UNIVERSITY OF PETROLEUM & ENERGY STUDIES, DEHRADUN

A Dissertation Report
On
Feasibility Study on Cost Effective Method of Drilling Waste Management

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DECLARATION

I hereby declare that this project titled **“Feasibility Study On Cost Effective Method Of Drilling Waste Management”** submitted by me to the University of Petroleum and Energy Studies Energy Campus, Dehradun for partial fulfilment of pre-requisites for completion of 2nd (final) semester under MBA (Oil & Gas), is a bonafide work carried out by me under the guidance of **Dr. Sumeet Gupta,** Senior Associate Professor and Head, Centre for Infrastructure and Project Finance, University of Petroleum and Energy Studies, Dehradun. This has not been submitted to any university or institution for the award of any degree, diploma/certificate or published any time before.

Place: Duliajan

Date: 01.08.2016

(Sushanta Datta Gupta)

CERTIFICATE

This is to certify that the Mr Sushanta Datta Gupta, a student of MBA (Oil & Gas), Roll No: R020115024 of UPES has successfully completed this dissertation report on "**Feasibility Study on Cost Effective Method of Drilling Waste Management**" under my supervision.

Further, I certify that the work is based on the investigation made, data collected and analyzed by him and it has not been submitted in any other University or Institution for award of any degree. In my opinion it is fully adequate, in scope and utility, as a dissertation towards partial fulfilment for the award of degree of MBA (Oil & Gas).

4/5/12

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(   )

SUSHANTA DATTA GUPTA

EXECUTIVE SUMMARY

Waste management is one of the problems facing the oil and gas industry. This has often thrown the industry into numerous challenges ranging from technological development to ensuring a clean and safe environment. Oil and gas well drilling processes generate large volume of drill cuttings and spent mud. Onshore and offshore operators have used a variety of methods to manage these drilling wastes.

In today's world of sustainable development, preservation of the environment for future generation is the need of the hour. This coupled with regulatory stringency has mandated the incorporation of DWM in each drilling sites. OIL has been using DWM in all its drill sites to preserve the environment to the utmost possible way. There seems to be scope of improvement and application of cost effective methods in these respect. In its endeavor to continually improve, Reverse Osmosis technique has been implemented in Effluent Treatment Plant at Loc. TLK#1 in KG Basin to process a part of the treated water to Assam Pollution Control Board (APPCB)norms.Furthermore, OIL has been using facility Treatment, Storage and Disposal Facility (TSDF) to transfer the waste materials to third party for necessary treatment before disposal to specially designated site. There is scope of better utility of the overall facility for cost effective way of handling these waste while taking care for the environment and the paper discusses the areas where scope of improvement is possible while eliminating the drawbacks.

This paper discusses the basic concepts for managing waste generated during drilling operations and provides systematic approach for pro-active waste management practices. It addresses the various stages in drilling waste management, and emphasizes the phases of waste identification, minimization, treatment and disposal as integral parts of waste management process and the paper discusses on the issues which will reduce/reuse and recycle the waste as well as deal with the generated waste in a cost effective manner.

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INTRODUCTION

1.1 Background of the study

The Block KG-ONN-2004/1 comprising of 549 Sq.km area was awarded in the year 2007 by the Ministry of Petroleum & Natural Gas (MOP&NG), Govt. of India, under its New Exploration Licensing Policy (NELP) round VI, to the consortium of Oil India Limited (OIL), A Govt. of India Enterprise (with 90% stake as the Operator) & Geo Global Resources (GGR: Barbados) with 10% stake as the partner for the Block, for carrying out extensive & expeditious exploration for Petroleum & Natural Gas in the region. This 549 Sq.km comprises of 511 Sq. Km on land area in the district of East Godavari, Andhra Pradesh (AP) and that of 38 Sq.km. in the district of Yanam, Puducherry (UT). This block is situated in SE of East Godavari sub basin of KG Basin.

Further the block area was reduced from 549 sq.kmto 353.46sq.km due to denial of clearance/permission by statutory authority to explore in Corringa wild life sanctuary, 1km along coast line, Reserve forest and also presence of subsurface and surface facilities of RIL & GSPC viz.pipelines, onshore terminal (29sq.km). The 353 sq Km comprises 315 sq. Km in East Godavari district of AP and 38 sq.km in Yanam under Puducherry (UT).

Presently a 3000HP HPHT rig has been deployed to drill the 1st HPHT well in the block. The well being drilled is TLK#1 at Thanelanka.

Summary of the well:

The drilling well TLK#1 is a very deep High Pressure High Temperature hole, approximately 5200 meters in total planned depth. The holes drilled in this area, generally have a 26inch surface hole section of approximately 600 meters followed by intermediate sections planned to 2000m, 3250m, 4600m and 5200m respectively. The drilling fluid plan for this hole is shown in Table:1.1

The drilling fluids commonly used in this area consists of a Gel slurry for surface hole, drilling out and ahead in the next two sections with potassium acetate polymer to approximately and the final two sections with a specialty high temperature fluid to the final depth. This well is considered exploratory so planned depths will change with realized lithology.

Normally wells drilled this deep and hot would utilize a synthetic oil based drilling fluid for the deeper sections. Due to local regulations this type of fluid would not be suitable due to concerns of spills and contamination of the fluid. While these types of fluids can cause contamination if handled incorrectly the decision was made to attempt to deploy a water based mud solution to drill this reservoir.

Interval 1 – 26 " hole	**Mud System**	**Density ppg**	**PV cP**	**YP lbs/100ft2**	**6 rpm**	**3 rpm**	**Gel 10 min**	**API F/L ml**	**LGS, %**
0-600 m MD	PHB	8.5-9.5	ALAP	25 – 35	18-20	8-14		≤ 15	< 5
Interval 2 – 18 ½ " hole	**Mud System**	**Density ppg**	**PV cP**	**YP lbs/100ft2**	**6 rpm**	**3 rpm**	**Gel 10 min**	**API F/L ml**	**LGS, %**
600-2000m MD	Potassium Acetate Polymer	9.5-10.5	ALAP	18-25	8-15	6-10		≤ 6	< 5
Interval 3 – *14 ¾ " hole*	**Mud System**	**Density ppg**	**PV cP**	**YP lbs/100ft2**	**6 rpm**	**3 rpm**	**Gel 10 min**	**API F/L ml**	**LGS, %**
2000-3250 m MD	Potassium Acetate Polymer Glycol	10.5-13.5	ALAP	18-25	8 – 15	6-10		≤ 5	< 5
Interval 4 – 12 ¼ " hole	**Mud System**	**Density ppg**	**PV cP**	**YP lbs/100ft2**	**6 rpm**	**3 rpm**	**HPHT FL ml**	**API F/L ml**	**LGS, %**
3250-4600 m MD	HTHP WBM	13.5-16.0	ALAP	25-35	8-15	6-10	≤ 20	≤ 5	< 5
Interval 5 – 8 ½ " hole	**Mud System**	**Density ppg**	**PV cP**	**YP lbs/100ft2**	**6 rpm**	**3 rpm**	**Gel 10 min**	**API F/L ml**	**LGS, %**
4600-6000 m MD	HTHP WBM	13.5-16.0	ALAP	25-35	8-15	6-10	≤ 20	≤ 5	< 5

Table1.1: Proposed Drilling Fluid Program

The solids control system consisted of a 3 rig owned Derrick linear motion shale shakers, and one Derrick mud cleaner/Shale shaker combo unit. Two Brandt 2172 decanting centrifuges complete with stands are being supplied for the sections after surface hole. Also a water filtering system and reverse osmosis equipment is being supplied for cleaning water.

Drilled solids generated from solids equipment, mud and cement are supposed be disposed of as the waste is generated. Waste would fall into a cement lined pit at the base of the shale shakers and after sufficient volume accumulated it would be hauled away as required. Three large sumps are in behind the rig and are to be dedicated water sumps for the reverse osmosis and filtering of clean water system. Water is being supplied by 3 water wells located inside the lease area drilled to an approximate depth of 20 – 30m.

Initially the DWM program was designed in house and not initially well thought out. There is no formal DWM program laid out to follow and is no protocols for tracking water and waste disposal or any waste tracking planned.

Execution

The surface hole of the well commenced on 12.01.2016 and it became apparent quickly that the waste pit at the shale shakers was not of sufficient size to hold the drill cuttings volume being produced. The pit quickly overflowed (See Figure 2) and started to leak onto the lease surface.

Figure 1.1: Waste pit overflowing

It was initially assumed that the entirety of the surface volume would fit into the shaker pit. Also there was a gap in the waste hauling contract; the contract was not yet awarded so no waste hauling could be initiated. At this time a decision was made to dig a trench to the nearby clean water sump and to fill it with cuttings and waste drilling fluid instead of water (See figure 3).

This deficiency reduced the effectiveness of the reverse osmosis unit and filtering unit to clean water and led to required water being hauled into from a remote source.

Figure 1.2: Overflow into water sump

Discussion

The TLK-1 well is still in its drilling phase. The overall impact of the poor implantation of the DWM plan has not been fully scrutinized. Some issues can be discussed prior to the end of the well in preparation for a more structured plan for upcoming wells.

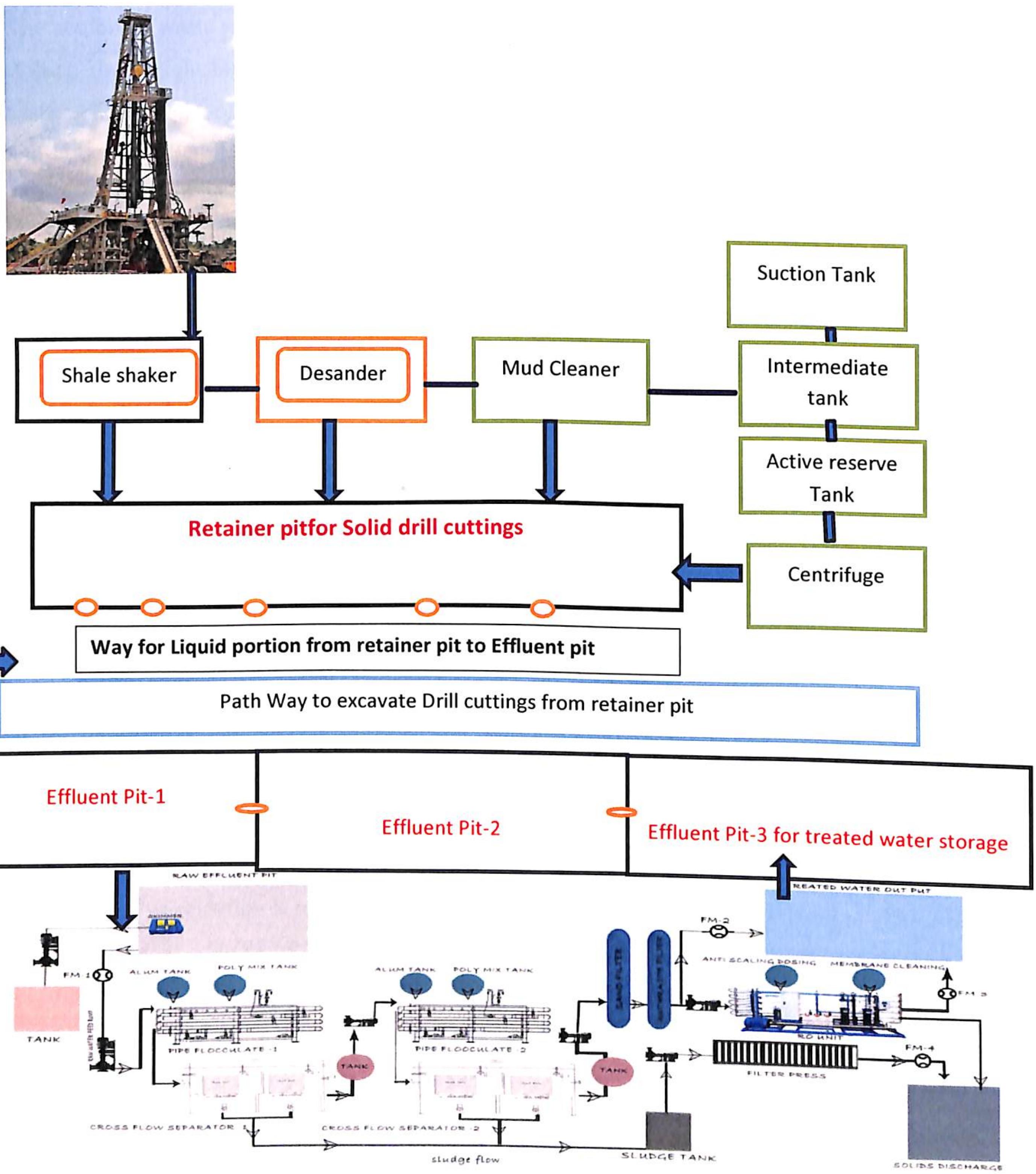
Detailed DWM program

No Detailed DWM program was ever created for the initial well. Waste and waste handling was implemented as per previous shallow wells. Longer deeper wells generate more waste quicker, require more build water and sometimes specific toxic chemicals. A DWM program can be very helpful for discussions with wellsite staff and relevant service companies and help build the basis for further optimization in an extended drilling program

Waste volumes

No waste or water recording was routinely completed. By keeping track of daily volumes we can project future requirements and routines. This routine can help to mitigate costs and ensure there are few gaps in the projected requirements for equipment and manpower.

Fig: 1.3-DRILLING WASTE MANAGEMENT AT LOCATION: THANE LANKA#1.



ETP & RO PROCESS FLOW CHART

Waste volumes

The combined waste volume of cuttings that are created while drilling and the excess or spent drilling fluid might be the best measure of performance and cost savings offered by a fluids system. The volume of spent mud determines what the mud-maintenance and disposal costs are and affects the long-term liabilities that are associated with waste disposal. Even under ideal situations, the volume of wet cuttings generated can easily exceed hole volume by a factor of two or more (three is a good rule of thumb). Minimizing the volume of spent mud and cuttings is the key to effective waste management. The increase in volume of the wet cuttings stems only partly from the added volume of cavings, washouts, or drilling a non-gauge hole. The drill cuttings that are separated from the drilling fluid on the surface by the solids control equipment. The separated drill cuttings shall be stored in retainer pit and shall be disposed through TSDF contract. Dilution was used to control solids content in the drilling fluid. The typical dilution procedure calls for dumping a portion of the active drilling-fluid volume to a waste pit and then diluting the solids concentration in the remaining fluid by adding the appropriate base fluid, such as water or fresh mud. This will increase the volume of waste water generation. Waste water shall be stored in HDPE lined effluent pits for treatment and reuse the treated water for mud preparation and cleaning purpose. ETP has the ability to treat 100 kl/day effluent water.The principal objective of wastewater treatment is generally to allow human and industrial effluents to be disposed of without danger to human health or unacceptable damage to the natural environment. The Effluent treatment is performed in following stages.

COAGULATION AND FLOCCULATION:

The object of coagulation is to alter these particles in such a way as to allow them to adhere to each other. Most colloids of interest in water treatment remain suspended in solution because they have a net negative surface charge that causes the particles to repel each other. The intended action of the coagulant is to neutralize that charge, allowing the particles to come together to form larger particles that can be more easily removed from the raw water. The usual coagulant is alum [Al2 (SO4)2• 18H2O], though FeCl3, FeSO4 and other coagulants, such as polyelectrolytes, can be used. Alum when added to water, the aluminium in this salt hydrolyses by reactions that consume alkalinity in the water such as:

$[Al(H2O)^6]\ 3^+\ 3HCO3^- \longrightarrow Al(OH)3(s) + 3CO2 + 6H2O$

The gelatinous hydroxide thus formed carries suspended material with it as it settles. In addition, however, it is likely that positively charged hydroxyl-bridged dimers such as higher polymers are formed which interact specifically with colloidal particles, bringing about coagulation. Metal ions in coagulants also react with virus proteins and destroy up to 99% of the virus in water. Anhydrous ion (III) sulphate can also act as effective coagulant similar to aluminium sulfate. An advantage with iron (III) sulphates it that it works over a wide range of pH.

FILTRATION:

The addition of chemicals for promoting coagulation and flocculation can remove both suspended and colloidal solids. After the flocs are formed, the solution is led to a settling tank where the flocs are allowed to settle. While most of the flocculated material is removed in the settling tank, some flocs do not settle. These flocs are removed by the filtration process, which is usually carried out using beds of porous media such as sand or coal. The current trend is to use a mixed -media filter which consists of fine garnet in the bottom layer, silica sand in the middle layer and coarse coal in the top layer which reduces clogging.

CROSS FLOW SEPARATOR (CFS)

The Cross flow separator system permits simultaneous separation of floating and settling materials like oils, fibres, sand etc. But are also individually applicable as oil and solids separators. The raw water containing oil and/or suspended solids passes in horizontal direction between the closely spaced plates in the plate pack. Completely laminar flow conditions are established while the water flows across the plate pack from the inlet to the outlet side. Laminar and stable flow conditions are essential conditions for the effective gravity separation of the water, oil and/or the suspended contaminants.

The CFS separator is a 3-phase separator, which is typically used as device for the separation of liquids with a density lower than water.The CFS contains a cross flow plate pack and the intercepted oil layer is skimmed off by a manually adjustable skim pipe. Heavy particles are collected and discharged via a conical bottom. Some applications are:

- Ballast water treatment
- Oil-water separation

Typical features of the CFS Cross Flow Separator:

- Very compact construction
- Easily adapted to existing constructions
- Suitable for effluents with strongly varying pollution and volumetric loads
- Large sludge cone to treat oily waste water with high amounts of sediment

REVERSE OSMOSIS:

In the reverse osmosis process, demineralization water is produced by forcing water through semipermeable membranes at high pressure. In ordinary osmosis, if a vessel is divided by a semipermeable membrane (one that is permeable to water but not the dissolved material), and one compartment is filled with water and other with concentrated salt solution, water diffused through the membrane towards the compartment containing salt solution until the difference in water levels on the two sides of the membrane creates a sufficient pressure to counteract the original water flow. The process can be reversed by applying sufficient pressure to the concentrated solution to overcome the osmotic pressure force the net flow of water through the membrane towards the dilute phase. The solute concentration (impurity) builds up on one side of the membrane while relatively pure water passes through the membrane. In order to obtain adequate solvent (water) flux through the membrane, pressures of the order of 4000 to 7000 kN/m2 are required. The RO plant manufactured by us ensures to give a high quality output ofDS in the water.

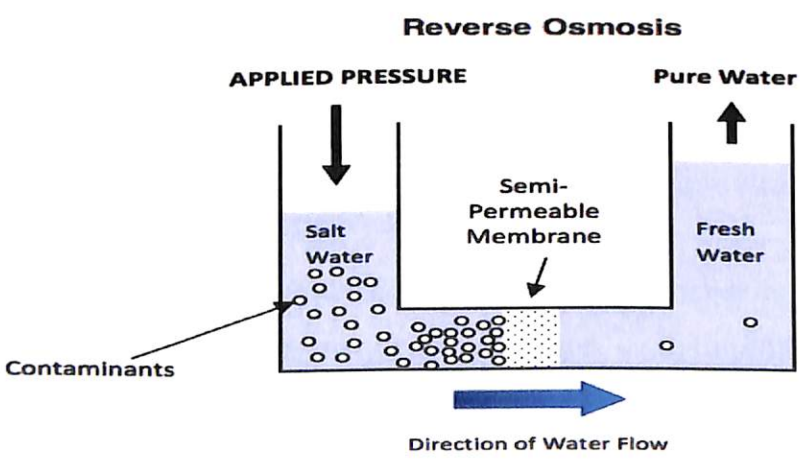


Fig 1.4 Reverse Osmosis

Features

- Low water- rejection rate
- Most modern membrane technology
- Produce high quality de-mineralized water
- Less operational and maintenance cost
- Works on the cross filtration method
- Gives a unique high quality output of TDS range
- Output water have 99.9% of pyrogens, viruses and bacteria rejection
- Excellent system efficiency.

Table: 1.2 TOTAL COST FOR DWM at Well TLK#1:

S. No	Product description	Cost in INR
1	Total cost of the Effluent treatment plant asper contract	Rs.178, 23,026.70
2	Total expenditure for TSDF contract till 18.7.16(for 3818 MT)	Rs.300,39,758.80
3	Total cost for retainer pits, effluent pits and cuttings drier pit construction	Rs. 20, 73,000.0
	Total cost of DWM contract	**Rs. 499,35,784.0**

Costs

The cost projected above are at actual as on date. Since drilling of the the well is still going on it is difficult to project the cost at the end of the well. Costs can still be analyzed at the end of the well. Running daily costing can help find pressure points for short term optimization and projections. Waste and water created and consumed can still be analysed ant the end of the well in order to establish baseline data and create future goals and objectives of waste reduction, environmental compliance and cost reduction.

1.2 Rationale of the study

Waste generated during drilling is a common phenomenon. The process of drilling oil and gas wells generates two primary types of wastes - used drilling fluids and drill cuttings. Drilling fluids (also known as muds) are used to aid the drilling process; the fluid phase can be water, synthetic or natural oils, air, gas, or a mixture of these components. Muds are circulated through the drill bit to lubricate and cool the bit, control the formation fluid pressures and to aid in carrying the drill cuttings to the surface, where the muds and cuttings are separated by mechanical means. Mud consist of a base fluid and various solid and liquid additives to allow for good drilling performance. Some of the additives introduce potentially toxic compounds into the fluids, which must be considered when the resulting wastes are managed. The main pollution of spent muds are caused by: biocides, oil, completion or stimulation fluid components, corrosion inhibitors, reservoir fluids (crude oil, brine), and drilling mud chemical components.

HIERARCHY OF WASTE MANAGEMENT: The Waste Management Hierarchy sets out a preferred sequence of waste management options. The first and most preferred option is source reduction. Source reduction is any activity that reduces or eliminates either the generation of waste at the source or the release of a contaminant from a process. The next preferred option is recycling. Recycling is the reclamation of the useful constituents of a waste for reuse, or the use or reuse of a waste as a substitute for a commercial feedstock or as a feedstock in an industrial process. Together, source reduction and recycling comprise waste minimization. The last two options, and least preferred, of the hierarchy are treatment and disposal. Effective waste management is an ongoing process within which the waste management plan can be revised as new waste management practices, or technological options of responsible disposal are identified. Over the past decades, oil and gas operators have used waste management approaches that minimize the volume and/or the toxic fraction of wastes generated, and disposal techniques that offer greater environmental protection and public safety. The three-tiered waste management hierarchy, namely waste minimization, treatment and disposal, are normally followed by the operator in their bid to control and manage drilling wastes in the most environmentally friendly manner possible.

1.3 Purpose of the study

The main purpose of the study is to critically examine the areas (in line with the hierarchy of waste management) where there is a scope for improvement with respect to managing the Drilling Waste and examining the factors which can lead to better management of Drilling Waste as per Ministry of Environment, Forest & Climate Change (MoEF&CC) guidelines matching the best or benchmark practices in the world.

The main objective of this paper is to analyze the determinants of the factors which may lead to better drilling waste management and then try to implement the same in next drilling well locations. Since the compliance report needs to be submitted to Ministry of Environment Forest and Climate Change every six month , it becomes all the more important to look into the scope of improvement and implement the same in an attempt to continually improve .

Region specific environmental requirements and constraints have also been noticed and our endeavor to comply the requirements to the full is also an aspiration.

1.4 Remaining parts of the report

Chapter 2 provides a comprehensive survey of the literature surrounding the best practices for managing the drilling waste in an effective and efficient manner not by passing the ministry stipulated regulations. Here emphasis on the areas which are the best practices worldwide for drilling waste management and the practical feasibility of the various methodologies adopted at various drilling well sites.

Chapter 3 provides the insights into the research methodology of the study. The main stress is on the practically feasible and successful methods applied worldwide. The proposed changes on the existing practices have been suggested based on the difficulties encountered while actually dealing with the subject in hand. It has been observed during the various stages of the drilling of the TLK#1 well that much needs to be done on the waste management issue as it is becoming really a big challenge to comply with the stipulated regulatory conditions. The problem has been further aggravated due to peculiar local issues.

Chapter 4 provides the analysis of the study and the alternative method of DWM that may be more effective and conforming to the MoEF&CC requirement.

Chapter 5gives the conclusion and suggestions that will be practically possible to implement with a way forward leading to positive results. Actual results can be visible only after implementing the suggested changes in near future in a new drilling location.

CHAPTER 2

LITERATURE REVIEW

2.1 Introducing the Impact of E&P Industry on Environment

The process of drilling oil and gas wells generates twoprimary types of wastes - used drilling fluids and drill cuttings. Drilling fluids (also known as muds) are used to aid the drilling process; the fluid phase can be water, synthetic or natural oils, air, gas, or a mixture of these components. Muds are circulated through the drill bit to lubricate and cool the bit, control the formation fluid pressures and to aid in carrying the drill cuttings to the surface, where the muds and cuttings are separated by mechanical means. .Mud consists of a base fluid and various solid and liquid additives to allow for good drilling performance. Some of the additives introduce potentially toxic compounds into the fluids, which must be considered when the resulting wastes are managed. The main pollution of spent mud are caused by: biocides, oil, completion or stimulation fluid components, corrosion inhibitors, reservoir fluids (crude oil, brine), and drilling mud chemical components [1]. Drilling wastes are the second largest volume of waste, behind produced water, generated by the E&P industry [2]. Operators have employed a variety ofmethods for managing these drilling wastes depending onwhatstatutory regulations allow and how costly those options are for the well in question. Onshore operations have a wider range of management options than offshore operations. These include land application, underground injection, thermal treatment, and biological remediation.

2.2 Environmental Impacts

Many of the wastes associated with oil and gas well drilling activities have the potential to impact the environment. The physical and chemical properties of the drilling wastes influence its hazardous characteristics and environmental impact ability. The most common measure of the potential environmental impact of a material is its toxicity. The potential impact depends primarily on the material, its concentration after release and the biotic community that is exposed. This also depends on the length of exposure to a substance. Exposure that causes an immediate effect is called acute, while repeated long-term exposure is called chronic. Most concentrations encountered during drilling activities are relatively low, therefore the environmental impact is generally observed only after chronic exposure.Also, the heavy metals associated with the constituents of drilling fluid additives are of concern, although their potential to leach away from the pit and contaminate the groundwater is limited by their low concentration and low solubility [4]. A number of studies have been conducted on the impact of these elements [5].

2.3 Regulation Requirements

Any waste materials which have the ability to cause cancer, and/or its toxicity to humans and other ecosystems are specifically regulated by a governmental authority. In the absence of governmental regulations, guidelines issued by relevant international or regional organisations are usually used.Because of this, the discharge of spent drilling mud and their associated cuttings is prohibited in many areas around the world with competitive advantages.

2.4 Hierarchy of Waste Management

The Waste Management Hierarchy sets out a preferred sequence of waste management options. The first and most preferred option is source reduction. Source reduction is any activity that reduces or eliminates either the generation of waste at the source or the release of a contaminant from a process. The next preferred option is recycling. Recycling is the reclamation of the useful constituents of a waste for reuse, or the use or reuse of a waste as a substitute for a commercial feedstock or as a feedstock in an industrial process. Together, source reduction and recycling comprise waste minimization. The last two options, and least preferred, of the hierarchy are treatment and disposal.

Effective waste management is an ongoing process within which the waste management plan can be revised as new waste management practices, or technological options of responsible disposal are identified.

Over the past decades, oil and gas operators have used waste management approaches that minimize the volume and/or the toxic fraction of wastes generated, and disposal techniques that offer greater environmental protection and public safety. The three-tiered waste management hierarchy, namely waste minimization, treatment and disposal, are normally followed by the operator in their bid to control and manage drilling wastes in the most environmentally friendly manner possible.

2.5 Waste Minimization

One important method for minimizing the amount of potentially toxic wastes generated is to use less toxic materials for the various operation processes. In the 1990s, drilling fluid companies devised new types of fluid that used non-aqueous fluids as their base. The base fluids included internal olefins, esters, linear alpha-olefins and linear paraffin. These Synthetic-based muds (SBMs) share the desirable drilling fluid properties of Oil-based muds (OBMs) but are free of poly-nuclear aromatic hydrocarbons and have lower toxicity, faster biodegradability and lower bioaccumulation potential. Use of SBMs results in a cleaner hole with less sloughing and they generate a smaller cutting volume and can be recycled where possible. A variety of new water-based muds (WBMs) are being developed as possible substitutes for OBMs. The additives for these muds have included various low-toxicity polymers and glycols [10].

Many of the additives used in the past for drilling fluids have contained potential contaminants of concern such as chromium in lignosulfonates. Also, barite weighting agents may contain concentrations of heavy metals such as cadmium or mercury. The use of such additives has diminished.

Pit burial is a low-tech method that does not require wastes to be transported away from the well site, and, therefore, is very attractive to many operators.

2.6 Land farming

Land farming involves spreading the waste on a designated area of land and working it into the soil. The objective of applying drilling wastes to the land is to allow the soil's naturally occurring microbial population to metabolize, transform, and assimilation waste constituents in place. It may be safely utilized as a means of immobilizing and biodegrading many oilfield wastes. Soil loading capacity must be known and should not be exceeded in order to maintain aerobic condition at site.

2.7 Thermal desorption

Thermal desorption process applies heat directly or indirectly to the wastes, to vaporize volatile and semi volatile 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 [16]- [18].

2.8 Deep-well Injection

This is a waste disposal technique where drill cuttings and other oilfield wastes are mixed into slurry. The resulting slurry is then injected into a dedicated disposal well where it is contained in the pores of permeable subsurface rocks far below freshwater aquifers. The primary disadvantage of this option is the possibility of freshwater contamination due to casing failure. Availability of the disposal option is also limited to certain geological setting. It is environmentally preferred when rock formations allow.

2.9Vermiculture

Vermiculture is the process of using worms to decompose organic waste into a material capable of supplying necessary nutrients to help sustain plant growth. For several years, worms have been used to convert organic waste into organic fertilizer. Recently, the process has been tested and found successful in treating certain synthetic-based drilling wastes [19]. Researchers in New Zealand have conducted experiments to demonstrate that worms can facilitate the rapid degradation of hydrocarbon-based drilling fluids and subsequently process the minerals in the drill cuttings [20]. Because worm cast (manure) has important fertilizer properties, the process may provide an alternative drill cutting disposal method.

3.0Waste Management Strategies

Successful implementation of waste management plan requires that the operations personnel generating and handling the wastes should be communicated adequately as to the available options there is to effectively manage waste. Table VI present a typical drilling waste management strategy. The application of each hierarchy theoretically diminishes the quantity of residual waste that ultimately requires disposal. The first and most important action in the waste management hierarchy is to reduce the volume of waste generated. The next is to recycle or reuse the wastes or materials in the wastes. Only after these should the remaining wastes be treated and disposed. By following this hierarchy, both the volume of waste to be disposed and the ultimate disposal cost will be minimized.

F1: WASTE MANAGEMENT HIERARCHY

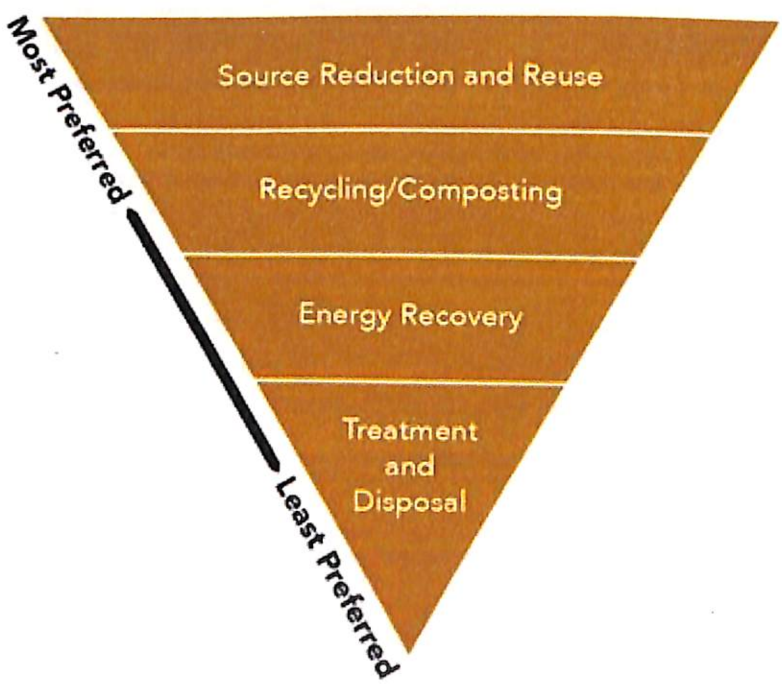


Fig: 2.1 – Depicting Hierarchy of Waste Management

Table 2.1 Literature Survey

	TITLE	PUBLISHED IN	AUTHOR/s
1.	Drilling Wastes Generation and Management Approach	International Journal of Environmental Science and Development, Vol. 3, No. 3, June 2012	S. I. Onwukwe and M. S. Nwakaudu
2.	Environmental Management In Oil And Gas Upstream Industry In India	Jr. of Industrial Pollution Control 30(1)(2014) pp 59-66 © EM International	PULAK DAS
3.	The Cutting Edge in Drilling Waste Management	M I Swaco, Houston Texas	Thomas Geehan, Allan Gilmour and QuanGuo
4.	Weatherford Drilling Waste Management Services	Information Brochure	--

CHAPTER-3
RESEARCH METHODOLOGY

3.1 Introducing Research

Research comprises defining and redefining problems, formulating hypothesis of suggested solution; collecting, organizing and evaluating data; making deductions and reaching conclusions to determine whether they fit the formulating hypothesis.

3.2 Research Problem

The research problem isto evaluate alternative technique for managing drilling waste in terms of cost and efficiency.

3.3. Research Question

(i) What is the cost and efficiency of existing practice of managing drilling waste vis-à-vis alternative method?

(ii) What is the alternative for managing drilling waste to be adopted at KG Basin?

3.4. Research Objective

(i) To analyze cost and effective method (in terms of benefit of existing practice) for managing drilling waste .

(ii) To suggest cost effective method of managing drilling waste.

3.5 Research Methodology

(i) Exploratory research- acquire data from existing well-site.

The system of collecting data for research projects is known as research methodology. The data may be collected for either theoretical or practical research for example in the present case, the observations in the present drilling location and the problems faced has been analyzed deeply in consultation with the service providers and the consultants and a strategic methodology has been devised and suggested . The efficacy of the suggested methodology will be clear when applied in future well.

A literature study was done to comprehend the context of multidisciplinary fields involved and to provide a clear practically feasible framework as the basis of which the desired relationship between existing and proposed waste management techniques can be established.

(ii) Exploratory research- using semi structured interview.

Semi structured interview was conducted with the service providers of DWM and the HPHT consultants. Additionally case studies were discussed with service providers and our consultants from RPS Inc. for HPHT well. After considering various options threadbare, an alternative but practically feasible DWM method has been suggested which has been observed to besuccessful in Canada and other parts of the world.

CHAPTER-4

FINDINGS AND ANALYSIS

After carrying out exploratory research within the available resources from the drilling waste management practices being followed in the existing drilling well at TLK#1 and subsequent semi structured interview with the service providers and the consultants from the HPHT well, the following pages briefly describe the suggested alternative DWM method which may be followed in next HPHT well.

4.1 Purpose of the study

As with any waste management program the purpose is to reduce waste, costs and give a structured approach to handling waste. This program deals specifically with waste handling in the land based KG basin drilling project operated by Oil India Limited.

The following represents the goals and objective of this program:

- Reducing waste (materials, time, money)
- Managing the interaction of fluids, solids control, waste management and waste disposal
- Aligning service company objectives with Oil India
- Ensuring quality delivery of services
- Teamwork
- Planning well construction & operating procedures
- Continuous improvement, lessons learned

4.2 Equipment and Materials Required

Most of the equipment required for this project is already available onsite or is available from aroid Drilling Fluids (Halliburton) via the Drilling Fluids, Solids control and Waste management contract awarded to Baroid by Oil India.

Equipment required:

- Rig shakers

- Three sided shale cuttings bins(s)
- 3 variable speed centrifuges (Brandt 2172 two on location, one enroute)
- Polymer injection tank (dosing tank)
- Rig Vacuum system (Optional)
- Mud/water transfer pumps
- Rig tanks
- Dedicated Dewatering tank with hopper
- Effluent Treatment Plant (ETP)
- Reverse Osmosis Equipment (RO)

Materials Required:

- Dewatering coagulants
- Flocculation polymers
- Filters and consumables for ETP and RO units

4.3 Operating Procedures

Mud System

To reduce water consumption and waste it is paramount to keep mud system volume as low as safety allows. Effort should be made to manage volumes prior to mixing new volume and especially as the well section comes to an end. In these wells, mud volumes can become large when running casing and cementing sections leading to issues of surface storage in the rigs tanks. Consider the following:

- Try and manage excess volumes before the end of each section
- Look forward to the next section to see which mud system are to be used, where to store volumes while dewatering and build drilling fluids,
- It may be necessary to delay build new fluids while the previous sections fluids are being treated
- Try and conserve water by reusing and recycling recovered water first

Surface Hole (26in)

Reduce surface volumes to minimum amount required to drill this section. Total mud volume in the hole is estimate at 1422bbs with 10%-hole washout, surface volume should be kept to 600bbl total active circulating with an additional 300bbl contingency premix of LCM.

At the end of this section, strip the drilling fluid back to water and solids via dewatering process through the centrifuges, polymer injection tank and specialty chemicals as per the dewatering operations below. Recovered water can be save for build volume for the next mud section and dry solids stored in a segregated berm area or hauled to landfillas per regulations.

1st Intermediate Hole (18.5 u/r to 20in)

This section will use recycled water from the surface hole as a base in order to save on water. Total mud volume in the hole is estimated at 2294bbl with a 10% washout, surface volume should be kept to a maximum of 1000bbl circulating with a 300bbl pre-mix contingency for LCM (this could be the same contingency as the surface hole if it was not used).

At the end of this section continue to run the centrifuges so that as many LGS can be removed as possible, target for LGS is less than 5% or better. This drilling fluid will be saved and used for build volume for the next section.

2nd Intermediate Hole (14.75 u/r to 16in)

This section will start by using processed drilling fluid from the 1st Intermediate hole section, extra volumes and water will be need to make fresh fluid as required to complete the section. Total mud volume in the holethis section is estimated at 2603bbl with a 10% washout, surface volume should be kept at a maximum of 1000bbl active plus contingency.

At the end of this section, strip the drilling fluid back to water and solids via dewatering process through the centrifuges, polymer injection tank and specialty chemicals as per the dewatering operations below. Recovered water can be save for build volume for the next mud section and dry solids stored in a segregated berm area or hauled to landfill as per regulations.

1st Production Section (12.25in)

This section will require a new volume of mud to be built for the HTHP drilling. Initially recovered water from the dewatering process from the previous section will be used for build volume; extra water can be added as required. Total mud volume in the hole in this section is estimated at 2296bbl with a 10% washout, surface volume should be kept at a maximum of 1200bbl active plus contingency.

2nd Production Section (8.5 in)

This final section will require the drilling fluid recovered in the previous section. This system may have to be weighted up to 16ppg so constant processing via the centrifuges in barite recovery mode is essential to control LGS. Total mud volume in the hole this section is estimated at 1224bbl with a 10% washout, surface volume should be kept at a maximum of 1200bbl active plus contingency.

After this section is drilled all drilling fluid is to be stripped of barite and dewatered. At this point it may be prudent to either save the dewatered volume for the next well or dispose of as Government regulations allow.

Volumes Summary

The following table summarized expected fluid volumes in the hole and tanks, it does not consider dilution additions or water lost via evaporation or via wet cuttings, only what the circulating and surface tank volume should be maintained at.

Mud Volumes	Surface Tanks Maximum Volume (bbl)	Contingency Volume LCM (bbl)	Casing plus Hole Volume Estimate	Total surface Volume	Total Mud Volume
Surface hole	600	150	1422	750	2172
1st Intermediate Hole	1000	150	2294	1150	3444
2nd Intermediate Hole	1000	150	2603	1150	3753
1st Production Hole	1200	150	2296	1350	3646
2nd Production Hole	1200	150	1224	1350	2574

Table 4.1: Drilling Fluid Volumes Summary Per section

Drilling Waste

Drilling waste is a constantly accumulating during the drilling process. Waste must be handled as it is created in order to prevent environmental issues and logistic confusion. Drilling waste on this project consists of:

- Solids Waste: This is a combination of waste from downhole cuttings and solids added to the fluid (such as Barite, Calcium Carbonate or Bentonite). These types of waste need to be cleared from the cuttings tanks below the shakers and moved to flat berm areas as quickly as they can to prevent interference with drilling operations.
- Water Waste: This is water recovered from the dewatering and effluent treatment process that cannot be recycled and reused and fails government regulations for pump off disposal. This type of water waste is stored into impermeable lined pits and left to evaporate. Material left behind from the evaporation process is collected and hauled to approved landfill as regulations allow.

Solid Waste

Solid waste are cuttings from the end of the shakers, effluent from the centrifuges and solids such as barite and bentonite added to the drilling fluid and recovered via the dewatering process. The Following table represents the approximate volume we can expect per well in the KG Basinassuming an expansion factor of two times hole volume, actual numbers may be greater or less:

Waste Volumes	Cuttings Waste Estimate (bbl)	Max Expected MW (ppg)	Barite and other mud solids Waste Estimate (bbl)	Total Waste Estimate
Surface hole	2844	10.5	80	2924
1st Intermediate Hole	3225	11.5	0	3225
2nd Intermediate Hole	2692	12.5	585	3277
1st Production Hole	1420	16.0	0	1420
2nd Production Hole	304	16.0	739	1043

Table 4.2: Estimated Solids Waste Per Section

Most of the solids will be recovered from the shale bins. Handling of cuttings is done with a front end loader or back hoe. Cuttings are transported to berm pits via the front end loader and segregated by hole section. Once berm areas become filled, transportation is arranged to haul them to approved disposal facilities. For this project two berm areas are required.

Berm Areas

A berm is a raised area that separates two areas, like an open topped earthen storage tank. Berm areas must be constructed to hold solids waste until there is enough waste to call out waste hauling transportation. These areas will also help to dry out the solids waste prior to transportation. Since most of the solids waste will be somewhat wet, the berm areas must be impermeable below the surface of the berm area floor.

Two berm areas will need to be constructed for this project. Each must include the following:

- Impermeable liner under the flat gravel bed top to prevent seepage of fluids into the soil
- Enough volume to hold 3300bbls of cuttings (~530m^3), for example 20m x 20m x 1.5m would be appropriate
- An opening in the berm wall at least 4m wide for the drilling rig front end loader to maneuver through
- The berm wall opening should still be slightly higher than the berm floor to prevent excess water from flowing out the berm area (~ 20cm is appropriate)

Water Waste

Water will be recycled and reused as much as it is practical. Drilling fluid will be stripped down to solids and liquid via the below dewatering process and then if required run through an Effluent Treatment Plant (ETP) and Reverse Osmosis (RO) equipment to maintain the cleanest water for use on the wellsite. Inevitably there will be some water that is not treatable and will have to be disposed of.

Water that is reused on the rig site will be stored in the rig tanks and clean water pit as required. The clean water pit will also act as a heat sink for the mud cooler on location so this pit must be kept full of water from the 1st production section to the wells completion.

In order to handle the expected volumes of water both waste water and reusable water at least two separate water pits will be required, one for treated reusable water and another pit for waste water that cannot be used. These pits should follow these parameters:

- Have an impermeable lining installed so no fluids can escape to the groundwater
- Large enough to handle a full hole section of recovered fluid; for this project pits should be a minimum of 3400 bbls or 550m^3
- Have room for the ETP and RO equipment to setup nearby
- Pits should be at a minimum 10m from any part of the drilling rig equipment on location to facilitate the movement of heavy equipment around the drilling rig as required.

Solids Control Equipment

Shakers (all sections)

The drilling rig is equipped with 3 derrick flo-line shakers and 1 derrick mud cleaner/desander unit.

For this project the mud cleaner/desander unit must not be used. The presence of the dual centrifuges makes this unit unnecessary. The desander and desilter cones on this can be bypassed and the unit used as a regular shaker.

Use the following parameters while circulating fluid and drilling

- Run the finest screens possible on shakers.
- Ensure shakers are in a level condition, both solids and volume capacities will be reduced if a shaker is not level.
- Provide the proper voltage to the motor, low voltage will reduce motor life.
- Provide proper frequency, low frequency reduces vibrating motion and capacity of the shaker.
- Ensure the vibrating motion is rotating in the proper direction, the top of the shaft should rotate toward the solids discharge end.
- All screens on the shakers should be the same mesh size right across.
- Ensure the screen cushions are installed as per manufacturer's specifications to optimize screens life.
- Ensure the screens are properly tension if not using pre-tensioned screens.
- Wash screens off during trips or periods of inactively, ensure wash water goes through the screens and not of the discharge end of the shaker in order to conserve water.
- Do not dress the shakers finer screens at the front and coarser at the end. Shakers are only as good as the coarsest screen.
- Nominal shaker performance requires fluid travels half way down the last screen panel. If possible, screen up to finer screens if the fluid line does not travel to this point.

- If lost circulation occurs, by-pass shakers. Re-engage the shakers as soon as is practical after curing lost circulation. Lost circulation is the only time the screens should be bypassed; do not bypass screens on trips.

Centrifuges

The centrifuges are very important in controlling unwanted low gravity solids. Also they can be used at the end of some sections to dewater unneeded drilling fluid and recover usable water. The centrifuges have large capacity and triple variable (variable front drive, back drive and feed rate). Three Brandt 2172 high volume centrifuges should be provided as per the contract.

General Centrifuge operating guidelines:

- Always keep shrouds and belt guards in place
- Rotate the bowl by hand to ensure smooth free operation with no drag
- If the centrifuge starts to vibrate or has some unusual noise lube the bearings
- Allow the centrifuge to get up to operating speed prior to starting the feed pumps
- Do not overfeed the centrifuge. Signs of overfeeding: Safety torque mechanism frequently disengages, unit packs off, very wet solids in the underflow
- Reduce feed for heavily weighted or viscous mud
- Ensure the barite return tank is properly agitated

Surface Hole: Run two of the centrifuges in parallel at high speed with a low back-drive differential and maximum flow rate during surface hole.These machines will both be connected to the rig tanks as per Figure 4.1.

One centrifuge will be dedicated to dewatering and can be located at a convenient point near the de-watering rig tank and chemicals (as per dewatering section below)

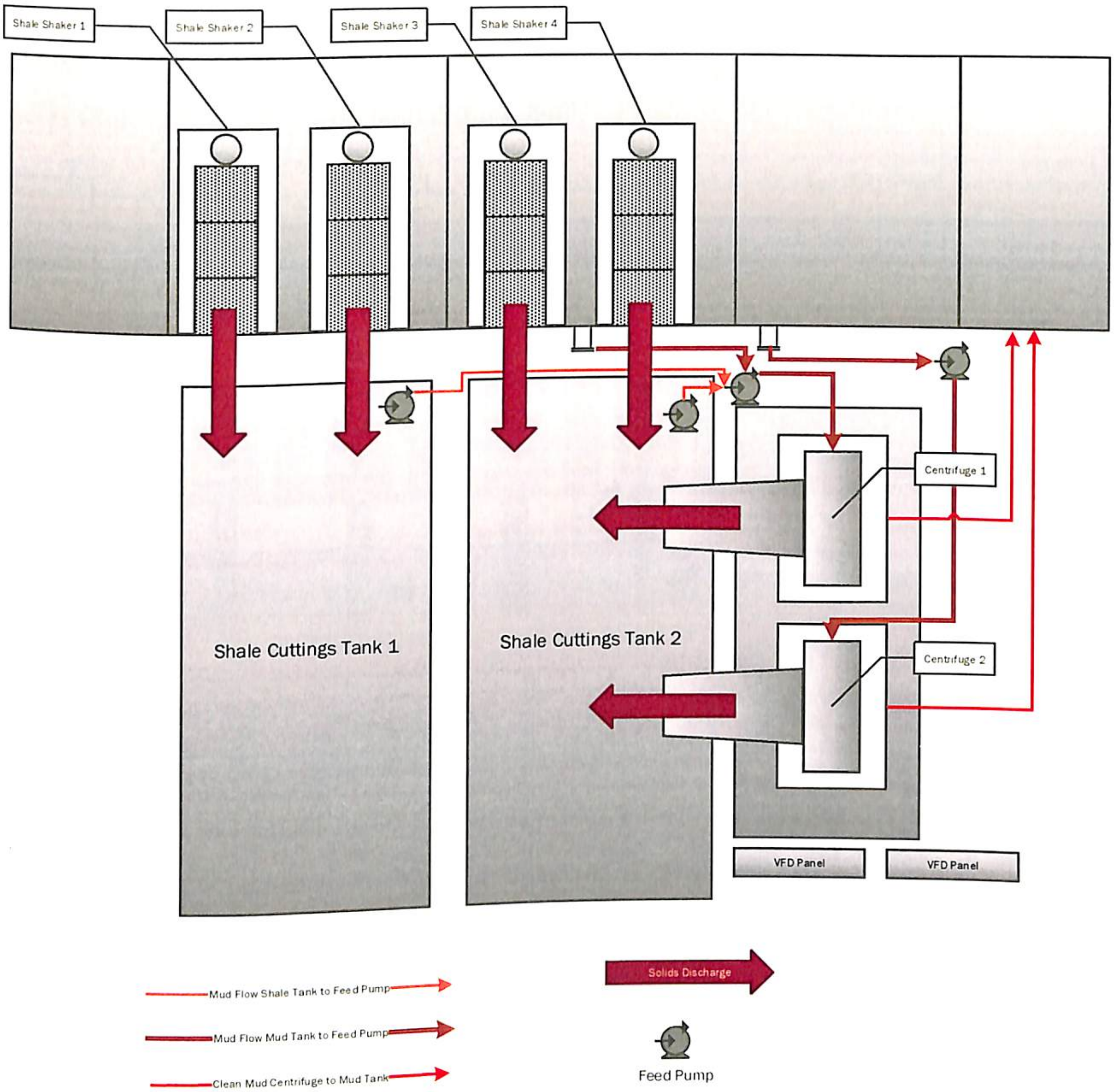


Figure 4.1: Centrifuges set up in parallel

Intermediate through to production sections: Centrifuges must be operated in series for barite recovery/LGS control while using weighted fluid(See Figure 3.2). As drill solids are a constant contamination while drilling, the centrifuges rigged to the rig tanks should be used at all times except while circulating freshly built drilling fluid.

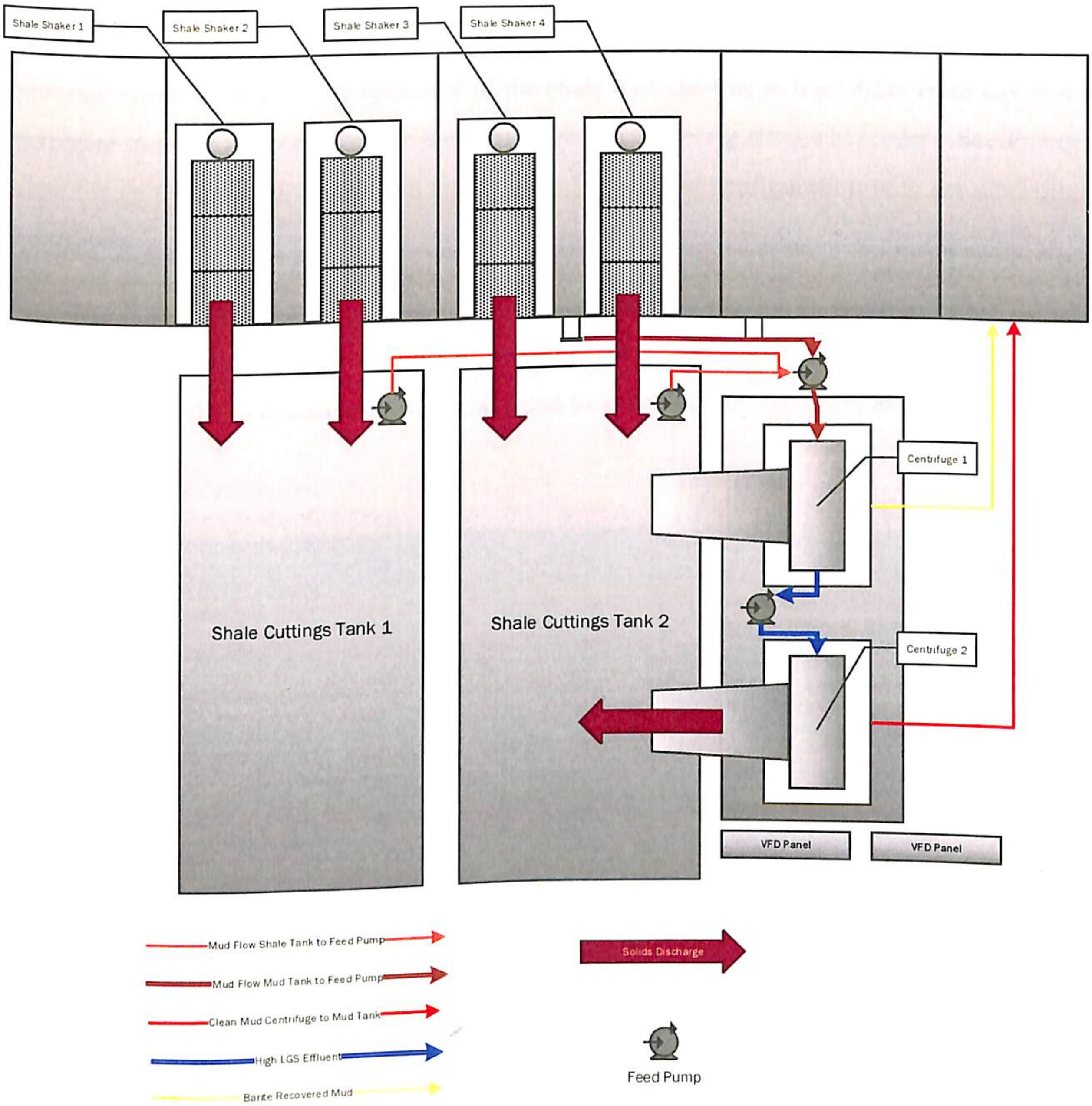


Figure 4.2: Centrifuges Operated in Series

Shale bin –three sided (2)

Cuttings will be collected in two shale bins located behind the shakers. These bins must be at least ~5m wide to accommodate the width of the drilling rig front end loader and 10 – 12m in length. The height of the walls should accommodate the rig and centrifuge slides. The shale bins should be dug slightly into the ground near the shakers (~50cm) as to provide a slope to prevent liquids from escaping out of the open end. A slight ramp at the open end will also help to prevent liquid seepage. The open end of the shale bins must be at least 8.5m from any pits or equipment in order to accommodate the turning radius of the rig front end loader. See Figure 3 below for an example of a shale bin and figures 1 and 2 for configuration with the centrifuges and shakers.

The shale bins should have trash pumps or a vacuum unit nearby in order to pump out any drilling fluid or water that may inadvertently be present in the ends. Every effort should be made to minimize any fluids entering the shale bins and to keep the cuttings as dry as possible.

Figure 4.3: Example of a Three Sided Shale Bin

Various pumps as required

Trash pumps, screw pumps, flight pumps and air pumps should be readily available as required to move fluid around the rig. Excess water and drilling mud must be dealt with promptly before the issue becomes serious; pump spilled drilling mud into the shaker distribution box promptly and spilled water can be processed through the EPT and RO units as required. No spill is too small to deal with immediately.

Cement

Cement design should be such that no returns are seen at surface. In the case of returns, they should be stored in the segregated cement sump on location, do not mix drill waste or water waste with cement returns. Once excess cement hardens in the segregated cement sump it can be broken up with a back hoe and hauled to an approved facility for disposal. If cement does not harden than add any sloppy material to waste drilling fluid during the dewatering process.

Water and Wash Water

Record daily volume of water (cubic meters) hauled in for rig use. Try to keep wash water to a minimum. Use brushes and wash guns. Recycle wash water where opportunity and equipment allows with the available EPT and RO system.

Drilling Fluid Waste (Dewatering)

All liquid drilling fluid waste must be dewatered appropriately, water recovered and reused as required for build volume for drilling fluid and general use around the drilling rig. A dedicated centrifuge will be on location with polymer injection tank and separate storage tank containing centrifuged drilling fluid (See Figure 4), the storage tank should have a dedicated hopper for coagulant feed. After dewatering is completed then the fluid may be sent through to the ETP and RO equipment if required. Typically dewatered fluid can be reused up to three times before being treated via the ETP and RO equipment. Pilot test drilling fluid with recycled water prior to mixing up large volume of drilling mud. A typical dewatering process is described below.

1. Add Centrifuged drilling fluid (barite taken out) to storage tank, slowly add prescribed amount of coagulant through the mixing hopper

a. Coagulant will help to form "flocs" in the drilling fluid, these flocs will be fed in to the centrifuge vis a feed pumps simultaneously with a flocculating polymer (Cationic or anionic as required for each mud system)

b. Samples of drilling fluid will need to be jar tested prior to dossing to ensure effectiveness of the dewatering process, this can be done prior to the dewatering schedule

c. Variable section of coagulants should be on location, it is not uncommon to add two separate coagulants in order to be effective (i.e. Calcium Nitrate and Lime are common coagulants that are very effective with Gel Based drilling fluids); typical coagulants include:
    i. (Ammonium) Calcium Nitrate
    ii. Calcium Sulphate
    iii. Ferric Chloride
    iv. Lime
    v. Soda Ash

d. A variable selection of flocculantswill need to be on location. High charged cationic acrylamides are effective for polymer based fluids, neutral and anionic charged acrylamides are typically effective for gel based and high clay content fluids. Typical flocculating polymersinclude:
    i. Zetag 7587 (High Charged Cationic)
    ii. Alkapam 1103 (High Charge Anionic)
    iii. Alkapam 1003 (Neutral charged acrylamide)

2. If the clean water produced from the dewatering process has been tested and requires further treatment the process it through the Effluent Treatment Plant (ETP) and Reverse Osmosis (RO) equipment as required.

See Figure 4.4 for visual view of equipment configurations for dewatering.

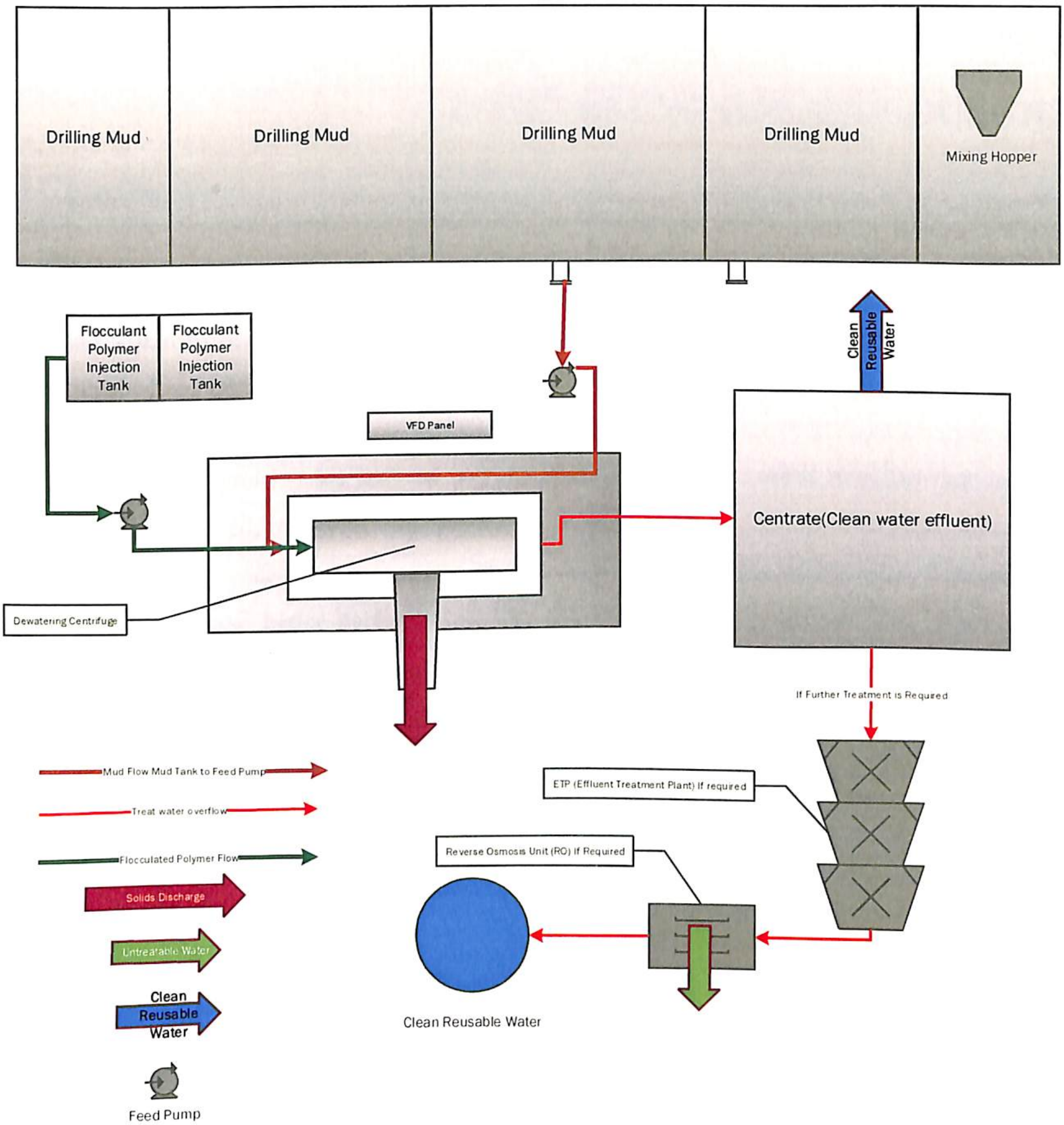


Figure 4.4: Dewatering Configuration Detail and Recycling Setup

CHAPTER 5

CONCLUSION AND SUGGESTIONS

5.1Conclusions

New technology and process has led to great step changes in controlling waste both in terms of costs and volume. Similar projects in other jurisdictions have seen cost reductions in the neighbourhood of 30% or more just by awareness and simple process control. The best conclusion is that a proper drilling waste management plan will reduce both costs associated with drilling waste and great reductions in volumes of total waste. Other benefits can include reduction of water used, recycling of clean fluids for other projects, less trucking required to haul material, less environmental impact, and a greater awareness and control of waste. This leads to greater confidence and better performance. The cycle of review, implement and optimize can continue until an endpoint setting a technical limit that can only be optimized by further technology breakthroughs.

5.2 Suggestions:

The key to any such program is to remain vigilant. Consider all the steps in the process and all the recommendations from field staff doing the actual operations right through to seasoned engineers and waste management experts. Each project will have its own set of unique problems and solutions that experience with previous project will aid in solving. Waste management succeeds when all involved parties "buy in" to the new process by seeing actual positive results. Detailed waste management programs, benchmark targets, quality equipment, and quality personnel, are the key; cost savings, reduced waste and environmental stewardship are the rewards.

CHAPTER 6

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