into the annulus.

Centralizers serve many functions including: centering the casing; preventing drag while casing is run in the hole; minimizing differential sticking; aiding in mud displacement; and reducing mud channeling when cementing is underway. Centralizers need to be installed either on a casing collar or a mechanical stop collar. American Petroleum Institute (API) Specification 10D is the industry standard for proper selection, design, and placement of centralizers.

Centralizers should be placed at the base and at the top of the casing, and at least one additional centralizer should be placed every 120' of the cemented interval. In deviated holes, additional centralizers may be needed.

In high angle holes, casing centralizers are very important. The heavy casing pipe will lie on the low side of the hole unless casing centralizers are used to force the pipe into the center of the hole. In a deviated hole, gravity drops the casing pipe to the low side of the hole making cementing difficult under the low side of the pipe. Additional centralizers placed around the casing in a deviated wellbore help to centralize the pipe in the hole, allowing a concentric cement barrier to be pumped around the casing. Casing in a horizontal well that is not properly centralized will have little or no cement where the pipe is either close to or in contact with the earth wall.

Cement volume calculations must be based on accurate as-built casing depths and caliper data, and must be subject to Quality Assurance/Quality Control (QA/QC) by the drilling engineer assigned to the project before the cement is pumped. The correct volume of cement must be pre-mixed before cement pumping operations begin. Inadequate cement mixed, can result in void spaces in the annulus, creating a poor cement seal. A minimum of 25% excess cement volume should be made available to ensure there is sufficient cement mixed and ready to pump. The excess cement volume may be reduced to as low as 10% if a caliper tool is run in the hole to more accurately estimate the hole dimensions and more accurately compute cement needs.

Cement volume needs are computed by estimating the amount of void space in the annulus between the earthen wall and the outside of the casing. Drill bits create irregular earthen wall surfaces making the actual wellbore hole geometry a non-standard cylindrical shape. To more accurately estimate the volume of this space, a caliper tool is run to measure the actual volume of the earthen hole. Cement volumes are estimated prior to drilling the well, and should be recomputed based on the caliper log data and actual casing depths.

Cement grade is a critical determinate of cement bond and integrity. Reservoir temperature and pressure must be well documented or conservatively estimated to ensure the correct cement is selected. Laboratory cement testing must be completed to ensure that adequate compressive strength and bond objectives are reached.

The operator should select a cement formulation that will resist future degradation by the chemical and physical conditions that may be encountered in the wellbore over its service life. Cement should be selected to resist naturally occurring corrosive fluids and gases, as well as stimulation or enhanced recovery fluids/gases that may be used to enhance production.

Gas channeling through cement can occur during cement transition from a liquid to a solid. During cementing operations, the hydrostatic pressure must be greater than the pore pressure of the gas-bearing zone to prevent gas from percolating through the cement and creating void spaces that will allow gas to migrate through the cement after it is set. The ability of cement slurry to transmit its hydrostatic pressure is a function of its gel strength.⁷ Cement slurries must be designed and mixed to maintain a hydrostatic pressure greater than the pore pressure, but less than the fracture pressure of the gas bearing zone. As long as the hydrostatic pressure exceeds the pore pressure, gas will not invade the cement. Gas-blocking additives can be added to the cement formulation to optimize the cement grade for specific wellbore conditions.

The operator or cementing contractor should test the mixing water for pH and temperature prior to mixing the cement and record the results on the cementing ticket. The cement slurry should be prepared according to the manufacturer's or contractor's specifications to minimize free water content in the cement.

When published performance data are not available, the operator or service company should test the cement mixtures. Tests should be made on representative samples of the basic mixture of cement and additives used, using distilled water or potable tap water for preparing the slurry. The tests should be conducted using the equipment and procedures adopted by the American Petroleum Institute, as published in the current API RP 10B.

After the cement is placed and the cementing equipment is disconnected, the operator should wait until the cement achieves a calculated compressive strength before the casing is disturbed in any way. This period of time is called Waiting on Cement (WOC) time and should be recorded on a drilling log. The WOC time should be sufficiently long, as required by the cement testing, to ensure that the cement is properly set-up before disturbing it. WOC times will vary based on the type of cement used, the wellbore pressure, and temperature conditions. Cement hardness tests are required to ensure that the cement has been given enough time to set up before continuing to drill the next section of the hole that will disturb the cement.

When surface casing is cemented, sufficient cement should be pumped to ensure that the cement completely fills the annular space and circulates to the top of the hole. In the event that cement circulation is not achieved on any surface casing cement job, cement must be grouted (or squeezed) down from the surface to ensure a complete cement bond. In lieu of or in combination with such grouting or squeezing from the surface, it may be necessary to perforate the surface casing to perform a cement squeeze to seal off voids in the annulus.

A formation integrity test (FIT) must be performed before a BOP is installed on the surface casing. A formation integrity test is run at the casing shoe (the bottom of casing string) to determine whether the wellbore will tolerate the maximum wellbore pressure anticipated while drilling the next interval. If a FIT test fails, then a cement squeeze is typically required to improve the casing/cement structural integrity before drilling deeper into the well. The test must be performed to a predetermined equivalent mud weight, leak-off or fracture pressure. The test should be conducted after drilling out of the casing shoe into at least 20', but not more than 50', of new formation. The test results should demonstrate that the integrity of the casing shoe is sufficient to contain the anticipated wellbore pressures. Cement should not

⁷ The lower the gel strength, the higher the annular hydrostatic pressure transmissibility. Journal of Petroleum Technology, Prevention of Shallow Gas Migration Through Cement, August 1999.

be drilled out until sufficient compressive strength has been reached to obtain a valid formation integrity test.

Surface casing strings should be allowed to stand under pressure until the cement has reached a compressive strength of at least 500 psi in the zone of critical cement before drilling out the cement shoe or initiating a test. The cement mixture in the zone of critical cement should have a 72-hour compressive strength of at least 1,200 psi. In addition to the minimum compressive strength of the cement, the API free water separation should average no more than 6 milliliters per 250 milliliters of cement tested in accordance with the current API RP 10B.

If there is any evidence of flow behind the surface casing, no drilling out of and below surface casing should commence until remedial action has occurred.

A state inspector should be present when surface casing is set and cemented. The inspector should ensure that the casing setting depth is set at least 100' below the deepest freshwater zone, that surface casing cement is of good integrity, and that the QA/QC checks described in these recommendations are met. The inspector should require cement evaluation logs to be run in wells where the risk and consequences of poor cementing practices are unacceptable, for example surface casing cement used to protect freshwater zones. The inspector should require remedial cementing (if needed) before allowing the well to be drilled deeper.

If possible, intermediate casing should be cemented behind the entire section of pipe. If intermediate casing is too deep to cement all the way to the surface, cement should be placed in the annular space at least 600' above any hydrocarbon zone, lost circulation zone, freshwater zone or any abnormally pressured zone.

Production casing should be cemented with sufficient cement to fill the annular space from the casing shoe to a minimum of 600' above all significant hydrocarbon zones and abnormally geo-pressured strata.

If the production string does not extend to the surface, at least 100' of overlap between the production string and next larger casing string should be required. This overlap should be cemented and tested by a fluid-entry test to determine whether there is a competent seal between the two casing strings.

If any indications of improper cementing exist, such as lost returns, or if the formation integrity test shows an inadequate cement job, remedial cementing action must be taken. If cementing repairs are ineffective, additional casing strings may be required.

A written record should document the procedures and specifications of the cementing operation and the chemical composition of the cement for each cemented casing string. The record should include the amount and composition of the cement slurry, the amount of cement returned to the surface, if any, the amount and type of additives to the cement slurry mixture. Cementing operation information should include a description of the stages and sequence of events during the cementing operation, calculations employed, and wellbore and casing information such as casing diameter and depth and hole size and depth and pump time.

Recommendation No. 10: A cementing plan should be developed and submitted for approval and should include:

- a. Cement type, a list of additives, and estimated volume;
- b. An adequate number of centralizers;
- c. Cement spacers to separate the cement from the borehole fluids to prevent cement dilution;

- d.** A plan to pump cement by the pump-and-plug or displacement method;
- e.** Plans to rotate and reciprocate the casing while conditioning and cementing;
- f.** A procedure to condition the hole and kill gas flow before the cement is pumped to ensure good drilling mud displacement and an effective cement seal;
- g.** Plans to run a caliper tool to more accurately estimate the cement volume requirements;
- h.** Revised cement calculations based on actual casing setting depth, and caliper log data;
- i.** Justification for cement grade selection based on reservoir temperature, pressures, and chemical and physical conditions that may be encountered in the wellbore over its service life.
- j.** Instructions and QA/QC procedures to properly mix the cement to the manufacturer's or contractor's specifications, including testing the mixing water for pH and temperature and minimizing free water content in the cement;
- k.** Cement mixture published performance data or cement testing data. All tests should be conducted using the equipment and procedures adopted by the American Petroleum Institute, as published in the current API RP 10B;
- l.** Calculated WOC times that ensure the cement has been given enough time to set up before continuing to drill the next section of the hole to avoid disturbing the cement;
- m.** Instructions to ensure that sufficient surface casing cement is pumped to completely fill the annular space and circulate cement to the top of the hole;
- n.** Instructions to carry out a formation integrity test before a BOP is installed on the surface casing. Cement should not be drilled out until sufficient compressive strength has been reached to obtain a valid formation integrity test;
- o.** Instructions to allow surface casing to stand under pressure until the cement has reached a compressive strength of at least 500 psi in the zone of critical cement before drilling out the cement shoe or initiating a test. The cement mixture in the zone of critical cement should have a 72-hour compressive strength of at least 1,200 psi. In addition to the minimum compressive strength of the cement, the API free water separation should average no more than 6 milliliters per 250 milliliters of cement tested in accordance with the current API RP 10B;
- p.** Instructions that no drilling out of and below surface casing should commence if there is any evidence or indication of flow behind the surface casing until remedial action has occurred;
- q.** Plans to run cement evaluation logs in wells where the risk and consequences of poor cementing practices are unacceptable;
- r.** Instructions to cement intermediate casing behind the entire section of pipe. If intermediate casing is too deep to cement all the way to the surface, cement should be placed in the annular space at least 600' above any hydrocarbon zone, lost circulation zone, freshwater zone or any abnormally pressured zone;
- s.** Instructions to cement the production casing with sufficient cement to fill the annular space from the casing shoe to a minimum of 600' above all significant hydrocarbon zones and abnormally geo-pressured strata. If the production string does not extend to the surface, at least 100' of overlap between the production string and next larger casing string should be required. This overlap should be cemented and tested by a fluid-entry test to determine whether there is a competent seal between the two casing strings;
- t.** Instructions to take remedial action to repair the well if any indications of improper cementing exist such as lost returns, or if the formation integrity test shows an inadequate

cement job. If cementing repairs are ineffective, additional casing strings may be required; and,

- u. A state inspector should be present when surface casing is set and cemented. The inspector should ensure that the casing setting depth is set at least 100' below the deepest freshwater zone, and that surface casing cement is of good integrity. The inspector should ensure that the QA/QC checks described in these recommendations are met, and should require remedial cementing (if needed) before allowing the well to be drilled deeper.

3. Ohio Oil & Gas Well Standard Permit Conditions

I reviewed the Ohio Oil & Gas Well Standard Permit Conditions. An analysis of the existing standard conditions is provided below. In most cases, the standard permit conditions do not contain sufficient instruction on casing and cementing to ensure the well is constructed in a manner that is protective of the environment, structurally sound, and safe. The recommendations listed in Section 2 of this memo should be considered for improving Ohio's standard permit conditions, or they can be incorporated Ohio's regulations to apply across the board to simplify the permit conditions.

As described below, some permit conditions are more robust than others, but it is not clear why there is such a wide disparity in permit condition quality across Ohio.

Permit Conditions for Devonian Shale/Oriskany Sandstone Wells in Ashtabula and Lake Counties

- Conductor Casing:** No conditions.
- Surface Casing:** Drill a 10" to 12-1/4" diameter hole using a freshwater mud system.
Set 180' of surface casing.
Ensure borehole conditions are static prior to cementing.
Use gas-blocking cement.
Cement must achieve a 500 psi compressive strength.
Use centralizers and pump 100% excess cement to surface.
- Intermediate Casing:** No conditions.
- Production Casing:** Includes a requirement to set 4-1/2" casing and place cement 50' above the top of the Big Lime.

Analysis: These permit conditions include five good requirements: (1) use of a freshwater mud system while drilling the surface hole; (2) use of gas-blocking cement; (3) use of cement that achieves a 500 psi compressive strength; (4) use of centralizers on the surface casing and (5) a requirement to pump excess cement to surface. However, most of the other environmental protection standards described above in this memo are not included.

Hole diameter should be a function of the total well depth and the number of casing strings designed. While many wells in the area may use 7" surface casing and 4-1/2" production casing, the operator should be given the flexibility to select the appropriate casing size based on well depths and other engineering and safety design considerations. The requirement to set exactly 180' of surface casing may not be protective of freshwater resources unless the freshwater depth is consistently at a maximum depth of 80' across the entire Ashtabula and Lake County area. Surface casing should be set at least 100' below the deepest freshwater zone. Standard conditions should specify the offset depth (100'), not an exact pipe length, because it may not be appropriate in all cases.

The requirement to set a 4-1/2" casing and place cement 50' above the top of the Big Lime is likely insufficient cement placement around the top of the hydrocarbon section. More information would be needed to examine this situation because I am not familiar with the Big Lime geophysical characteristics and hydrocarbon potential, but if this is a hydrocarbon bearing zone, 600' of cement should be placed in the annular space above the most shallow hydrocarbon zone.

Lake & Ashtabula Counties-North of Route 90 Permit Conditions for Fluid Rotary Rigs (Devonian Shale Wells)

- Conductor Casing:** No conditions.
- Surface Casing:** Drill a 12-1/4" diameter hole using a freshwater mud system.
Set 200' of 8-5/8" surface casing.
Use gas-blocking cement.
Minimum WOC time of 8 hours.
Cement must achieve a 500 psi compressive strength.
Use centralizers and pump 100% excess cement to surface.
- Intermediate Casing:** No conditions.
- Production Casing:** No conditions.

Analysis: These permit conditions include five good requirements: (1) use of a freshwater mud system while drilling the surface hole, (2) use of gas-blocking cement; (3) use of cement that achieves a 500 psi compressive strength, (4) use of centralizers on the surface casing and (5) a requirement to pump excess cement to surface. However, most of the other environmental protection standards described above in this memo are not included.

Hole diameter should be function of the total well depth and the number of casing strings designed. While many wells in the area may use 8-5/8" surface casing, the operator should be given the flexibility to select the appropriate casing size based on well depths and other engineering and safety design considerations. The requirement to set exactly 200' of surface casing may not be protective of freshwater resources unless the freshwater depth is consistently at a maximum depth of 100' across the entire Ashtabula and Lake County areas north of Route 90. Surface casing should be set at least 100' below the deepest freshwater zone. Standard conditions should specify the offset depth (100'), not an exact pipe length, because it may not be appropriate in all cases.

I. Lake Plain Region Permit Conditions for Air/Fluid Rotary Rigs (Oriskany or Deeper Wells)

- Conductor Casing:** No conditions.
- Surface Casing:** Set 200' of 8-5/8" surface casing.
Ensure borehole conditions are static prior to cementing.
Cement must achieve a 500 psi compressive strength.
Use centralizers and pump 100% excess cement to surface.
- Intermediate Casing:** No conditions.
- Production Casing:** If gas is encountered in the Oriskany, the production string must be cemented 200' above the Oriskany.

Analysis: These permit conditions include three good requirements: (1) use of cement that achieves a 500 psi compressive strength, (2) use of centralizers on the surface casing and (3) a requirement to and pump excess cement to surface. However, most of the other environmental protection standards described above in this memo are not included.

Hole diameter should be function of the total well depth and the number of casing strings designed. While many wells in the area may use 8-5/8" surface casing, the operator should be given the flexibility to select the appropriate casing size based on well depths and other engineering and safety design considerations. The requirement to set exactly 200' of surface casing may not be protective of freshwater resources unless the freshwater depth is consistently at a maximum depth of 100' across the entire I. Lake Plain Region. Surface casing should be set at least 100' below the deepest freshwater zone. Standard conditions should specify the offset depth (100'), not an exact pipe length, because it may not be appropriate in all cases.

The requirement to place cement 200' above the top of the gas bearing Oriskany zone is likely insufficient. At least 600' of cement should be placed in the annular space above the most shallow hydrocarbon zone.

Permit Conditions for All Wells Drilled to the Trempealeau Dolomite

- Conductor Casing:** No conditions.

- Surface Casing:** Set 450' of surface casing.
Pump excess cement to surface.
- Intermediate Casing:** No conditions.
- Production Casing:** No conditions.

Analysis: These permit conditions do not contain sufficient instruction on casing and cementing. The environmental protection standards described above in this memo are not included.

The requirement to set exactly 450' of surface casing may not be protective of freshwater resources unless the freshwater depth is consistently a maximum depth of 350' across the entire region where wells are drilled into the Tempealeau Dolomite.

Permit Conditions for Areas of Thin Glacial Till Overlying Fractured Bedrock Aquifers (Wells Drilled to the Knox Unconformity Play); Shallow Surface Casing Permit Conditions

- Conductor Casing:** No conditions.
- Surface Casing:** Set surface casing 50' below the deepest drinking water formation or at least 10% of the total depth of the well.
Pump excess cement to surface.
- Intermediate Casing:** No conditions.
- Production Casing:** No conditions.

Analysis: These permit conditions do not contain sufficient instruction on casing and cementing. The environmental protection standards described above in this memo are not included. Surface casing should be set at least 100' below the deepest drinking water formation.

Permit Conditions for All Wells Drilled Through the Knox Unconformity

- Conductor Casing:** No conditions.
- Surface Casing:** Set surface casing 50' below the deepest drinking water formation or at least 10% of the total depth of the well.
Pump excess cement to surface.
- Intermediate Casing:** No conditions.
- Production Casing:** No conditions.

Analysis: These permit conditions do not contain sufficient instruction on casing and cementing. The environmental protection standards described above in this memo are not included. Surface casing should be set at least 100' below the deepest drinking water formation.

Permit Conditions for Oil and Gas Wells Drilled in Municipal Wellhead Protection Areas (Wells Drilled to the Knox Unconformity Play)

- Conductor Casing:** Drill conductor hole using a freshwater mud system.
Set a 11-3/4" diameter new conductor pipe at least 125' through the glacial drift.
Cementing must be circulated to surface using the pump and plug method, pumping at least 50% excess cement to surface.
Cement baskets are not allowed.
Cement must be within 5% of the API optimum density standard.
Cement records must be maintained.
Cement must achieve a 500 psi compressive strength.
- Surface Casing:** Drill conductor hole using a freshwater mud system.
Set a 8-5/8" diameter new surface casing to at least 550'.

Cementing must be circulated to surface using the pump-and-plug method, pumping at least 50% excess cement to surface.

Cement baskets are not allowed.

Cement must be within 5% of the API optimum density standard.

Cement records must be maintained.

Cement must achieve a 500 psi compressive strength.

Intermediate Casing: No conditions.

Production Casing: No conditions.

Analysis: These permit conditions include five good requirements: (1) use of a freshwater mud system while drilling the conductor and surface hole, (2) use of API cementing standards; (3) use of cement achieves a 500 psi compressive strength, (4) a requirement to pump excess cement to surface and (5) keep cementing records. However, most of the other environmental protection standards described above in this memo are not included.

Hole diameter should be function of the total well depth and the number of casing strings designed. While many wells in the area may use 11-3/4" conductor casing and 8-5/8" surface casing, the operator should be given the flexibility to select the appropriate casing size based on well depths and other engineering and safety design considerations. The requirement to set at least 550' of surface casing may not be protective of freshwater resources unless the freshwater depth is consistently at a maximum depth of 450' across the Knox Unconformity Play Area. Surface casing should be set at least 100' below the deepest freshwater zone. Standard conditions should specify the offset depth (100'), not an exact pipe length, because it may not be appropriate in all cases.

Permit Conditions for Oil and Gas Wells Drilled in a Municipal Wellhead Protection Area (Wells Drilled no deeper than the Clinton Sandstone)

Conductor Casing: Drill conductor hole using a freshwater mud system.
Set a 11-3/4" diameter new conductor pipe at least 60' through the glacial drift.
Cementing must be circulated to surface using the pump-and-plug method, pumping at least 50% excess cement to surface.
Cement baskets are not allowed.
Cement must be within 5% of the API optimum density standard.
Cement records must be maintained.
Cement must achieve a 500 psi compressive strength.

Surface Casing: Drill conductor hole using a freshwater mud system.
Set a 8-5/8" diameter new surface casing to at least 50' below the base of the Berea.
Cementing must be circulated to surface using the pump-and-plug method, pumping at least 50% excess cement to surface.
Cement baskets are not allowed.
Cement must be within 5% of the API optimum density standard.
Cement records must be maintained.
Cement must achieve a 500 psi compressive strength.

Intermediate Casing: No conditions.

Production Casing: No conditions.

Analysis: These permit conditions include five good requirements: (1) use of a freshwater mud system while drilling the conductor and surface hole, (2) use of API cementing standards; (3) use of cement that achieves a 500 psi compressive strength, and (4) a requirement to pump excess cement to surface and (5) keep cementing records. However, most of the other environmental protection standards described above in this memo are not included.

Hole diameter should be function of the total well depth and the number of casing strings designed. While many wells in the area may use 11-3/4" conductor casing and 8-5/8" surface casing, the operator should be given the flexibility to select the appropriate casing size based on well depths and other engineering and safety design considerations.

Permit Conditions for Oil and Gas Wells Drilled in the Lake Plain Region (Wells Drilled to the Utica or Deeper)

- Conductor Casing:** Requirement to drill the conductor hole⁸ with freshwater mud, and set a 11-3/4” diameter new conductor pipe at least 200’ into the Ohio Shale.
Cementing must be circulated to the surface using the pump-and-plug method, pumping at least 50% excess cement to surface.
Cement baskets are not allowed.
Cement must be within 5% of the API optimum density standard.
Gas-blocking cement is required.
Cement records must be maintained.
Cement must achieve a 500 psi compressive strength.
Inspector must be present during setting and cementing of the conductor casing.
- Surface Casing:** Requirement to drill the surface hole with freshwater mud, and set a 8-5/8” diameter new surface⁹ pipe at 850’ deep.
Cementing must be circulated to surface using the pump-and-plug method, pumping at least 50% excess cement to surface.
Cement baskets are not allowed.
Cement must be within 5% of the API optimum density standard.
Cement records must be maintained.
Cement must achieve a 500 psi compressive strength.
Centralizers must be installed.
Inspector must be present during setting and cementing of the surface casing.
- Intermediate Casing:** No conditions.
- Production Casing:** No conditions.

Analysis: These permit conditions include eight good requirements: (1) use of a freshwater mud system while drilling the conductor and surface hole, (2) use of API cementing standards; (3) use of cement that achieves a 500 psi compressive strength, (4) use of centralizers on the surface casing; (5) use of gas blocking cement; (5) a requirement to pump excess cement to the surface; (6) a requirement to have an inspector present during conductor and surface casing setting and cementing, (7) use of new piping for conductor and surface casing; and (8) a requirement to keep cementing records. These permit stipulations are the most comprehensive of the examples provided and reviewed for this memo. However, some of the other environmental protection standards described above in this memo are not included and should be considered.

Hole diameter should be function of the total well depth and the number of casing strings designed. While many wells in the area may use 11-3/4” conductor casing and 8-5/8” surface casing, the operator should be given the flexibility to select the appropriate casing size based on well depths and other engineering and safety design considerations. The 850’ surface setting depth should be checked to ensure that the casing shoe is set at least 100’ below the deepest freshwater interval.

Shallow Surface Casing Permit Conditions

- Conductor Casing:** Landed into bedrock.
Circulation must be established and the hole must be properly conditioned before the conductor casing is cemented.
Inspector must be present during setting and cementing of the conductor casing.
- Surface Casing:** Requirement to drill the surface hole with freshwater mud.
Set a 8-5/8” casing 50’ below the deepest drinking water formation.
Cementing must be circulated to surface.
Circulation must be established and the hole must be properly conditioned before the surface casing is cemented.
Inspector must be present during setting and cementing of the surface casing.

⁸ The permit stipulation calls this first casing string “surface casing,” but it should be called “conductor casing.”

⁹ The permit stipulation calls this second casing string “intermediate casing,” but it should be called “surface casing.”

If the annular pressure exceeds 70% of the hydrostatic pressure at the casing shoe of the surface casing string, remedial cementing is required.

Intermediate Casing: No conditions.

Production Casing: Cement must be placed at least 100' above the top of the Lockport formation before perforating, acidizing or stimulating the well.
A cement bond log must be run to verify the top of cement if there is a significant break in circulation during the cement job.
Annular pressure must be monitored for a period of five days after the longstring casing is cemented.

Analysis: These permit conditions include five good requirements: (1) use of a freshwater mud system while drilling the surface hole; (2) circulating and conditioning the hole prior to cementing; (3) requiring an inspector to be present during the conductor and surface casing setting and cementing; (4) pressure testing; and (5) a cement bond log. However, most of the other environmental protection standards described above in this memo are not included.

Hole diameter should be function of the total well depth and the number of casing strings designed. While many wells in the area may use 8-5/8" surface casing, the operator should be given the flexibility to select the appropriate casing size based on well depths and other engineering and safety design considerations. The 850' surface setting depth should be set at least 100' below the deepest freshwater interval.

The requirement to place cement 100' above the top of the Lockport formation is likely insufficient. At least 600' of cement should be placed in the annular space above the most shallow hydrocarbon zone.

Please contact me at (907) 694-7994 if you have any questions on these recommendations.

Sincerely,

Susan L. Harvey

Susan L. Harvey

Cc: Scott Anderson (EDF)
Joanne Spalding (Sierra Club)