AADE 01-NC-HO-19

# Using a System Cost Analysis to Quantify Drilling Fluids and Solids Control Costs

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## Abstract

A System Cost Analysis is a methodology used to quantify drilling fluid costs to a common value, the monies spent/saved which are impacted by the mud system. Traditionally, most drilling fluid vendors and operators are concerned only with the actual costs of the mud materials, trucking, etc.. These "costs" only provide a minor piece of the total impact which mud has on the total well drilling costs. The System Cost Analysis provides a more complete picture of drilling fluid costs by considering both the material costs and actual time lost and/or gained due to the fluid. In addition, production data is readily included in a System Cost Analysis to ascertain the amount of impairment seen in the drilling process.

Items considered in an analysis include lost time due to mud related problems such as lost circulation, borehole instability, inability to log properly, ineffective solids control, etc.. In addition, drilling fluids can have a positive/negative impact on time by increasing/decreasing ROP's; the System Cost Analysis fixes a dollar value to this important variable.

The measurement method provides a framework for measuring both past, present and future performance of drilling fluid performance in a given study area. This paper describes how a System Cost Analysis is done and gives examples of analyses completed on projects in Western Canada and South America.

## Introduction

Over the last number of years, the quantification of drilling costs has been rising dramatically, especially in offshore and remote locations. As a result, a number of studies have been published on quantifying those costs in order to both understand where the dollars are being spent and where savings potential exists.[1-4]

While drilling fluids normally account for a relatively small percentage (< 10% normally) of a well cost, they are directly involved in a large number of the costs incurred on a well. This is especially true for borehole instability where the correct drilling fluid choice can eliminate problems, or conversely lead to large cost overruns. Similarly, improper handling of solids control equipment can lead to massive wellbore problems and needlessly expensive drilling costs.

This paper will describe the use of a "System Costs Analysis" methodology to quantify the actual costs of a drilling fluid on the actual costs of drilling a well. The analysis looks at more than just the material costs of mud products. It also focuses on the problems associated with poor drilling fluid performance and on the benefits of that drilling fluids can provide in drilling wells faster.

## System Cost Analysis Methodology

A System Cost Analysis (SCA), in basic terms, equates all incidences on a well impacted by drilling fluids, either positive or negative, back to a fundamental value – dollars and cents. The analysis attempts to remove the "fuzzy" qualitative feelings often associated with drilling, items such as "trying hard, unforseen circumstances, bad luck, etc.". While there will always be some qualitative measurement needed to reflect trust and honesty on the multidisciplinary task of drilling a well, the System Cost Analysis provides a quantitiative measurement tool. This tool is a direct measuring stick on how well an operator and service company perform.

The simplest version of a System Cost Analysis for drilling fluids is determined in one simple equation:

*System Cost = Material Costs + Unproductive Time*

This System Cost has been further refined, as will be discussed in the following section.

The material costs are quite simple, the costs of the drilling fluids added to the well, plus any associated costs as required for trucking, engineering services, etc.. It is generally common for drilling fluid companies and the contribution of fluids to be evaluated on this "material cost" alone.

The unproductive or problem time for drilling fluids involves any drilling function that has to do with drilling fluids. A list of items is given in Table 1. Reaming and cleaning, lost circulation, stuck pipe and mud rings are just some of the items included in the trouble time cost.

The actual dollar value of the trouble time cost is governed by the rig cost, usually determined on an hourly basis.

In practice, the rig cost is agreed upon by the operator and drilling fluid provider prior to the commencement of the analysis. Any additional items to be covered in the trouble time costs are also agreed upon by the parties involved.

## System Cost Analysis Methodology - Enhanced

Quantitative measurement of drilling fluid performance is only one step in the process of how mud impacts on the well performance and costs. Three additional items may be included in a System Cost Analysis. First, drilling fluids will certainly impact the time to drill as seen in rate-of-penetration (ROP). ROP's will vary greatly depending upon densities, viscosities and filtration control properties. Solids control and disposal costs are directly related to mud types, especially in offshore and environmentally sensitive regions. Thirdly, the production of hydrocarbons from wells and fields may be included if formation impairment is a real possibility.

Therefore the expanded System Cost equation is:

*System Cost = Material Costs + (Trouble Time*hourly rig cost) + ROP impact + solids control/disposal + production*

For example, comparison of water-based and oil-based fluids by only the material costs only will invariably show that water-based fluids cost less. The SCA may provide a different answer once unproductive time, ROP, solids/disposal costs and production data is included.

## Benefits of a System Cost Analysis

System Cost Analyses can be done for any drilling project, but are best utilized in areas where drilling is troublesome and where a number of wells have previously been drilled. In order to provide a relevant analysis, ideally the wells included in the study should be less than two years old. Wells older than this tend drill somewhat slower (and are more costly) because of the changes in technology (bits, MWD, etc.). In addition, the wells used in the study should be of similar deviational design and pass through similar lithologies since wellbore trajectory plays a major part in well costs.

Drilling fluids system costs analysis are primarily used for the following applications:

- *Benchmarking*: Drilling in troublesome areas often involves problems with borehole instability. A number of drilling fluids are often used to alleviate that instability with varying degrees of success. The System Cost Analysis provides a means of determining which drilling fluid, casing design, etc. is the most efficient fluid to use. In addition, benchmarking provides a dollar value on the problems which are most acute in the drilling region. A risk cost analysis at this stage provides an excellent tool for determining which drilling fluid and casing design is optimum for drilling difficult, expensive wells.
- *Measuring change*: Benchmarking in itself is a good tool to determine the optimal method of how a well/area is drilled now. Most times in difficult drilling areas, the benchmarking exercise provides a tool for indicating where improvements need to be made and then provides a method of measuring those changes. The real beauty of a dedicated system cost analysis is in the cooperation of the drilling fluid supplier to lower the overall well costs to the operator by the cost effective means of mud technologies and practices. Measuring change provides a method of accomplishing this objective in a quantifiable organized manner.
- *Production measurement*: Drilling fluids are the first fluid to contact the native reservoir and often have a large impact on the formation impairment of a well/field. The System Cost Analysis is easily modified to include the fluid costs as well as the production numbers in a field. This type of analysis is ideal for fields where different mud types are being used and/or horizontal and vertical wells have or will be drilled.

## System Cost Analysis - Examples

1. *Chicken/Route Area – Western Canada*
   The Chicken/Route area of the Alberta Foothills (Figure 1) is characterized by instability problems leading to some reaming and cleaning, but primarily an inability to get logs to bottom. A system cost analysis of 38 wells in the field was undertaken to determine the root cause of the problem, whether different drilling fluid types have helped this problem, whether the problem was localized to a certain portion of the field, and to determine if any improvements could be made to the drilling fluid and drilling practises. Typical well design in this field is to drill with flocculated water as deep as possible

(usually about 3600-3900 feet) and then mud-up to either a gel-polymer or $K_2SO_4$-gel mud system to TD around 5300 feet.

Figure 2 shows the wells in which logs either bridged on first (or more) attempts and wells in which no logs were obtained. Also on this area map is an indication of where major lost circulation occurred. As can be seen, logging problems were evident on 23 of the 38 wells in the study. These problems are evident in the system costs per foot seen in the wells as shown in Table 2 and Figure 3. Wells with the bridging problems always had greater system costs than those without the problems. Note that the data is given per foot to normalize the data and is only for the main hole section where mud was in the hole.

Following completion of the data gathering and analysis phases of the SCA, a number of conclusions and recommendations were made, including:

- Wells in the 62-8 sector were generally trouble free as seen by the system cost being twice the material cost. This "twice value" or less of system cost over material cost is generally seen for land-based wells experiencing only minor problems.
- majority of lost time which increased system costs were due to logging difficulties as caused by poor hole conditions. Logs normally bridged somewhere in the water drilled section of the well between 2625 and 3275 feet.
- A direct correlation existed between logging problems and mud-up depth in which wells which mudded-up deeper than 3925 feet were most likely to experience logging problems. For future wells, recommendations to drill no deeper than 3900 feet with water were made.
- For all wells in area study, recommendation was made to use silicate sweeps while floc water drilling to stabailize the wellbore.
- Recommend drilling wells in 62-8 sector with simple gel polymer mud systems previously used. In all other areas, an inhibited fluid with K+ as provided from $K_2SO_4$ was recommended.

The recommendations were implemented in the field over a series of wells. The results from some of the wells are shown in Table 3. All of the newly drilled wells successfully ran logs to bottom on the first attempt and hole problems due to wellbore instability were minor. While the material costs were higher for the post System Cost Analysis wells, the fewer problems hours resulted in lower system costs.

2. *Tipischa Jungle Basin – Ecuador*

A System Cost Analysis in the Tipischa basin compared the performance of an initial 14 well program to a later 12 well program. The initial 14 wells were drilled with gel PHPA muds while a $KNO_3$ ss-PHPA fluid was used on the later wells. A typical well schematic with intermediate casing is shown in Figure 4.

Table 4 and Figure 5 summarize the material and system costs for the total well data for wells. Also included is the solids control costs for the wells. The following conclusions were made from the information contained within the data:

- material costs/ft for the later drilled set of wells was 13% greater than the previous wells. In contrast the system costs were 5% less for the later well grouping. The average amount of unproductive time on the earlier wells was 79 hours while the later wells had 60 hours of unproductive time.
- Solids control costs improved on the later wells by 25% of $4.40/ft drilled. The savings were a direct result of the $KNO_3$ ss-PHPA system being easier to strip solids from and tereby minimize dumping and dilution of drilling fluid.

The Tipischa SCA study also analyzed drilling time in terms of ROP, time to TD and time to rig release. The data is summarized in Table 5 and Figure 6. While the drilling fluid is certainly not the only parameter which influences ROP, it is an important variable. Other parameters such as bit type, weight on bit, rpm, etc. are also of major importance. The conclusions drawn from the data include:

- ROP, as refelcted in the drilling ft/day was ~ 175 ft/day faster in the later well set.
- The later well set was about 10% faster or 1.8 days to TD. This is due to a combination of higher ROP's and fewer unproductive hours.
- The days to rig release was also faster, 2.4 days faster, on the later well set. The additional 0.6 days of savings resulted from increased efficiencies in running logs and in conducting liner/cementing operations.

## Conclusions

- A System Cost Analysis provides a quantitative tool for measuring the actual costs of drilling fluids on overall well drilling costs.
- Simple System Cost is composed of drilling fluid material costs, unproductive time due to drilling fluid performance - converted to cost.
- An ideal total analysis of driling fluid performance will include the System Cost as noted above, an ROP analysis, solids control/disposal impact

analysis and formation impairment – production review.

- The prime benefits of a SCA are (1) benchmarking current drilling fluid performance and (2) measuring the impact of changes on the drilling fluid performance.
- System cost Analysis provides operators and service companies with methodology of determining where costs are most prevalent.
- In general terms for a land-based operation, a well with minimal problems related to mud will have System Costs no greater than twice the material cost.
- SCA lends itself well to using a risk analysis method for determing relative well costs using varying well casing and drilling fluid combinations. The SCA will provide a large number of accurate input data sets in order to generate accurate output well cost information.

## Acknowledgements

The authors would like to thank the many people involved in the gathering of the data included in these studies and in this paper. Special thanks goes to George Rajbar of Q'Max who has brought the SCA to a usable and functional methodology.

## Nomenclature

*ft = feet*
*K+ = potassium sulphate containing fluids*
*$KNO_3$ =potassium nitrate*
*$K_2SO_4$ = potassium sulfate*
*MWD = measurement while drilling*
*N/A = not available*
*PHPA = partially hydrolyzed polyacrylamide*
*ROP = drilling rate of penetration*
*rpm = revolutions per minute*
*ss-PHPA = sterically stabilized partially hydrolyzed polyacrylamide*
*SCA = System Cost Analysis*
*TD=total depth*

## References

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| SYSTEM COST ITEM | DESCRIPTION OF TROUBLE TIME INCLUDED |
|---|---|
| | |
| Lost Circulation | ▪ Material costs and time (rig and other items such as water hauler). |
| Reaming and Cleaning | ▪ Reaming and/or cleaning while rih or pooh due to poor hole conditions. Does not normally include reaming undergauge hole after motor drilling. |
| | |
| Logs Bridging | ▪ Due to poor hole conditions. Includes time spent reaming logging tool to bottom, time lost due to no logs run, hole conditioning and running tool back into hole. |
| Casing/Liner | ▪ As above noted in “Logs Bridging” section. |
| | |
| Sidetrack/Redrill | ▪ Includes time and material costs incurred from running cement plugs to reaching original depth before plugging back. Does not include sidetracks for geological reasons. |
| Stuck Pipe | ▪ Includes material/time due mechanically stuck pipe. May or may not include problems because of differentially stuck pipe. |
| | |
| Gravel/Boulders | ▪ Material costs and time. |
| Mud Rings | ▪ Material costs and time. |
| | |
| Kicks | ▪ Material costs and time. |
| Additional Costs | ▪ Includes items such as cementing, disposal (fluids and cuttings), trucking, engineering, etc. as appropriate. |
| | |
| Rate-of-Penetration | ▪ Hours on bitover footage intervals. May include time spent on trips. |
| Production Comparisons | ▪ Captures formation damage issues. Works best for large sample sets and fairly homogeneous reservoirs. |
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**Table 1 – Items Included in a System Cost Analysis**

| Well LSD | Mud Type | ft drilled | $ material | $ material/ft | $ system cost | $ sc/ft |
|---|---|---|---|---|---|---|
| 02-20-61-7 W6 | K+/K+ | 1365 | 33445 | 24.50 | 42445 | 31.10 |
| 12-26-61-7W6 | PHPA | 3491 | 25248 | 7.23 | 70623 | 20.23 |
| 05-33-61-7 W6 | gel chem | 1654 | 18586 | 11.24 | 76336 | 46.17 |
| 09-11-62-7 W6 | PHPA | 738 | 2735 | 3.71 | 9860 | 13.36 |
| 07-03-62-7 W6 | PHPA | 3940 | 33261 | 8.44 | 151761 | 38.52 |
| 16-21-62-7W6 | PHPA | 1165 | 16614 | 14.26 | 46052 | 39.54 |
| 06-22-62-7 W6 | PHPA | 3694 | 13640 | 3.69 | 25265 | 6.84 |
| 16-20-62-7W6 | gel chem | 3002 | 11939 | 3.98 | 43252 | 14.41 |
| 09-31-62-7 W6 | PHPA | 1388 | 10423 | 7.51 | 37611 | 27.10 |
| 14-07-62-7 W6 | PHPA | 965 | 28023 | 29.05 | 38336 | 39.74 |
| 16-15-62-7 W6 | K+/K+ | 978 | 22792 | 23.31 | 97417 | 99.64 |
| 16-14-62-7 W6 | /K+ | 2510 | 38744 | 15.44 | 56744 | 22.61 |
| 05-12-62-7 W6 | /K+ | 2707 | 25330 | 9.36 | 30393 | 11.23 |
| 11-23-62-7 W6 | K+/K+ | 2461 | 34095 | 13.86 | 53408 | 21.70 |
| 03-28-62-7 W6 | K+/K+ | 2411 | 34830 | 14.44 | 48143 | 19.96 |
| 04-18-62-7 W6 | K+/K+ | 2871 | 45434 | 15.83 | 62872 | 21.90 |
| 10-23-62-8W6 | PHPA | 548 | 4467 | 8.15 | 13280 | 24.24 |
| 14-11-62-8W6 | PHPA | 2126 | 12649 | 5.95 | 25024 | 11.77 |
| 11-14-62-8W6 | PHPA | 1234 | 13168 | 10.67 | 32293 | 26.18 |
| 05-26-62-8 W6 | /K+ | 2280 | 23632 | 10.36 | 33945 | 14.89 |
| 01-33-62-8 W6 | PHPA | 1772 | 8972 | 5.06 | 18160 | 10.25 |
| 02-04-63-8 W6 | PHPA | 1611 | 9102 | 5.65 | 29352 | 18.22 |
| 04-09-63-8 W6 | PHPA | 1453 | 5655 | 3.89 | 16530 | 11.37 |
| 08-12-63-8 W6 | gel chem | 600 | 9755 | 16.25 | 75943 | 126.49 |
| 13-12-63-8W6 | gel chem | 876 | 10353 | 11.82 | 45228 | 51.63 |
| 03-13-63-8W6 | gel chem | 1732 | 20868 | 12.05 | 30993 | 17.89 |
| 06-14-63-8 W6 | gel chem | 912 | 9742 | 10.68 | 63180 | 69.27 |
| 13-28-63-8W6 | PHPA | 1188 | 5480 | 4.61 | 15043 | 12.67 |
| 02-31-63-8W6 | PHPA | 1401 | 5297 | 3.78 | 16360 | 11.68 |
| 12-32-63-8W6 | PHPA | 1332 | 5190 | 3.90 | 13440 | 10.09 |
| 12-33-63-8W6 | PHPA | 1690 | 6667 | 3.95 | 28042 | 16.60 |
| 16-20-63-8W6 | PHPA | 755 | 5603 | 7.43 | 60353 | 79.98 |
| 13-14-63-8W6 | PHPA | 2051 | 11880 | 5.79 | 19005 | 9.27 |
| 04-15-63-8W6 | PHPA | 1325 | 6903 | 5.21 | 47966 | 36.19 |
| 10-18-63-8W6 | PHPA | 509 | 6102 | 12.00 | 32915 | 64.72 |
| 13-19-63-8W6 | PHPA | 525 | 5463 | 10.41 | 9963 | 18.98 |
| 07-21-63-8W6 | PHPA | 2461 | 5204 | 2.11 | 7829 | 3.18 |
| 05-22-63-8W6 | PHPA | 2927 | 6824 | 2.33 | 46387 | 15.85 |
| 10-22-63-8W6 | gel chem | 663 | 10699 | 16.14 | 66762 | 100.74 |
| **TOTAL WELL MEAN** | | **1712** | **15265** | **9.73** | **41408** | **31.29** |
| 61-7 MEAN | | 2170 | 25760 | 14.33 | 63135 | 32.50 |
| 62-7 MEAN | | 2218 | 24451 | 12.53 | 53932 | 28.97 |
| 62-8 MEAN | | 1592 | 12578 | 8.04 | 24540 | 17.46 |
| 63-8 MEAN | | 1334 | 8155 | 7.67 | 34738 | 37.49 |

**Table 2 - Chicken Area (Alberta) Material and System Cost Values in Main hole mud drilled section. Lowest mean material cost/ft as well as the highest system cost/ft was in the 63-8 section. The 62-8 section had the lowest system cost mean and therefore the fewest amount of problems.**

| Well LSD | Mud Type | ft drilled | $ material | $ material/ft | $ system cost | $ sc/ft |
|---|---|---|---|---|---|---|
| | | | | | | |
| 61-7 MEAN | | 2170 | 25760 | 14.33 | 63135 | 32.50 |
| 06-36-61-07 | $K_2SO_4$ | 2648 | 78335 | 29.58 | 90335 | 34.11 |
| | | | | | | |
| 62-7 MEAN | | 2218 | 24451 | 12.53 | 53932 | 28.97 |
| 16-30-62-07 | $K_2SO_4$ | 2415 | 29286 | 12.13 | 56474 | 23.38 |
| 12-18-62-07 | $K_2SO_4$ | 2740 | 45821 | 16.73 | 64196 | 23.43 |
| | | | | | | |
| 63-8 MEAN | | 1334 | 8155 | 7.67 | 34738 | 37.49 |
| 12-27-63-08 | $K_2SO_4$ | 722 | 6720 | 9.31 | 24720 | 34.23 |
| 16-07-63-08 | $K_2SO_4$ | 6115 | 46163 | 7.55 | 54788 | 8.96 |

**Table 3 - Chicken Area System Cost Analysis Comparison for wells drilled pre- and post-analysis. The individual well locations are for the post-drilled SCA wells. Note that all of the post-analysis wells achieved successful logs on first attempt. The well @ 06-36-61-07 had a high material cost due to massive lost circulation.**

| WELL NAME | Ft DRILLED | $ MATERIAL | $ MATERIAL/ft | $ SYSTEM COST | $ SYSTEM COST/ft | $ SOLIDS CONTROL | $ SOLIDS CONTROL/ft |
|---|---|---|---|---|---|---|---|
| **INITIAL 14 WELL SET** | | | | | | | |
| M 8 | 8870 | 297531 | 33.54 | 421281 | 47.50 | 172,000 | 19.39 |
| D 1 | 9599 | 351809 | 35.77 | 735559 | 74.79 | 186,000 | 19.38 |
| F 18b 13 | 8656 | 135135 | 15.74 | 300135 | 34.96 | 132,000 | 15.25 |
| F 18b 14 | 8557 | 122928 | 14.37 | 244178 | 28.54 | 122,000 | 14.26 |
| F18b 15 | 8762 | 96549 | 11.02 | 96549 | 11.02 | 136,000 | 15.52 |
| D 2 | 9600 | 216650 | 22.60 | 352900 | 36.81 | 134,000 | 13.96 |
| F 18b 16 | 8150 | 149112 | 18.28 | 229112 | 28.08 | 116,000 | 14.23 |
| D 3 | 9356 | 305746 | 32.68 | 610746 | 65.28 | 232,000 | 24.80 |
| D 7 | 10805 | 218232 | 20.20 | 385732 | 35.70 | 148,000 | 13.70 |
| F 18b 20 | 8880 | N/A | N/A | N/A | N/A | 145,000 | 16.33 |
| D 8 | 9093 | 148487 | 16.33 | 343487 | 37.77 | 100,000 | 11.00 |
| F 18b 21 | 8880 | N/A | N/A | N/A | N/A | 188,000 | 21.17 |
| M 4A | 9145 | 144592 | 15.81 | 144592 | 15.81 | 125,000 | 13.67 |
| F 18b 26 | 9388 | 240252 | 25.65 | 547752 | 58.47 | 166,000 | 17.68 |
| | | | | | | | |
| **LATER 12 WELL SET** | | | | | | | |
| T 1 | 10255 | 193515 | 18.87 | 434765 | 42.40 | 159,000 | 15.50 |
| F18b 27 | 9061 | 281302 | 31.04 | 753802 | 83.18 | 130,000 | 14.35 |
| P 1 | 9017 | 243320 | 26.98 | 329570 | 36.55 | 141,000 | 15.64 |
| F 18b 25 | 9036 | 191113 | 21.15 | 256113 | 28.34 | 57,000 | 6.31 |
| F 18b 37 | 9413 | 427153 | 43.93 | 528403 | 54.35 | 121,000 | 12.85 |
| D 6 | 9220 | 243940 | 26.46 | 360190 | 39.07 | 131,000 | 14.21 |
| M 4A2 | 8771 | 234838 | 26.77 | 347338 | 39.60 | 84,000 | 9.58 |
| M 4A3 | 9362 | 163872 | 17.50 | 321997 | 34.39 | 93,000 | 9.93 |
| T 1 | 9249 | 219644 | 23.75 | 318394 | 34.42 | 98,000 | 10.60 |
| F 18b 46 | 8890 | 264718 | 29.78 | 395968 | 44.54 | 93,000 | 10.46 |
| M 4A4 | 9207 | N/A | N/A | N/A | N/A | 89,000 | 9.67 |
| T 2 | 9088 | 239000 | 26.30 | 312750 | 34.41 | 138,000 | 15.18 |
| | | | | | | | |
| **Initial 14 MEAN** | **9135** | **218588** | **23.51** | **417088** | **44.79** | **150,100** | **16.43** |
| **Later 12 MEAN** | **9240** | **245674** | **26.59** | **396299** | **42.84** | **111,200** | **12.03** |

**Table 4 - System Cost Analysis raw data and solids handling costs for Ecuador Tipischa Basin area. Data is included for total well analysis, surface hole to TD.**

| WELL NAME | Ft DRILLED | DRILLING DAYS | ft/ DRILLING DAY | DAYS to TD | ft/ DAYS to TD | DAYS to RIG RELEASE | ft/ DAYS to RIG RELEASE | TROUBLE TIME (hrs) |
|---|---|---|---|---|---|---|---|---|
| **INITIAL 14 WELL SET** | | | | | | | | |
| M 8 | 8870 | 6.7 | 1318 | 24.0 | 370 | 26.6 | 334 | 49.5 |
| D 1 | 9599 | 12.4 | 795 | 31.0 | 317 | 35.0 | 281 | 153.5 |
| F 18b 13 | 8656 | 7.4 | 1168 | 14.0 | 615 | 15.7 | 546 | 66.0 |
| F 18b 14 | 8557 | 7.3 | 1170 | 13.7 | 623 | 19.1 | 448 | 48.5 |
| F18b 15 | 8762 | N/A | N/A | N/A | N/A | 17.0 | 515 | N/A |
| D 2 | 9600 | 8.8 | 1085 | 19.0 | 505 | 21.0 | 457 | 54.5 |
| F 18b 16 | 8150 | 7.5 | 1094 | 13.6 | 600 | 17.4 | 470 | 22.0 |
| D 3 | 9356 | 10.5 | 888 | 31.0 | 302 | 41.0 | 228 | 122.0 |
| D 7 | 10805 | 14.7 | 735 | 24.6 | 440 | 27.5 | 393 | 67.0 |
| F 18b 20 | 8880 | 8.9 | 1003 | 21.0 | 423 | 25.0 | 355 | 20.5 |
| D 8 | 9093 | 7.8 | 1173 | 16.8 | 541 | 21.0 | 433 | 78.0 |
| F 18b 21 | 8880 | N/A | N/A | N/A | N/A | 34.0 | 261 | N/A |
| M 4A | 9145 | N/A | N/A | N/A | N/A | 24.0 | 381 | N/A |
| F 18b 26 | 9388 | 13.9 | 675 | 26.5 | 353 | 29.9 | 313 | 123.0 |
| **LATER 12 WELL SET** | | | | | | | | |
| T 1 | 10255 | 13.0 | 789 | 28.7 | 357 | 31.7 | 323 | 96.5 |
| F18b 27 | 9061 | 11.3 | 801 | 18.7 | 485 | 29.4 | 308 | 179.0 |
| P 1 | 9017 | 9.2 | 977 | 23.5 | 384 | 26.3 | 343 | 34.5 |
| F 18b 25 | 9036 | 5.4 | 1662 | 11.3 | 799 | 14.6 | 620 | 26.0 |
| F 18b 37 | 9413 | 7.4 | 1317 | 26.5 | 367 | 32.1 | 303 | 40.5 |
| D 6 | 9220 | 5.9 | 1553 | 17.1 | 540 | 19.5 | 474 | 46.5 |
| M 4A2 | 8771 | 8.3 | 1053 | 17.0 | 516 | 19.6 | 448 | 45.0 |
| M 4A3 | 9362 | 9.8 | 955 | 18.6 | 502 | 19.5 | 479 | 63.25 |
| T 1 | 9249 | 5.8 | 1591 | 16.4 | 565 | 17.5 | 528 | 39.5 |
| F 18b 46 | 8890 | 9.3 | 956 | 18.9 | 471 | 22.5 | 396 | 52.5 |
| M 4A4 | 9207 | N/A | N/A | N/A | N/A | 21.0 | 438 | N/A |
| T 2 | 9088 | 6.5 | 1398 | 19.2 | 474 | 20.8 | 438 | 29.5 |
| | | | | | | | | |
| **Initial 14 MEAN** | **9135** | **9.6** | **1009** | **21.4** | **463** | **25.4** | **387** | **79** |
| **Later 12 MEAN** | **9240** | **8.4** | **1186** | **19.6** | **496** | **23.0** | **424** | **60** |

**Table 5 - Time Analysis information for wells drilled in Ecuador Tipischa Basin area. Initial 14 wells used a gel-PHPA system while the later 12 wells used a KNO3 ss-PHPA fluid. Drilling Days is a measure of rotating time to reach total depth.**

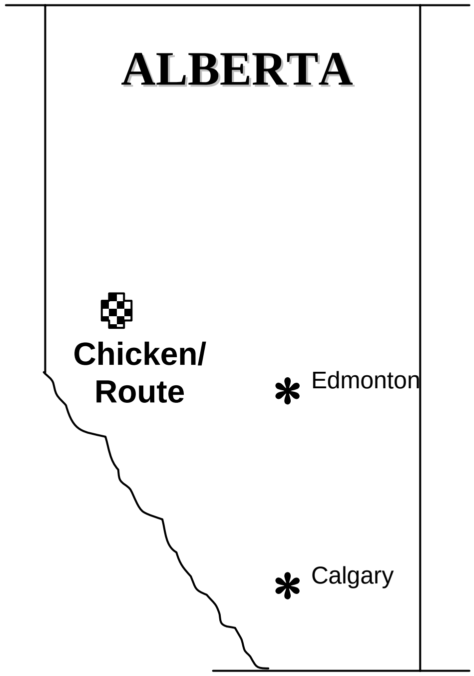


**Figure 1 - Location of Chicken/Route area in West Central Alberta**

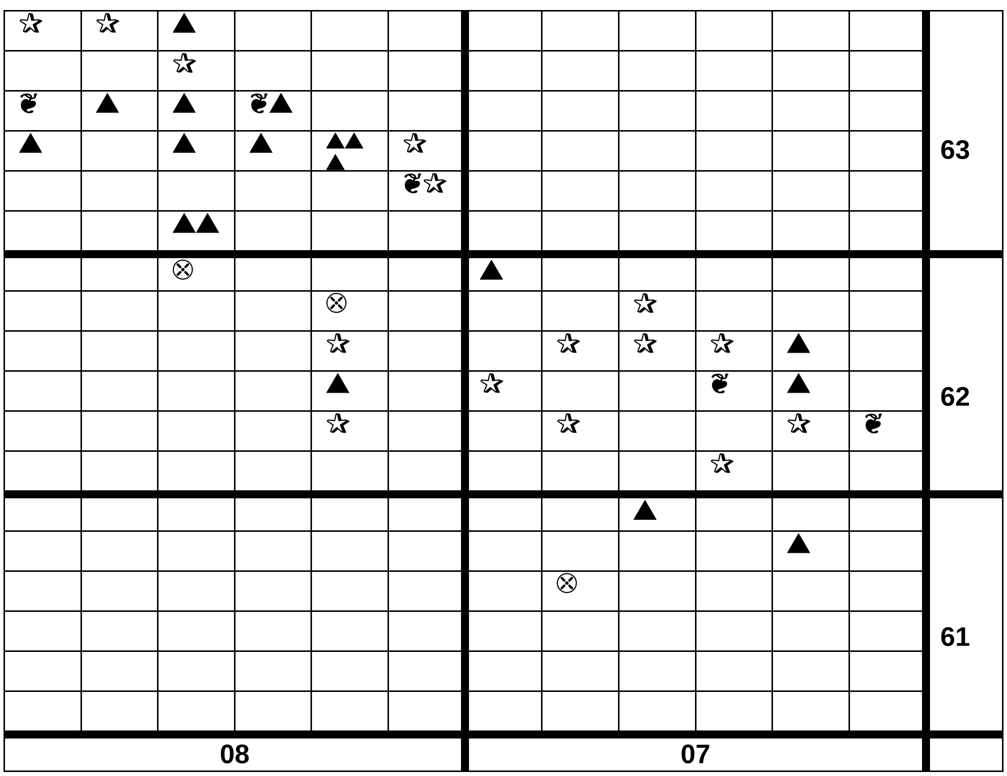


**Figure 2 – Chicken/Route area detailed well map. Wells with ✰ symbol indicate those with no logging or lost circulation problems, ▲ symbol indicates logging problems or no logs run and ⊗ symbol is for wells with lost circulation. A well with ❦ symbol has both logging and lost circulation problems.**

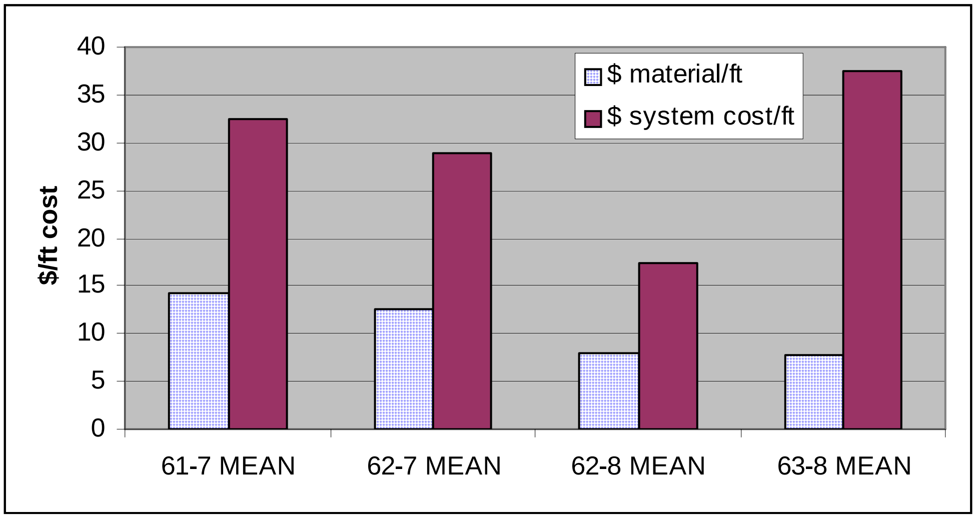


**Figure 3 – Comparative material and system costs for Main Hole section of wells in the various sectors of the Chicken/Route area. Data taken from Table 2.**

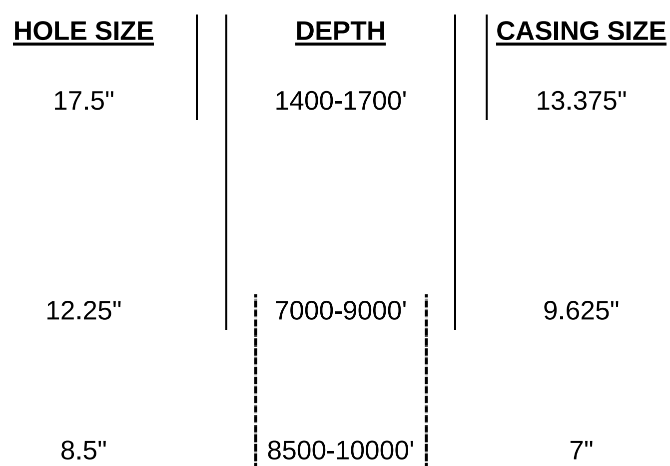


**Figure 4 – Typical well design for Ecuadorian Tipischa Jungle basin wells.**

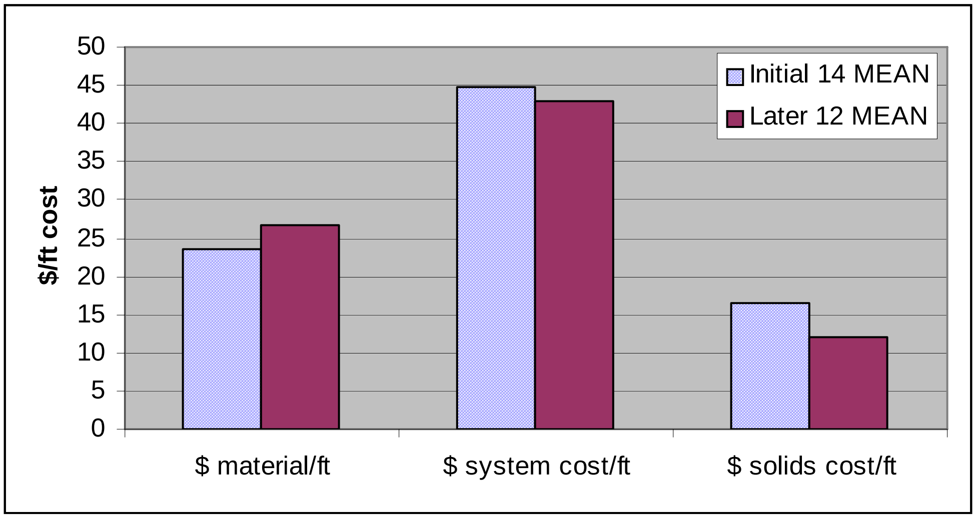


**Figure 5 – Comparison of material costs, system costs and solids costs for initial 14 and later 12 wells in Tipischa study area. Costs are given per foot to normalize the data and are shown for the entire well. Data taken from Table 4.**

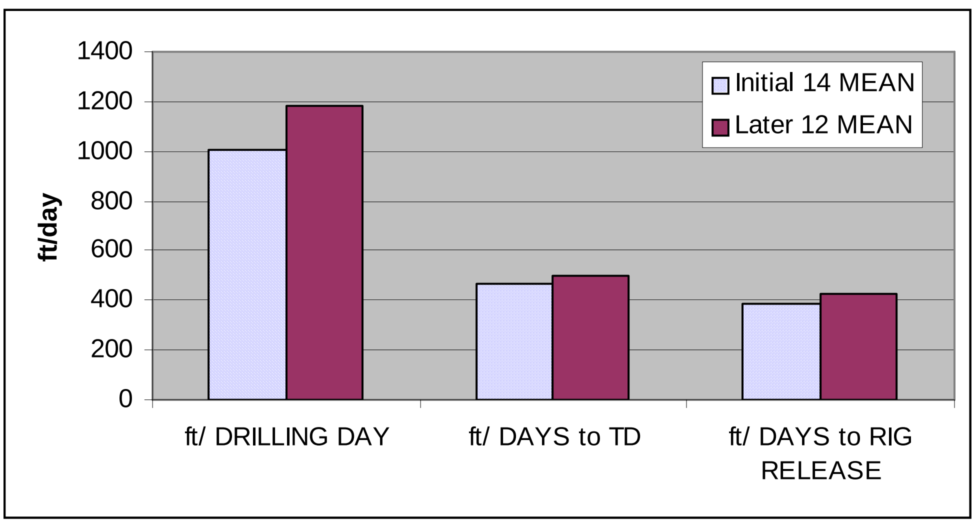


**Figure 6 – Comparison of drilling rate (ROP), time to total depth and time to rig release for initial 14 and later 12 wells in Tipischa study area. Information is presented in value ft per days to normalize data. Data taken from Table 5.**