Reducing the High Cost of an ASR Test Well

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Aquifer Storage and Recovery (ASR) is a viable technology used to store significant quantities of water from a variety of sources (e.g., groundwater, surface water or reuse water), to meet a wide range of water management needs. Once a municipality or other entity determines a need for underground storage, some general design questions must be answered to see if ASR is locally feasible.

The criteria for an ASR system could be summarized as:

- *What are the storage and recovery objectives?*
- *What is the injected water supply?*
- *What is the injected water chemistry?*
- *What is the native water chemistry?*
- *What is the storage zone reservoir geology?*
- *What are the storage zone hydraulic properties?*
- *Is there confinement above and below the storage zone?*

These questions are similar to the ones posed by the Environmental Protection Agency (EPA), which need to be addressed to determine ASR feasibility during the initial test-well drilling program.

During the Underground Injection Control (UIC) permitting process, the applicant provides a proposed construction and testing plan to the regulatory agency. The plan identifies specific hydrogeological, water quality, and well-construction data that will be collected during construction and includes safe guards to avoid any environmental impacts.

Once the UIC permit is issued, the requirements as outlined in the construction and testing plan are incorporated within the UIC permit and can not be changed easily. At this point, it is too late to attempt to optimize your ASR test-well drilling program to reduce cost without incurring lengthy time delays.

An optimum construction and testing plan must be developed prior to the submission of the UIC permit application. This requires a detailed understanding of regulatory requirements and concerns, the owner's specific objectives, and any site-related issues that could affect costs. Once these design objectives are understood, a minimal well design should be engineered to accommodate them.

UIC Rule 62-528 requires that lithologic information and groundwater quality data must be collected during the proposed drilling program. It also requires that a proposed methodology to test confining zones be included, along with a method of testing the proposed injection horizon, plans for deposition of drill cuttings and fluids, and a well cementing and abandonment plan.

It is not the regulatory agency's responsibility to optimize the proposed construction and testing program, included as part of the permit application, but only to ensure that the proposed plan meets regulatory requirements. If extra work is included over and above these requirements, it is generally accepted and included as part of the final permit requirements.

If there are issues or requirements that have not been included in the proposed construction and testing program, then the regulatory agency will include additional requirements under the *Specific Conditions* section of the permit or ask for a revision.

An ASR test well drilling program should not be considered a full-scale ASR system (ASR well and corresponding monitor wells), but rather an exploratory drilling project that focuses on the regulatory components to determine ASR feasibility—specifically, per Federal Code and Regulation 62-528 pertaining to:

- Groundwater Quality—Primarily total dissolve solid (TDS) concentration as it relates to drinking water standards 0 – 500 milligrams per liter (mg/L) and upper limit of the underground source of drinking water; considered those waters with TDS concentrations less than 10,000 mg/L.
- Confinement—Upper and lower confining potential.
- Hydraulic Properties—Transmissivity, storage coefficient, and production capacity.

If the initial exploratory test well proves these factors are favorable, a full-size ASR well and shallow monitor well would then be designed based on this new information. The test well would also be modified to become the storage zone monitor. If the exploratory test well proves that the site is not feasible for underground storage, then minimum funds have been spent and other sites can be considered.

Cost Considerations

What are the costs involved to address the regulatory and technical concerns via well drilling, construction, and testing operations?

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Site Cost (site access, site clearing, drilling pad, pad monitor wells, project office, water supply, power supply, and site restoration)

It is important for the consultant to visit the proposed test site with the owner and discuss site issues and their related costs. These issues include site access, security, and available water and/or power They also include determining whether drill cuttings and/or drilling fluids can be disposed of onsite and the most cost-effective means (discharge to a river or canal, stormwater sewer, or onsite holding pond) to handle large quantities of formation water produced during drilling and hydraulic testing operations.

The ranges of cost associated with some of these issues are:

- Site Access and Clearing—$1,500 to $2,500 per day plus material
- Drilling pad cost—$10,000 to $35,000 depending on design.
- Monitor wells—$500 to $1,500 each
- Trailer/Phone/Fax/etc.—$300 to $500 per month
- Water—$2,000 to $10,000, depending on distance to the source
- Power (40kw-110kw)—$130 to $285 per day
- Disposal Cost—$3000 to $35,000, depending on volume
- Site Restoration—$1,500 to $5,000

An onsite office trailer/phone/fax is not a regulatory requirement and, based on the short project duration, should be avoided.

Site costs are a considerable portion of the overall project cost, but they are also areas where substantial cost savings can be made. In many cases, the owner's willingness, concerns, and restrictions are assumed, costing the project thousands of dollars.

Other areas where site cost may be reduced include direct subcontracting of services related to site clearing, construction of the drilling pad, and/or site access. It may also be necessary to delay the project if there are seasonal site weather conditions.

Once the drilling and testing program is completed, the drilling equipment and debris is removed and the site graded smooth. These tasks are part of the demobilization cost. Any additional work such as reseeding or soding, landscaping, or fencing is typically third-partied, and these costs are generally marked up between 15 and 30 percent. If this additional site work is required, consider arranging the subcontractors directly.

Drilling Cost (drill rig size, drilling methods, and drilling cuttings and drilling fluids)

Generally, the smaller the final well diameter, the smaller the drilling cost. As the borehole diameter and the depth increases, material costs begin to escalate and a large drill rig is required. Figure 1 represents this relationship between total drilling cost as a function of borehole diameter and depth.

This relationship increases quicker above 12-inch diameter, primarily due to increasing material cost, and is compounded at depths approaching 1,000 feet because of the larger drill rig requirement.

Regardless of the method of drilling—Dual Tube, Sonic, Cable Tool, or Rotary—all drilling operations produce formation cuttings, drilling fluids, and water during pump tests. The disposal cost of these materials can range from $500 to $1,000 per 3,000-gallon load, depending on travel time to the disposal site.

Disposal cost is a very large component of a drilling program and is directly related to volume, as seen in Figure 2. This expense needs to be quantified and then discussed with the land owner.

Material Cost (casing, cement, drilling mud)

Most drilling operations require that a surface casing be installed to stabilize shallow formations prior to drilling deeper. A second casing string is then installed into the top of the water-bearing formation to isolate overlying unconsolidated sediments and non-productive formations. Generally, if the well depth increases, a third casing string is considered to seal off formations with lower pressure gradients and/or unstable formations prior to advancing the well bore to the target reservoir.

Water well construction regulations require a minimum of a 2-inch annular space between the casing and the well bore for cementing purposes; however, in practice, allow 3-inch annular spacing between deeper casing strings to ensure that themie pipe can be run between cementing stages.

To see the relationship of casing sizes, if the planned test well is to be completed with 12-inch casing, it would require 18-inch intermediate casing and 24-inch diameter surface casing to be set. If the well design is reduced to be completed with 5-inch diameter casing, it would only require 10-inch intermediate and a 14-inch surface casing.

Regardless of the material, all well casing costs increase with diameter. Figure 3 represents this cost relationship with diameter and compares the different types of well casing materials.

As expected, the volume of cement required to install the larger casing sizes also increases with diameter and is represented in Figure 4. This graph incorporates both material and labor cost.

The final cost of a cement operation also

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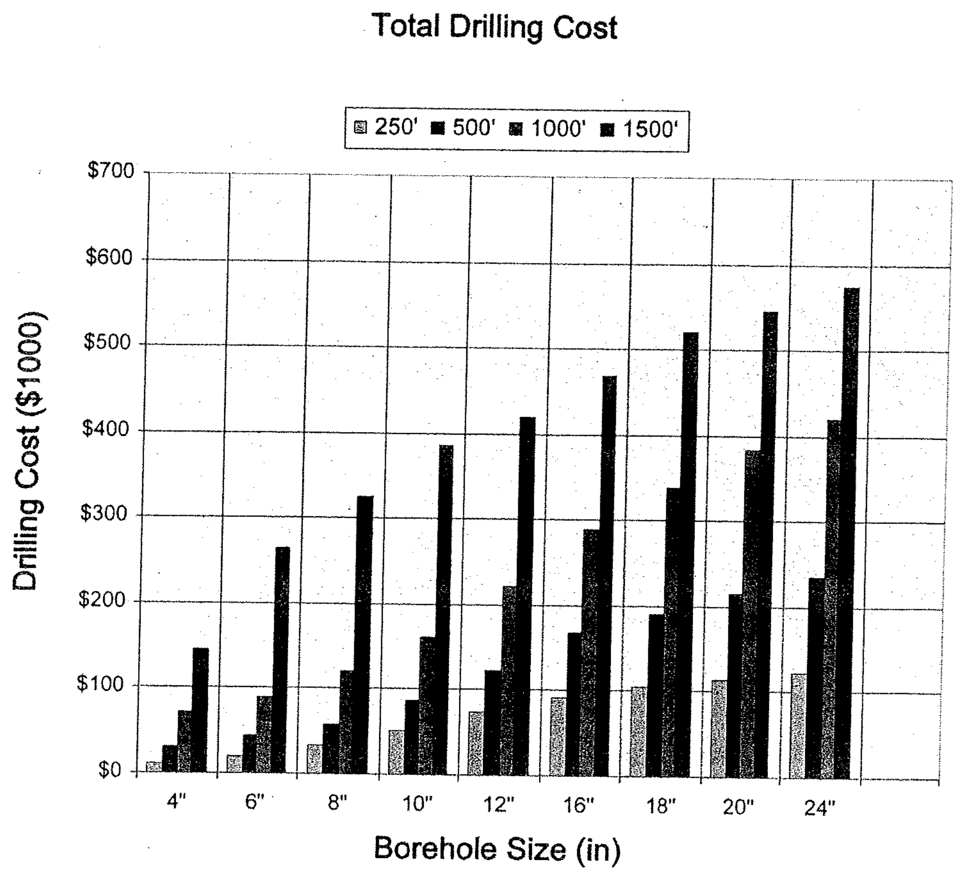

Figure 1

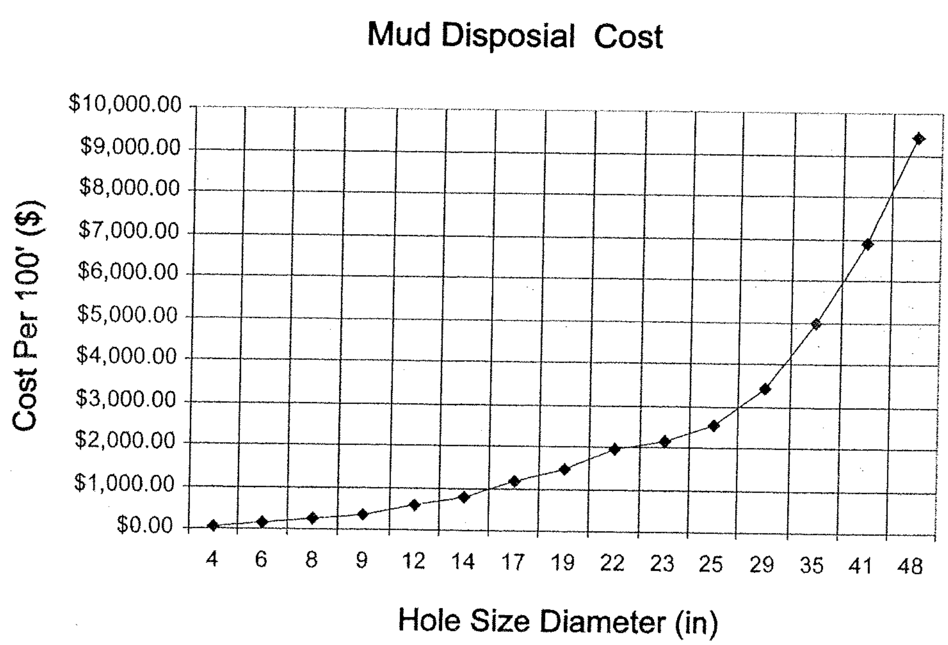

Figure 2

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depends on the number of cementing stages, the yield of the cement slurry, and any formation losses. The cementing operation should begin with a blended cement slurry (cement + bentonite or other additives) and end with a 100-percent neat cement slurry (yield 1.18 cubic feet per 94-pound sack) around the bottom of the casing: the "casing shoe".

It is very important to always have a good cement bond with high compressive and shear strengths around the shoe to provide a good seal and support. The blended slurry thereafter in further stages reduces the number of sacks of cement required because of the increase yield value (4 to 8 percent bentonite increases yields to 1.73 to 1.92 Cu. Ft/Sk).

Cementing operations are very dynamic; it is important to watch the return flow from the annulus to make sure that the cement slurry is displacing the well bore fluids. If the return flow stops, then the cement is moving out into the formation; at this point, the cementing operation should be stopped to save costs. If there are loss circulation areas, it is important to obtain a variance from the permitting agency to use gravel or fill material to help seal off these zones, reducing the total cementing cost.

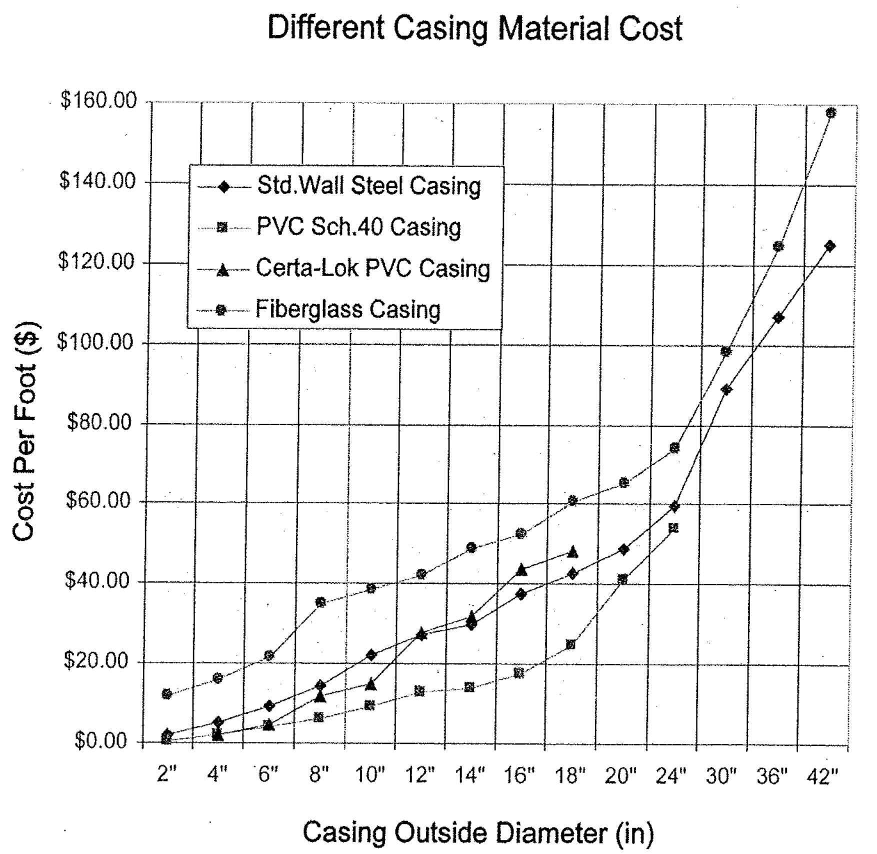

Figure 3

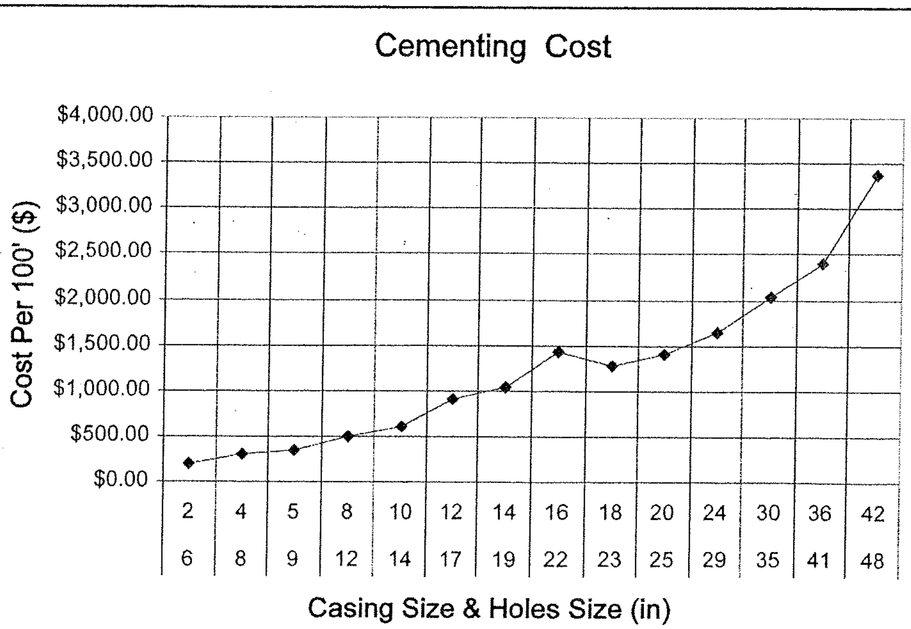

Figure 4

<u>Testing Cost (geophysical logs, packer tests, cores, specific capacity test, aquifer performance test, step test)</u>

UIC Rule 62-528 requires that the proposed testing methodology for the confining and injection zones be submitted as part of the permit application. In Section 62-528.405 of the UIC guidelines, the applicant is required to provide as part of the drilling program sufficient data such as geophysical logs, lithological cores, physical core analysis, borehole video, formation water samples, or drill stem test to demonstrate the confining characteristics.

These guidelines include a list of geophysical logs which "shall be considered" for determining adequate confinement. There are similar recommendations for testing the injection horizon. In some cases, all the suggested methods are included in the construction and testing plan to determine adequate confinement and the injection zone performance.

The goal should be to provide a cost-effective, scientific proposal that demonstrates adequate confinement and transmissivity of the target reservoir, provides "reasonable assurance" to the regulatory agency, and does not include every option to make the proposed drilling plan easily accepted.

There are many different methods to gather data. New technology and new methods of testing should always be investigated to save time and money. Some technologies that need to be considered to reduce costs are:

- Sonic and Dual Tube Drilling, which provides an almost continuous core of the upper confinement, storage zone, and lower confinement, and can provide discreet water samples over the entire length of the borehole, with minimum drilling fluids produced. The Sonic rigs, however, are limited to a depth of +/- 650 feet with a 4-inch hole size.
- Water Quality Logs are available to measure water quality changes within a static well bore after the well is fully developed. These could be used as an alternative to running a packer test, which always has the possibility of colored results if the packer or packers do not seal completely. The main cost saving with water quality logs is the time savings: one day logging, compared to three days to run a packer test in each zone.
- Orientated Fracture Detection Logs are

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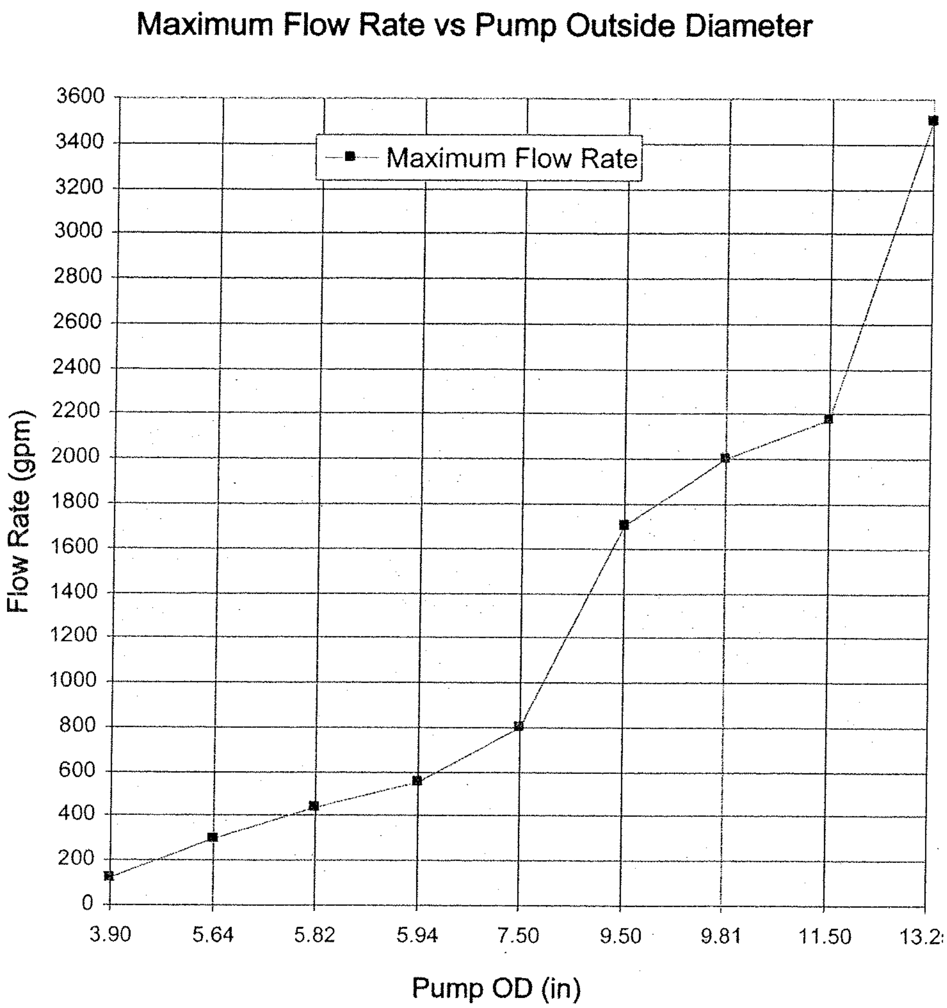

Figure 5

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also available to model the flow of the injected water, reducing the number of required monitor wells by better understanding the fluid flow.

Methodology to design an ASR Test Well

While developing test-well drilling programs, it is important to use all available local well information and hydrogeological data. There is a vast amount of public well data available. Sources include local state agencies, local water management districts, the DEP, EPA and USGS. Local drilling contractors can also provide valuable information that could prevent some very expensive problems from occurring.

Based on any local information and keeping cost in mind, first determine if there is a critical factor that will determine the success of the project. This factor could be the total dissolve solids (TDS) value of the native water, the native water geochemistry, sufficient transmissivity in the reservoir, or sufficient confinement above or below. If there is a go/no-go issue, then design the test well to answer the linchpin question first.

If there is not one particular issue of concern, then it is important to design the smallest well diameter over the shortest depth to meet the objectives. The following thought process could be used to develop your drilling program:

What is the maximum flow rate required to give meaningful results regarding transmissivity?

Relevance is important. If a 5-inch diameter test well produces 120 gallons per minute (gpm) with 1 foot of drawdown, the specific capacity of the well would be 120 gpm per foot of drawdown. If this specific capacity value is within the range required, then a small-scale step test and aquifer performance test (APT) could be conducted to derive a potential transmissivity value for the aquifer.

This small-scale test will not provide the aquifer performance data results for higher flow rates, but will determine if the results are good enough to spend additional money for a full-scale ASR well. If the test results are just marginal at the small flow rates, then the results at the high flow rates will be worst.

What pump size is required to provide a given flow rate?

Figure 5 illustrates the relationship between the outer diameter (OD) and maximum flow rate for submersible and turbine pumps that will be used for hydraulic testing. You can consider using a centrifugal pump during reservoir testing if initial water level and anticipated drawdown level do not realistically exceed 20 feet. Centrifugal pumps provide ease of use and are an economical option.

What is the casing size required to accommodate that size pump?

Because of the potential of a deviated well bore, an out-of-round and bent well casing, and the fact that submersible pumps require the electrical cables to be run back to the surface past the bowl assembly, allow two inches of clearance between the maximum outside diameter (OD) of the pump and the internal diameter (ID) of the casing.

What type of casing is required? (Carbon Steel, PVC, Certa-Lok PVC, FRP)

This will depend on the diameter of the casing, the long-term objectives of the well, and the salinity of the target reservoir. If you are drilling a test well for one specific go/no-go parameter, use the least expensive well casing option available. If there is a good chance that the site is ideal for ASR, then consider using a more expensive casing material for better long-term results. The cost difference between 6-inch schedule 40 PVC and 6-inch SDR17 Certa-Lok is only $ 0.75/ft.

What are my proposed methods for testing confinement?

Verifying confinement typically requires a collaboration of different test results. This could include a combination of core data, packer data, geophysical logs, drill cutting, and/or drill stem test.
Determining which combination of tests to use will depend on the method of drilling; however, testing will include some type of geophysical logs to insure that the final well bore diameter can accommodate the largest logging tools you plan to run. It is always good practice to include a final video survey run upon completion as a final as-built.

What is the best method of construction? (Mud Rotary, Reverse Air, Sonic, Dual Tube or Cable Tool)

Each drilling method has benefits and limitations. The ability to provide continuous cores and retrieve discreet water samples is a benefit of Dual Tube or Sonic rigs; however, they are more suited for a test-well program rather than a full-size well.

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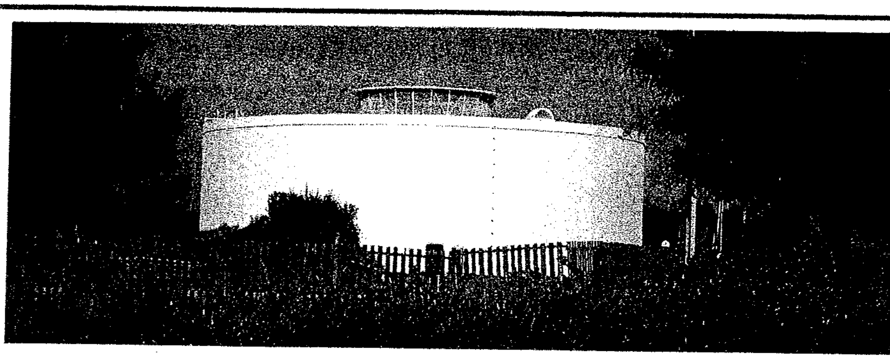

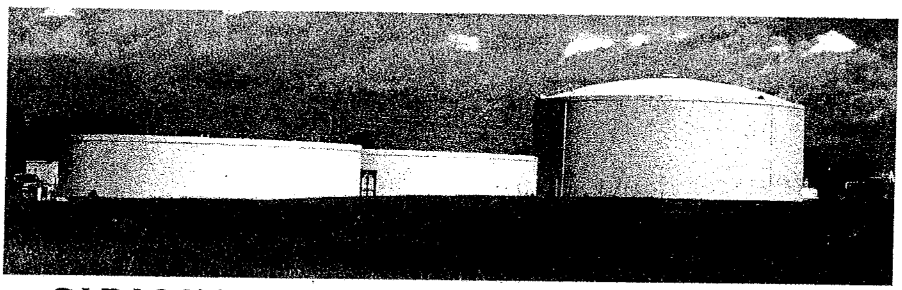

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Rotary rigs and Cable Tool rigs have the ability to also advance the casing while drilling and are capable of installing larger-diameter casings to deeper depths. These drilling methods provide discreet drill cuttings and can provide discreet water samples.

For the deeper well designs and larger casing requirements, rotary rigs are preferred. Rotary drilling rigs require that the complete hole section be drilled prior to running casing. To obtain a discreet formation samples like cores or discreet water samples require the use of specialized equipment. Rotary drilling also produces additional drilling fluids because of the continuous circulation.

It is important when evaluating different drilling methods or combination of methods to consider their drilling efficiency. Total project cost is directly related to total time on site.

What are my site constraints (size, available services, seasonal changes, and discharge issues)?

It is important to provide a stable access to the drilling site and sufficient area to set up the drilling equipment. If the drilling site will allow, drill cuttings and the drilling fluids should be disposed of onsite. Discuss site-related costs with the landowner, and have a pre-bid site meeting to explain the limitation or benefits.

In Summary

An optimized ASR Test well program addresses all the technical questions in a minimal hole size, applies new technology, and includes the actual site conditions. The plan focuses on any go/no-go parameters and should include alternative test sites and uses for the exploratory well. The extra time and money spent developing and minimizing your test-well drilling program will reduce the overall cost of the well.

Only when the scope of work has been optimized should it be submitted with the UIC permit application for approval.

The costs relationships and methodology included in this article can be applied to any well-drilling operation.

References

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