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Minimizing Waste during Drilling Operations

Richard C. Haut, Ph.D., Houston Advanced Research Center; John D. Rogers, Ph.D., Noble Technology Services a subsidiary of Noble Corp.; Bruce W. McDole, BP America; David Burnett, Director of Technology, GPRI, Texas A&M University and Oluwaseun Olatubi, Texas A&M University

Abstract

A collaborative academic, industry, and government partnership is described to address the sustainability concerns of E&P development in sensitive and restricted ecological areas. The partnership is to identify commercial off-the-shelf technology that can reduce the impact of drilling operations in sensitive areas and to prove technical ability to reduce the impact if not eliminate the collateral damage of E&P operations. One thesis of reducing the impact would be the minimization of waste during the life cycle of the extractive process.

The principal aim of waste management is to ensure that waste does not contaminate the environment at such a rate or in such a form or quantity as to overload natural assimilative processes. Eliminating or minimizing waste generation is crucial, not only to reduce environmental liabilities but also operational cost. The current state-of-the-art will be discussed and initial plans to develop a new bioremediation process to treat drill site wastes will be presented.

Introduction

Environmental issues are a part of every energy industry endeavor whether exploiting new natural gas resources in the Western USA or extending field development in coastal areas. Texas A&M University, Anadarko Petroleum, Noble Technology Services a subsidiary of Noble Corp. and the Houston Advanced Research Center have formed an integrated petroleum resource environmental program. Designated as the Environmentally Friendly Drilling Systems Program (EFD), the purpose is to incorporate dual engineering and environmental research specifically to reduce the environmental impact on ecologically sensitive areas from oil and gas extraction activities. The first phase of the project is identifying low impact technologies for two extreme environmental conditions: desert-like ecology environments and a coastal margin ecosystem. Balancing the value of energy production with social and environmental costs will provide a different perspective on the true cost of resource development.

As part of the EFD, a task working group (TWG) on waste management was established to explore various technologies to reduce discharges associated with drilling and production operations. The TWG's objective is the integration of novel wastewater and solid waste treatment processes into a system that captures and treats all run-off and effluent fluids, drill cuttings, and other waste streams.

Sustainable development of petroleum resources requires appropriate management of all waste streams generated over the life cycle of a development beginning with initial planning of projects and operations through decommissioning and site restoration. Quality waste management approach is crucial to achieve this goal.

The principal aim of waste management is to ensure that waste does not contaminate the environment at such a rate or in such a form or quantity as to overload natural assimilative processes and cause pollution. Eliminating or minimizing waste generation is crucial, not only to reduce environmental liabilities but also operational cost.

After an introduction to the Environmentally Friendly Drilling Systems Program, the current state-of-the-art related to drilling operations waste management will be reviewed. Afterwards, a new approach incorporating the bioremediation treatment at the drill site of the drilling waste will be discussed.

Environmentally Friendly Drilling Systems Program

A misconception that the oil and gas industry does not provide the proper stewardship to responsibly produce hydrocarbons in a sustainable manner results in many sensitive areas in the continental U.S. and worldwide being set aside or severely restricted from oil and gas production. The protection of the fragile ecologies of semi-arid deserts, ephemeral wetlands, and coastal marshes is the targeted issue in these areas. The U.S. Department of Energy (DOE) awarded GPRI (Global Petroleum Research Institute) at Texas A&M University and Noble Technology Services a subsidiary of Noble Corp. a financial assistance partnership to create an engineering and environmental development and demonstration project to address this issue. A Joint Industry Partnership (JIP) funds the shared cost required by DOE and to provide industry support, guidance, and direction of the project. This partnership includes academic and governmental ecologist, environmental scientist, and sociologists to provide the social and ecological balance to the technical economic needs to produce the oil and gas in sensitive areas.

The purpose of the project is to integrate current and new technology into a field demonstrable drilling system that would be compatible with ecologically sensitive, restricted access, off-limits areas (e.g., Otero Basins of New Mexico, Wetlands of Louisiana, East Texas and Mississippi Coasts, and Rocky Mountain areas etc.). The concept is to incorporate currently known but unproven or novel technology into a drilling process or system that enables moderate (TVD of 10,000 to 15,000 feet) to deep (TVD of 15,000 to 20,000 feet) drilling and production operations for hydrocarbons with a target of no environmental impact, or as minimal as possible, during the lifecycle of a well and field development. To date, four main subsystems and work flow product areas have been identified for the program. The four main subsystems are rig foundations, waste management, regulatory and community relations. These may be adjusted and others incorporated as defined by the industry advisory board (participants), Project Management and DOE.

Individually, many concepts have been developed to varying degrees. The key objective of the project is the synergistic incorporation of a number of current and emerging technologies into a single clean drilling/production system with no or very limited impact to the ecology. The ultimate deliverable is to define a system that includes the best available technology and demonstrate that the industry has the technical capability and environmental stewardship for a sustainable life cycle process in sensitive areas for the exploration and exploitation of natural gas and oil. Exploration and production waste management is a key part to the attainment of this goal.

Current Approaches

Historically, waste pits (reserve pits) were used at land rig sites. At the end of each well the wet cuttings were left to dry naturally and then bulldozed or covered with natural soil. Current practice for operators onshore and offshore employs extensive fluids recovery and cuttings disposal methods. Often, because they want to be considered responsible guests by their host country, oil and gas operators impose even more stringent environmental regulations on their operations than those imposed by the country in which they are drilling.

Exploration and production waste-management has evolved beyond managing the drill cuttings and excess drilling fluids during drilling and workover operations. Though these comprise the vast majority of the wastes, other materials include contaminated water, material and chemical packaging, air emissions such as carbon dioxide and oxides of nitrogen, scrap metals, fuel, lubricants and other oils as well as the usual human and industrial wastes associated with E&P operations[1]. Application of computer models is a new tool to help manage solids control, wastes, and liability issues from a drilling project.[2]

Shell Exploration and Production Company established a Rig Waste Reduction Pilot Project in 2001 to identify potential waste reduction strategies.[3] They developed a preferential hierarchy: *reduce, reuse, recycle, recover and dispose.* The major component of the total waste stream was found to be drilling discharges and non-hazardous oilfield waste. Mud use was reduced by 20% and mud component packaging was reduced by 90% through a combination of solids control efficiency, cuttings dryer technology and bulk mixing equipment. In addition, Shell implemented a sorting, compaction and recycling process for solid waste (consumables and trash) to reduce landfill disposal.

Schlumberger has introduced a total waste management program to mitigate rising quantities of landfill waste.[4] Benefits included an overall improvement in general housekeeping that reduced health and safety exposure and a general increase in environmental awareness and concern.

Mobil implemented a waste management program for the Hugoton field operations.[5] The waste management system decreased overall waste-related costs while improving compliance assurance and reducing potential liability. The key element was a mechanical solids control system consisting of a semi-closed loop centrifuge flocculation dewatering process that removes solids for burial on location.

A on-site drilling waste treatment system, using de-watering or closed-loop drilling, was used successfully on nearly 40 wells in New Mexico.[6] The process reduced waste volume, long-term liability and cost. The condition of the treated material also improved disposal.

Waste management, however, incorporates other aspects in addition to drilling fluids and cuttings. Air emissions and water runoff from the site should also be considered. With the increase in rig activity in the Rocky Mountain States, pollution from drilling rigs and other oil field related equipment has become a concern.[7] Wyoming's Jonah Field near Pinedale is a concern where an estimated 3,100 wells will be added. EnCana has tested a natural gas fired drill rig that reduces emissions by 90 percent compared to conventional diesel rigs.[8] EnCana is also evaluating the possibility of providing electrical service to the Jonah field to power drilling rigs with direct electrical power, reducing emissions to negligible amounts.[9] A water runoff management program may be developed to control discharges of waste water to the environment.[10]

Solids and Cuttings Management

API estimated that in 1995 about 150 million barrels of drilling waste was generated from onshore wells in the United States alone. Drilling wastes are the second largest volume of waste, behind produced water, generated by the E&P industry. Operators have employed a variety of methods for managing these drilling wastes depending on what state and federal regulations allow and how costly those options are for the well in question. Onshore operations have a wider range of options than offshore operations. These include landspreading and landfarming, dewatering and burial onsite, underground injection, incinerating and other thermal treatment, bioremediation and composting and reuse and recycling.[11]

Chevron has published ten years of lessons learned concerning biotreating exploration and production wastes.[12] They have successfully implemented bioremediation in diverse climates and in remote locations. The most common biological treatment techniques in the exploration and production industry are composting and land treatment. Landfarming and composting have been successfully used for drilling wastes.[13]

A novel technique for effective drilling waste management is vermicomposting.[14] Vermicomposting uses worms to remediate the cuttings, converting them into a compost material that is useful as a soil enhancer. This technique not only cleans the cuttings but converts them into a valuable resource. For environmentally sensitive areas, this bioremediation technique may be applicable. The vermicompost technique, combined with environmentally friendly design of the drilling fluid, is by far the preferred treatment technique compared to thermal treatment of the cuttings.

The Drilling Waste Management Information System, developed by Argonne National Laboratory and industry partners, Chevron and Marathon, under the U.S. Department of Energy's (DOE's) Natural Gas & Oil Technology Partnership program provides a summary of thermal treatment technologies.[15]

Thermal technologies use high temperatures to reclaim or destroy hydrocarbon-contaminated material and are efficient for destroying organics reducing the volume and mobility of inorganics such as metals and salts.[16] After-treatment may be necessary for metals and salts. Waste streams high in hydrocarbons (typically 10 to 40%), like oil-based mud, are prime candidates for thermal treatment. Thermal treatment can be an interim process to reduce toxicity and volume and prepare a waste stream for further treatment or disposal (e.g., landfill, land farming, land spreading), or it can be a final treatment process resulting in inert solids, water, and recovered base fluids.

Thermal treatment technologies can be grouped into two categories.[15] The first group uses incineration (e.g., rotary kilns, cement kilns) to destroy hydrocarbons by heating them to very high temperatures in the presence of air. The second group uses thermal desorption, in which heat is applied directly or indirectly to the wastes, to vaporize volatile and semivolatile components without incinerating the soil. In some thermal desorption technologies, the off-gases are combusted, and in others, such as in thermal phase separation, the gases are condensed and separated to recover heavier hydrocarbons. Thermal desorption technologies include indirect rotary kilns, hot oil processors, thermal phase separation, thermal distillation, thermal plasma volatilization, and modular thermal processors. Various thermal processes have been patented.[17,18,19]

Cuttings Injection

Cuttings injection is a waste disposal technique where drill cuttings and other oilfield wastes are mixed into a slurry by being milled and sheared in the presence of water, usually seawater (offshore) and contact stormwater (onshore). The resulting slurry is then pumped into a dedicated disposal well, or through the open annulus of a previous well or into the annulus of the well being drilled, into a fracture created at the casing shoe set in a suitable formation.

Drilling a dedicated injection well is sometimes ruled out in favor of an annular injection plan on a cost basis but more frequently, operators are deciding not to risk damaging their well and would rather drill a separate shallow injection well.

For single well programs or areas with specific logistical limitations (Cook Inlet) – annular injection is the norm. However, for development drilling, a dedicated injection well (or two) is often used. For development drilling from a platform, the first well could be drilled with water based fluids to an injection depth and can then be used as the injection well for the balance of the wells to be drilled on the Platform or Pad. Then, after all other wells are drilled, the annulus of one of the other wells can be used as the original injection well is drilled to TD and completed.

Operations are usually batch by nature and carried out at low pump rates (2.0 - 8.0 bpm). Typically the 13 3/8" by 9 5/8" annulus is selected as the disposal location. These kinds of operations have been carried out all over the world, with disposal into many different types of strata.

Stormwater Management

Drilling operations can produce large volumes of wastewater that contains sediment, mud and drilling additives. The proper handling, containment and disposal of the wastewater are important to mitigate potential harm to the environment.

Stormwater should contain only clean rainwater, not pollutants such as wastewater, sediment, mud, drilling additives or other pollutants. Only clean, non-contaminated stormwater should be allowed to flow directly into rivers, oceans and other waters.

Addressing potential stormwater pollution

- Improves awareness of the impact of well drilling on the environment
- Meets public expectations that drilling activities do not pollute
- Reduces environmental impacts
- Complies with legal and environmental responsibilities
- Provides a cleaner work environment and improves efficiency
- Increases long-term cost savings through increased efficiency and reduced costs.

Wastewater should be contained on site and disposed of away from any watercourse or wetland area. Wastewater can usually be contained by constructing a temporary reserve pit of adequate size, protected from stormwater by banks. The section on best practices, later in this paper, discusses the handling of wastewater/stormwater in more detail.

Air Emissions

Drilling operations involve the use of diesel engines for delivery/logistics of equipment, materials and supplies and for the generation of power at the drill site. Much advancement has been made to reduce emissions from diesel engines. Diesel engines emit particulate matter (PM) and oxides of nitrogen (NO_x) into the atmosphere, along with other toxic air pollutants. Health experts have concluded that pollutants emitted by diesel engines adversely affect human health and contribute to acid rain, ground-level ozone and reduced visibility. Studies have shown that exposure to diesel exhaust causes lung damage and respiratory problems and there is evidence that diesel emissions may cause cancer in humans.

Significant improvement in diesel emission levels, in both light- and heavy-duty engines, was achieved in the 1970 - 2000 period. PM, NO_x, and HC emissions were cut by one order of magnitude. Most of that progress was achieved by emission-conscious engine design, such as thorough changes in the combustion chamber design, improved fuel systems, implementation of low temperature charge air cooling, and special attention to lube oil consumption.

However, more progress was still required, as the NO_x and PM emissions from diesels remained higher than those from Spark Ignited (SI) engines. A new series of diesel emission regulations was developed with implementation dates around 2005-2010, which require the introduction of exhaust gas aftertreatment technologies in diesel engines, as well as fuel quality changes and additional engine improvements.

The array of emission control methods provides the designer with building blocks which need to be chosen and combined into the emission control system, which in turn is integrated with the engine to achieve a given emission target. A system approach is necessary to develop the clean emission diesel engine. There is no miraculous “plug-in” device available which could be installed on a particular engine and effectively clean emissions. An effective emission control strategy has to combine elements of engine design with the use of appropriate fuels and exhaust after-treatment methods.

Selective catalytic reduction (SCR) of NO_x by nitrogen compounds, such as *ammonia* or *urea*—commonly referred to as simply “SCR”—has been developed for and well proven in large-scale industrial stationary applications. The SCR technology was first applied in thermal power plants in Japan in the late 1970s, followed by widespread application in Europe since the mid-1980s. In the USA, SCR systems were introduced for gas turbines in the 1990s, with increasing potential for NO_x control from coal-fired powerplants. In addition to coal-fired cogeneration plants and gas turbines, SCR applications also include plant and refinery heaters and boilers in the chemical processing industry, furnaces, coke ovens, as well as municipal waste plants and incinerators. The list of fuels used in these applications includes industrial gases, natural gas, crude oil, light or heavy oil, and pulverized coal.[20]

SCR is the only proven catalyst technology capable of reducing diesel NO_x emissions to levels required by a number of future emission standards. Urea-SCR has been selected by a number of manufacturers as the technology of choice for meeting the Euro V (2008) and the JP 2005 NO_x limits—both equal to 2 g/kWh—for heavy-duty truck and bus engines. The first commercial diesel truck applications of SCRs were launched in 2004 by Nissan Diesel in Japan and by DaimlerChrysler in Europe.

SCR systems are also being developed in the USA in the context of the 2010 NO_x limit of 0.2 g/bhp-hr for heavy-duty engines, as well as the Tier 2 NO_x standards for light-duty vehicles.

The technologies and strategies being developed for the 2007/2010 heavy-duty highway diesel engine and Tier 4 nonroad diesel engine standards may be applicable to stationary diesel engines provided adequate lead-time is given. The issue is to match the right technologies to the right applications. Reduction of emissions is influenced by the duty cycle of the engine.

DieselNet (www.dieselnet.com) provides current information about emission standards and regulations.

Best Practices

In November 2006 a trip was made to a drilling operation in an environmental sensitive area with the intent to document best practices. In particular, the trip focused on the reserve pit system layout and operation, water base mud recirculating/ reuse system operation and the oil base mud/cuttings system operation. The layout of the operation and operating practices showed special sensitivity of the impact of drilling operations on the land and water environment in the area. It is important to note that the selection of best practices includes project economic considerations. The cost of implementing various practices must be weighed with the impact on project costs. For example, additional best practices could have been included in the operations at the site visited, however, the cost of the additional practices prevented their implementation.

An overview photo of the rig site is given in Figure 1. The Mississippi River is in the background. Entrance to the rig site is from the left. Crew quarters are set up away from the pad to minimize the chances of involvement in a rig incident. The wellsite leader’s trailer is behind the rig mast. Drill pipe and casing lie to the left of the rig. Mud pits are in the foreground. A typical HPHT wellbore that includes planned annular injection, similar to the one visited, is illustrated in Figure 2.

Solids Control Installation

Figure 3 gives a layout of the reserve pit configuration along with the stormwater runoff calculation. Downstream from the rig equipment (3 linear motion shakers, 3/12 desander and 16/5 desilter fluid conditioner, is installed a high speed/high volume centrifuge mounted on a stand. The centrifuge helps to maintain proper mud weight and viscosity while drilling the unweighted waterbase sections and reduces the liquid mud disposal. The centrifuge processes the 16/5 fluid conditioner underflows and whole mud from the active system. The ‘dry’ solids are processed into the dry cuttings pit combined with the fluid conditioner’s ‘dry’ solids. The ‘clean’ fluid from the centrifuge is discharged back into the active mud system.

Figure 4 is a photo of one of the pumps used to circulate the pits and transfer fluids from one pit to another.

Solids Control Operations by Hole Section

All waste drill mud and cuttings are segregated by fluid content (wet and dry cuttings). The wet discards, from the linear motion shakers, are deposited into pit # 1. The dry discards, from the centrifuge and desilter, are deposited into pit # 2. Recovered mud, that cannot be immediately transferred to the active mud system, is stored in pit # 3 (1,923 bbls capacity). Pit # 1 (3,967 bbls capacity) is excavated to pit #5 (wet storage 14,426 bbls capacity) as it fills. Pit # 2 (1,923 bbls capacity) is excavated to pit # 4 (dry storage 28,851 bbls capacity).

During the casing/cementing process in the initial hole section, pit # 1 will be emptied, transferred to pit # 5, to avoid contamination of potentially recoverable mud. The hole volume of good mud will be recovered between pit # 1 and pit # 3 for reuse after the cementing process is completed.

During the open hole displacement to oilbase mud process pit # 1 and pit # 2 are emptied, transferred to pit # 5 and pit # 4 respectively, to avoid contamination of waterbase mud/cuttings which allows a greater range of disposal options. The hole volume and active system of good mud are recovered between pit # 1 and pit # 3, stored in pit # 5 for reuse in the injection process.

In the weighted section, the use of the 3/12 desander is discontinued while the use of the 16/5 desilter is continued along with supplemental barite recovery, oil recovery and solids discharge through the use of the barite recovery centrifuge and high speed centrifuge.

During casing/cementing operations in this section, pit # 1 may be emptied, transferred to pit # 2, to avoid contamination of potentially recoverable mud. The hole volume of good mud will be recovered between pit # 1, pit # 2 and pit # 3 for reuse after the cementing process is completed.

At this point the supplemental solids control equipment is rigged down and moved out. While the crane is on location the slurification and annular injection equipment will be moved in and rigged up.

The first phase annular injection of drill mud and cuttings will commence as soon as the annulus is available for injection. The drill mud and cuttings with the highest contaminant values will be injected first. The larger pits used to store waste drill mud and cuttings will be emptied and closed as soon as possible to reduce contact stormwater. The second phase annular injection will commence after drilling and completion operations are finalized.

Pit closure activities include the removal of all contact soils which are commingled with drill mud and cuttings and are injected into the annulus. The heavy sand and shale, which cannot be effectively slurried, is transported to an offsite commercial disposal facility. The pits are backfilled, compacted and recontoured to preproject elevation. The final step in pit closure is the replacement of stockpiled topsoils and revegetation.

Bioremediation

Biotreatment of drilling associated waste has continued to gain wide acceptance and recognition in the industry and there are numerous reports about the successes and challenges of the various bio-treatment methods used in treating different associated wastes and the use of biotreatment methods in the remediation of soils and aquifers contaminated with crude oil, gasoline and various oil-based wastes. Different studies have been carried out manipulating various parameters in these methods that are essential to effective bio-degradation of wastes and significant insights have been shed at optimizing these bio-treatment methods for better results. Biotreatement of contaminated soils and aquifers to conditions near their pre-contamination states have also been reported[21] showing that these bioremediation methods are efficient in the restoration of impacted soils and aquifers. Biotreatment methods are acclaimed to represent one of the most promising, cost effective, safe technologies in treating waste and remediating impacted areas.[22,23]

One challenge posed by the wholesale adoption of bio-treatment methods is optimizing conditions to achieve regulatory waste limits within a reasonable period within reasonable costs. Another challenge posed is the “whole” treatment of the waste of all contaminants, or rather the “custom” treatment of the waste to levels within all permissible regulatory limits rather than employing different treatment methods for the same waste. To face this challenge pilot studies need to be carried out to determine appropriate treatment methods on a case-by-case basis, this would provide adequate information on choice of treatment methods and modifications to be made to achieve optimal results.

Finally, a holistic approach needs to be adopted for proper waste management of exploration and production associated wastes. This should be an integrative approach that looks at the constituents of the drilling process with the aim of making them environmentally friendly and easily biodegraded. The approach should look at waste minimization from the source, the optimal use and re-use of materials and should view treatment options as a process to generate safe re-useable products.

Such an integrative and scientific approach would effect environmentally friendly drilling for the industry.

Bioremediation Pilot Project

A project has been established to investigate the possibility of developing a bioremediation treatment processor that can be located at a drill site. The key deliverable for the project is a small footprint, low-impact environmental treatment process adaptable to real-life drilling operation, based on sound engineering and biological principles capable of converting drilling wastes to a useable product. Figure 5 illustrates the conceptual design of the processor.

The goals associated with the project include:

1. Determine optimized treatment process that can be adapted to build mobile, small footprint treatment processes.
2. Determine waste(s) that can be effectively treated using this treatment method.
3. Determine conditions such as climate, environmental areas, drilling sites where treatment process can be used and limitations.
4. Determine efficiency of the process, cost implication, the environmental implications, product uses and environmental laws and regulations associated with process.

The work will investigate an environmentally safe conversion of drilling wastes to an environmentally friendly end product. Rather than burying wastes in reserve pits, landfills and wells, the goal is to reduce the ecological footprint. The focus also entails designing methods aimed at making the drill cuttings more amenable to bioremediation coupled with methods aimed at drastically reducing the volume of the final biodegradable waste material by extracting as much re-useable products from the waste as possible thereby making the final treatable waste volume more manageable.

The hypothesis is that biotreatment methods would be proven as the preferred process in the treatment of exploration and production associated wastes in the near future, especially in the perspective of increasingly strict environmental regulations and community interest in safeguarding the environment. Biotreatment methods could represent viable long-term treatment options that would satisfy both host communities and oil industry operators criteria. The science behind biotreatment methods is easily communicated to stakeholders thereby allaying established fears and distrust accompanying other treatment methods.

Summary

This paper discusses various aspects of waste management during drilling and completion operations. The main points covered in the paper include:

1. A multidisciplinary academic, industry and government partnership has been established to demonstrate oil and gas industry technical environmental stewardship.
2. Industry has significant technology to demonstrate environmental stewardship but needs to integrate the various technologies into a systems process.
3. Vermicomposting could be a process to minimize E&P wastes in the near future.
4. Implementation of best practices needs to be prioritized with respect to project economics.
5. Biotreatment methods are a promising, cost effective way of treating waste and impacted areas.

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Nomenclature

API	*American Petroleum Institute*
NO_x	*Oxides of nitrogen*
SCR	*Selective catalytic reduction*

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Figures

Figure 1. Environmentally Sensitive Rig Site Visited.

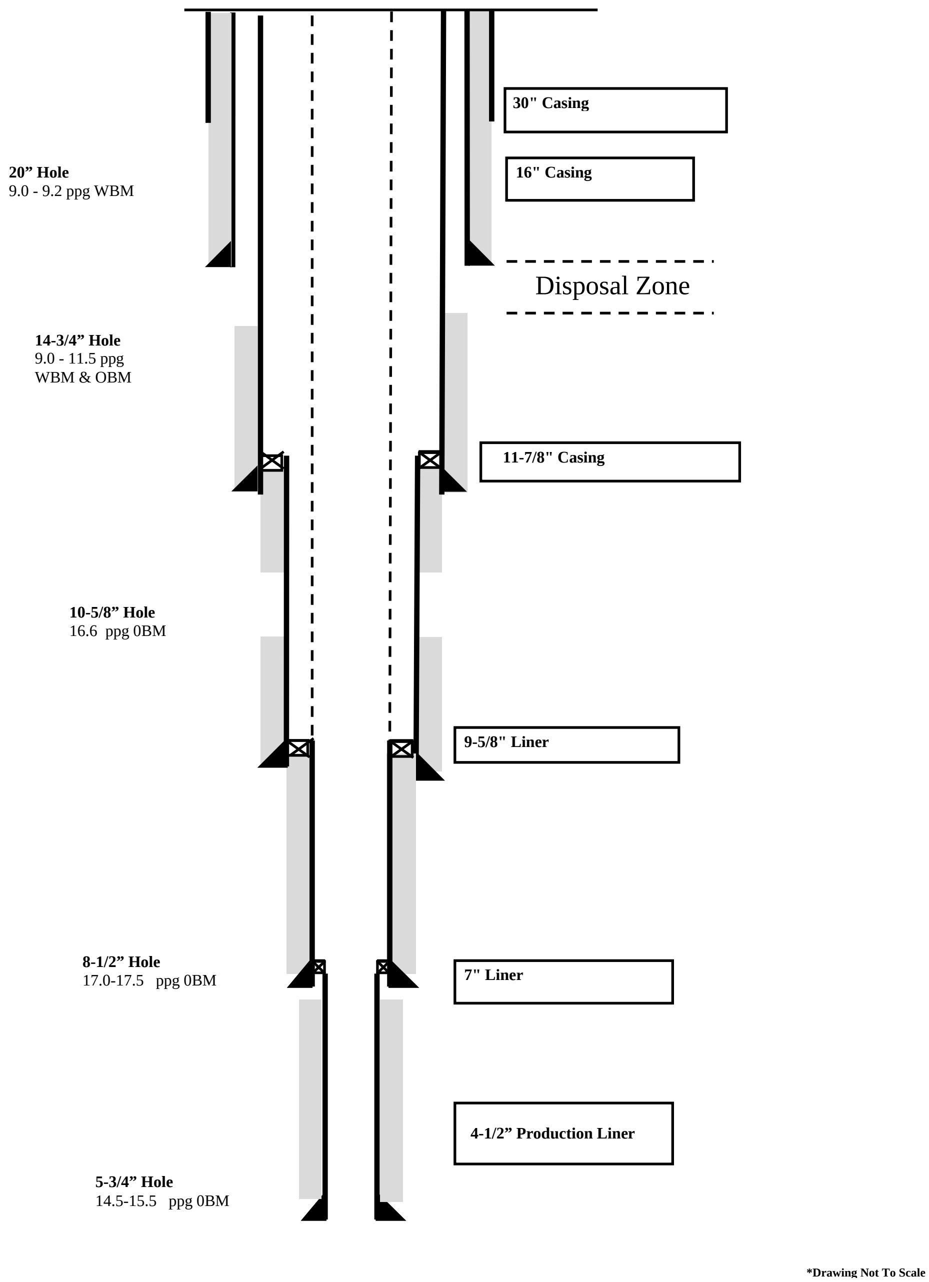

Figure 2. Typical Deep HTHP Wellbore Diagram Including Planned Annular Disposal.

2.6 inches rain	
1,719	bbls per inch of volume rig location
4,469	total bbls rain
3,352	bbls per inch at 75%
633	bbls per inch of volume pit location
1,650	total bbls at 100%
5,002	Total bbls rain water

9.2 inches rain	
1,719	bbls per inch of volume rig location
15,878	total bbls rain
11,840	bbls per inch at 75%
789	bbls per inch of volume pit location
7,258	Total bbls 100%
19,098	Total bbls rain water

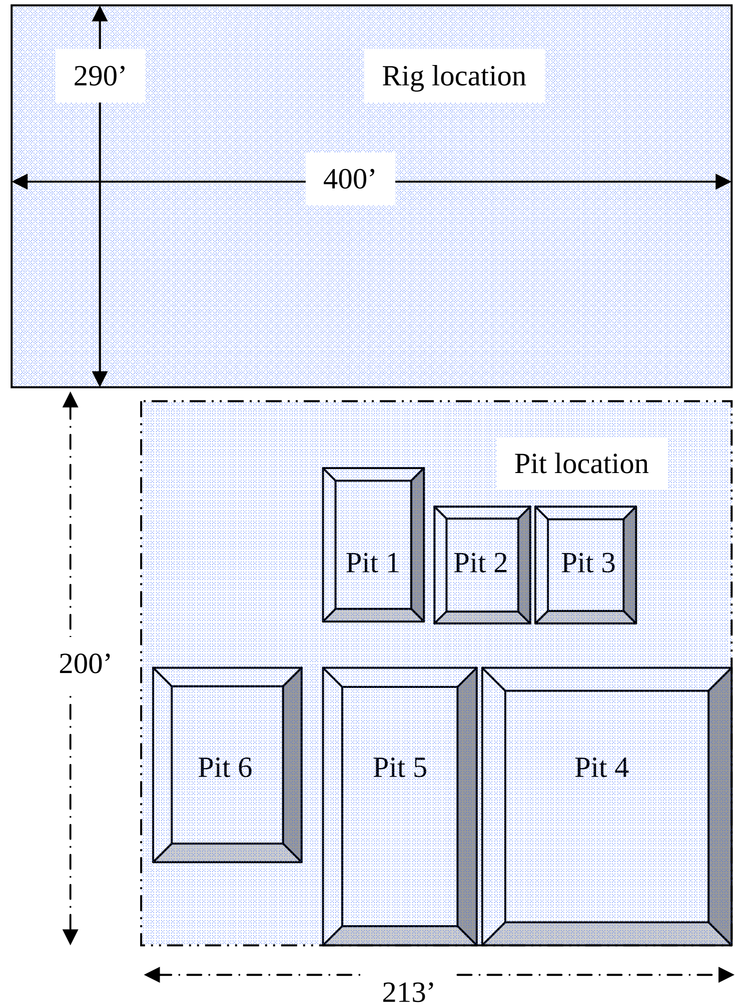

Figure 3. Estimated Stormwater Runoff and Pit Layout.

Figure 4. Slurry Pump Used for Pit Circulation, Fluid Transfers, etc.

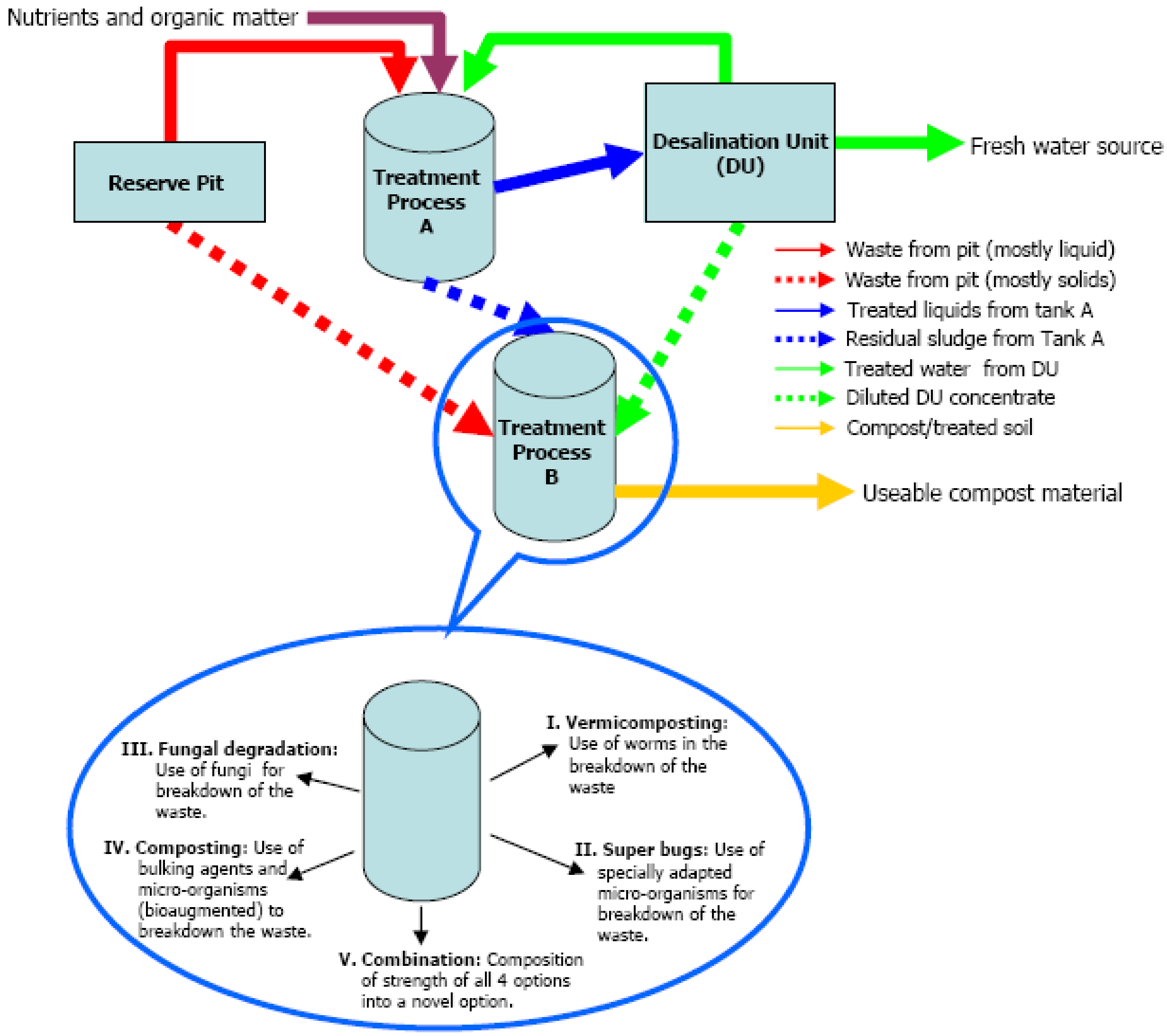

Figure 5. Conceptual Design of Bioremediation Treatment Processor.