WELL AND FIELD CONTINUOUS IMPROVEMENT – THE VALUE OF FAILURE TRACKING

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ABSTRACT

During recent discussions with operating company field and engineering personnel, it was discovered that some companies may not have a failure tracking process nor know the benefits of establishing one.

This paper will provide a summary of prior published industry efforts and include three (3) separate failure reduction studies showing the benefits of failure tracking ranging from over 17 years to a few months of operation. These studies from three (3) different operators in the Permian Basin showed the benefits of: determining what downhole equipment failed and the cause of the failure, tracking the failure location in the well, and calculating the final reduction in operating costs due to reduced failures and reduced workovers. This paper will also show the additional benefits from keeping good records and knowing the manufacturer of the downhole equipment and/or if the downhole equipment manufacturer was changed.

BACKGROUND

All of us working in the artificial lift segment of the Oil and Gas Industry are expected to maximize the profits from oil and gas producting wells. One of the areas that can provide instant savings in operating expenses, increased production and ultimately increased earnings is the area of reduced downhole failures. There have been many studies, but most not published, that have shown that the benefits of reducing failures in an existing field may out-perform and generate greater earnings than the glamour associated with drilling and completing of new wells.

One of the first studies done on operating practices and associated failure reductions was a joint industry study called Artificial Lift Energy Optimization Consortium (ALEOC). In this project, 11 different operating companies in the Permian Basin provided an impartial assessment of over 25,000 producing wells. A comparison was made of the failure frequency of sucker rods and couplings, downhole sucker rod pumps and production tubing.[1]

For this ALEOC research project, the total failure frequency was determined by adding the number of sucker rod and coupling failures, pump failures and tubing failures and dividing this total by the total number of sucker rod lifted wells in a field. **Graph 1** provides the graphical analysis of the project results, showing the eight (8) years operators provided their failure data and the downward trend of failure frequency for all operators during the time of this research project. The ALEOC paper also showed a detailed analysis for the failure frequency for each production component (rods and coupling, pumps and tubing) and also showed comparisons of the failure frequencies of the various operators in selectively reported producing fields.

While the total failures and the associated failure frequency reduction can be attributed to this project, no cost savings or earning increases were provided in this project. Also, not discussed was that once failure data was provided, then the root cause of the failure could be obtained and changes could be made then for the future to prevent similar failures from occurring. So, while knowing the failure rate is useful, without making the necessary changes in operating practices or equipment type, design or manufacturer, then the overall reductions would not be possible.

There have been a few other publications of failure reduction projects providing more detail. These publications have involved tracking the history of field operations and their associated failure reductions and cost savings in the Spraberry field.[2-5] These papers provide the original operating practices and periodic performance history updates after 6 and 10 years. Additionally, there are a few other publications that have discussed the development and analysis of well failure tracking information.

With increased interest in failure reduction and the associated tracking and analyzing of failures, a number of questions and concerns have developed that must be addressed in order to establish and maintain a successful failure reduction program. These include:

Establishing and Maintaining a Successful Failure Tracking Program

1. How effective are your existing Failure Reduction Programs?
2. How frequently do you meet to discuss failures?
3. Do you discuss solutions to reduce the number of failures?
4. Who are involved in these discussions?
5. Are these Failure Reduction Meetings regularly scheduled?
6. How have you developed a past Failure History?
7. How are you developing your current Failure History?
8. What are the expectations of your Failure Reduction Program?

This paper will document the success of three (3) different Failure Reduction Programs and their Failure Tracking Programs. These Failure Tracking Programs are identified as Programs 1, 2 and 3.

SAVINGS FROM FAILURE REDUCTION PROGRAMS

Program 1 $24.5 – $41.9 Million saved during 17 consecutive years
$1.4 - $2.5 Million average savings per year

Program 2 $1.2 Million saved in the 2013-14 period compared to the 2012-13 period.

Program 3 $1.7 Million saved in last 5 years
$2.8 Million (projected) savings in last 6 years

EXPLANATION OF FPWPY

To measure the success of Failure Reduction Programs, the Oil and Gas Industry has adopted a measurement tool to compare the failure reduction performance of all Failure Reduction Programs. FPWPY is an acronym for Failures per Well per Year. FPWPY is defined as the number of Failures per Well during a continuous 12 month period. This measurement tool is sometimes referred to as the "Failure Rate" for a specific Failure Reduction Program.

EXPLANATION OF FAILURES

The number of failures is determined by the focus of the Failure Reduction Program. For this paper, our failures will be restricted to Tubing Leaks, Rod Failures (rod body, rod coupling, rod pin) and Pump Failures.

EXPLANATION OF WELLS

Wells can be identified by various classifications. Wells can be classified as; Producing, Injection, Disposal, Active, Temporarily Abandoned (T&A) or Plugged and Abandoned (P&A). For this paper, our well count will be the number of active producing (sucker rod lifted) wells at the end of a continuous 12 month period.

EXPLANATION OF YEAR

The year can be defined as a calendar year or a running 12 month period. For this paper, our year will be a January through December calendar year or a fixed 12 month period of time for each Failure Reduction Program.

EXAMPLE CALCULATION OF FPWPY

How do you calculate FPWPY?
Example, a producing company for the 2012 calendar year recorded the following failure performance;

1200 Failures (Tubing Leaks, Rod Failures and Pump Failures)
3000 Active Producing Wells as of 12-31-2012

(1200 Failures / 3000 Wells / 1 Year) = 0.40 FPWPY

The number of years between failures can be determined by inverting your FPWPY number. For example; (1 / 0.40 FPWPY) = 2.5 Years between failures. This term is sometimes referred to as the "Mean Time between Failures".

Program 1

This Failure Reduction Program was initiated on August 17, 1996. A performance baseline was established based on the 87 existing producing wells selected for this program and the number of Tubing Leaks, Rod Failures and

Pump Failures during the 12 months prior to the initiation of this program. From August 17, 1995 to August 17, 1996 this baseline was established as listed below;

Tubing Leaks	152	1.75 FPWPY
Rod Failures	45	0.51 FPWPY
Pump Failures	40	0.46 FPWPY
Total Failures	237	2.72 FPWPY

This failure rate represents a downhole failure every 4.4 months or 134 days.

On August 17, 1997, after completion of year 1 of this Failure Reduction Program the performance of these 87 existing producing wells was compared to the 12 months prior to the start of this program;

Tubing Leaks	114	1.31 FPWPY	**25% Reduction in Tubing Leaks (FPWPY)**
Rod Failures	59	0.68 FPWPY	33% Increase in Rod Failures (FPWPY)
Pump Failures	53	0.61 FPWPY	33% Increase in Pump Failures (FPWPY)
Total Failures	226	2.60 FPWPY	4% Reduction in Total Failures (FPWPY)

Because of the dramatic reduction of Tubing Leaks, this Failure Reduction Program was expanded to include newly drilled wells. The first of these 63 new wells was drilled and completed on August 23, 1997. The total number of wells in this program peaked at 150 wells during the 1997-98 year. This total included the original 87 existing wells along with 63 newly drilled wells. Performance was monitored for the existing wells, the new wells and all wells in the program.

On August 17, 2013, after the completion of year 17 of this Failure Reduction Program the performance of the remaining 138 well program (81 existing wells, 57 newly drilled wells) is listed below;

Tubing Leaks	5	0.0362 FPWPY	**Please refer to Graph 2 – Existing & New Wells**
Rod Failures	10	0.0725 FPWPY	**Please refer to Graph 3 – Existing Wells**
Pump Failures	4	0.0290 FPWPY	**Please refer to Graph 4 – New Wells**
Total Failures	19	0.1377 FPWPY	

Inverting these failure rates calculates a Tubing Leak every 27.6 years, a Rod Failure every 13.8 years, and a Pump Failure every 34.5 years.

Program 1 Savings

$24.5 Million saved during 17 consecutive years – straight line extrapolation
$41.9 Million saved during 17 consecutive years – logarithmic extrapolation
$1.4 Million saved (average) per year – straight line extrapolation
$2.5 Million saved (average) per year - logarithmic extrapolation **Please refer to Graph 5**

Cost Basis of downhole savings from this Failure Reduction Program;
Constant Tubing Leak Expense of $11,000 until 2003-2004 then equal yearly increases to $16,500
Constant Rod Failure Expense of $4,000 until 2003-2004 and equal yearly increases to $6,000
Constant Pump Failure Expense of $5,500 until 2003-2004 and equal yearly increases to $8,300

> "If only 25% of the producing wells in the Permian Basin adopted this successful failure reduction program, $500 Million would be saved each year in reduced failure expenses"
>
> Dr. Sam Gibbs, developer of the wave equation,
> 2011 Inductee to the Petroleum Hall of Fame

This Failure Reduction Program is now utilized by over 6,000 wells operated in the Permian Basin.

Program 2

This Failure Reduction Program was started by one (1) Foreman reviewing his failed wells and expanded to regularly scheduled failure meetings involving all Foremen and their failed wells. Initially there were no regularly

scheduled, formal failure meetings. These initial failure meetings reviewed approximately 300 wells. Today, this Failure Reduction Program has expanded to include approximately 4,700 wells.

The first regularly scheduled All Foreman Failure Meetings reviewed wells with three (3) failures or more in the last 12 months. This decision was reached to respect the time each Foreman spent in these Failure Meetings, away from his responsibilities in the field. This initial criterion focused the failure review on the worst performing wells.

After twelve (12) months of regularly scheduled All Foreman Failure Meetings, the number of wells being reviewed at each meeting had reduced from 22 wells to 9 wells. Because of this successful reduction in failed wells and failure rate, the well selection criterion was reduced from three (3) failures or more in the last 12 months to two (2) failures or more in the last 12 months.

After four (4) years of this program, the failure rate has again reduced to levels similar to those at the end of the first year. The next improvement of this Failure Reduction Program will be to change the well selection criteria from two (2) failures or more in the last 12 months to one (1) failure or more in the last 12 months.

The failure rate used for this Failure Reduction Program is different than Failures per Well per Year (FPWPY). The failure rate is; Failures per Day between Failure Meetings. The total number of Tubing Leaks, Rod Failures and Pump Failures discussed at each Failure Meeting is divided by the number of days since the last failure meeting and plotted on the date of the most recent Failure Meeting.

Please refer to Graph 6.

Program 2 Savings

$1.2 Million saved during the 2013-2014 period compared to the 2012-2013 period

The cost basis for these downhole savings from this Failure Reduction Program is based on $20,000 per Tubing Leak, $15,000 per Rod Failure and $10,000 per Pump Failure

Analysis of Failure Rates during the last 12 Months

To better understand the reduction of failure rate during the last 12 months (Failures per Day between Failure Meetings), the last 12 months of failure reduction performance was isolated from this four (4) year program.

The greatest failure rate reduction during 2013-2014 was from Tubing Leaks, followed by Pump Failures and then by Rod Failures. This kind of analysis shows that the reduction of Tubing Leaks is the driver behind the 12 month reduction in total downhole failures from this Failure Reduction Program.

Please refer to Graph 7

Cumulative Failure Trend Graph

A Cumulative Failure Trend Graph was developed for this Failure Reduction Program to identify when changes to this Failure Reduction Program impacted the failure frequency of Tubing Leaks, Rod Failures and Pump Failures.

The number of Tubing Leaks, Rod Failures and Pump Failures at each Failure Meeting were recorded since the initiation of this Failure Reduction Program. The cumulative totals of these Tubing Leaks, Rod Failures and Pump Failures were tabulated and plotted on the date of each Failure Meeting.

Please refer to Graph 8

These Failure Trend Lines can increase in failure rate, decrease in failure rate or show little change in failure rate. These rate changes may signal the consequence of a modification of a drilling or completion program, the change of rod manufacturer or rod inspection company, the performance of a tubing tester, pump company or chemical company. When these trend lines signal a change in rate someone should ask what is causing these changes in Tubing Leak, Rod Failure and Pump Failure Rate trend lines.

Program 3

This Failure Reduction Program was initiated in 2008 and included a total of 144 Spraberry producing wells. The first year of this Failure Reduction Program established the performance baseline for this program as listed below;

2008-Year 1 Baseline

Tubing Leaks	40	0.28 FPWPY	
Rod Failures	21	0.15 FPWPY	
Pump Failures	25	0.17 FPWPY	
Total Failures	86	0.60 FPWPY	(A downhole failure every 20 months or 1.7 year)

From the end of 2008 to the end of 2012 or year 5, the well count for this Failure Reduction Program had increased from 144 to 331 Spraberry producing wells. This increase in well count was due to new well drilling and well well acquisitions.

2012-Year 5 compared to 2008-Year 1 Baseline

Tubing Leaks	30	0.09 FPWPY	68% Reduction in Tubing Leaks (FPWPY)
Rod Failures	50	0.15 FPWPY	No Change in Rod Failures (FPWPY)
Pump Failures	31	0.09 FPWPY	47% Reduction in Pump Failures (FPWPY)
Total Failures	111	0.33 FPWPY	**45% Reduction in Total Failures (FPWPY)**

In 2013 the well count again increased from 331 wells to 601 wells. This 601 well increase included 253 wells acquired by acquisition. A consequence of this acquisition of wells was an increase in well count with an associated increase in Tubing Leaks, Rod Failures and Pump Failures.

2013-Year 6 compared to 2012-Year 5 – 253 well Acquisition

Tubing Leaks	87	0.14 FPWPY	56% Increase in Tubing Leaks (FPWPY)
Rod Failures	96	0.16 FPWPY	7% Increase in Rod Failures (FPWPY)
Pump Failures	81	0.13 FPWPY	44% Increase in Pump Failures (FPWPY)
Total Failures	264	0.43 FPWPY	**30% Increase in Total Failures (FPWPY)**

Most of the increases in Tubing Leaks, Rod Failures and Rod Failures were from the 253 acquisition wells. The purchased condition of these acquisition wells did not meet the new company operating standards. Projecting to the end of 2014 or year 7 with failure data through February 2014, it appears that the results of well work and continued retro-fitting of these acquired wells will be rewarded with reduced Tubing, Rod and Pump failure frequency rates.

2014-Projected Year 7 compared to 2013-Year 6 – After Acquisition **Please refer to Graph 9**

Tubing Leaks	72	0.12 FPWPY	**14% Decrease in Tubing Leaks (FPWPY)**
Rod Failures	60	0.10 FPWPY	**38% Decrease in Rod Failures (FPWPY)**
Pump Failures	60	0.10 FPWPY	**23% Decrease in Pump Failures (FPWPY)**
Total Failures	192	0.32 FPWPY	**26% Reduction in Total Failures (FPWPY)**

Program 3 Savings
$1.7 Million saved in last 5 years
$2.8 Million (projected) savings in last 6 years **Please refer to Graph 10**

During 2008 (Baseline Year), $1,365,000 was spent on Tubing Leaks, Rod Failures and Pump Failures. This failure expense is based on an estimated downhole failure cost of $20,000 per Tubing Leak, $15,000 per Rod Failure and $10,000 per Pump Failure. The average 2008 failure cost per well for 144 wells was **$9,479 per well**.

During 2013 (Year 6), $3,990,000 was spent on Tubing Leaks, Rod Failures and Pump Failures. The average 2013 failure cost per well for 601 wells was **$6,639 per well**. This is a $2,840 savings per well or a 30% reduction in failure costs for the last five (5) years.

At the completion of 2014 (Year 7) the average 2014 failure cost per well for 601 wells is projected to be **$4,892 per well.** This is a projected $4,587 savings per well or a 48% reduction in failure costs for the last six (6) years

Summary and Conclusions

This paper has documented the success of Failure Tracking Programs 1, 2 and 3.

Program 1 $24.5 – $41.9 Million saved during 17 consecutive years
$1.4 - $2.5 Million average savings per year

Program 2 $1.2 Million saved in the 2013-14 period compared to 2012-13 period.

Program 3 $1.7 Million saved in last 5 years
$2.8 Million (projected) savings in last 6 years

Savings from Programs 1, 2 and 3

$27.5 - $44.8 Million has been saved in reduced downhole failures from the 17 years of Program 1, last year of Program 2 and the last 5 years of Program 3 as documented in this paper.

This is an average of $1.2 – $1.9 Million per year for 23 recorded performance years.

Program 1 - started with 150 wells.	Program 1- has expanded to 6,000 wells
Program 2 - started an undetermined number of wells.	Program 2 - has expanded to 4,700 wells
Program 3 - started with 144 wells.	Program 3 - has expanded to 601 wells

Other conclusions and recommendations can be made from this continuous improvement process. These include:

- Failure tracking can extend from simply monitoring rod, pumps and tubing failures to determining and recording details associated with the root cause of the failure, where failure was located (both well depth and locating on the equipment),
- The more data obtained and verified, the better and more effective changes can be made to prevent future failures.
- The prevention of the failures will reduce operating expense, increase production, and increase earnings from the individual well and extend across the whole field making the overall property more valuable.
- The first steps to developing a successful failure tracking program is start "NOW" but, be sure that someone is responsible for collecting the correct data and analyzing these data to make the best, appropriate changes for the future life of the field.

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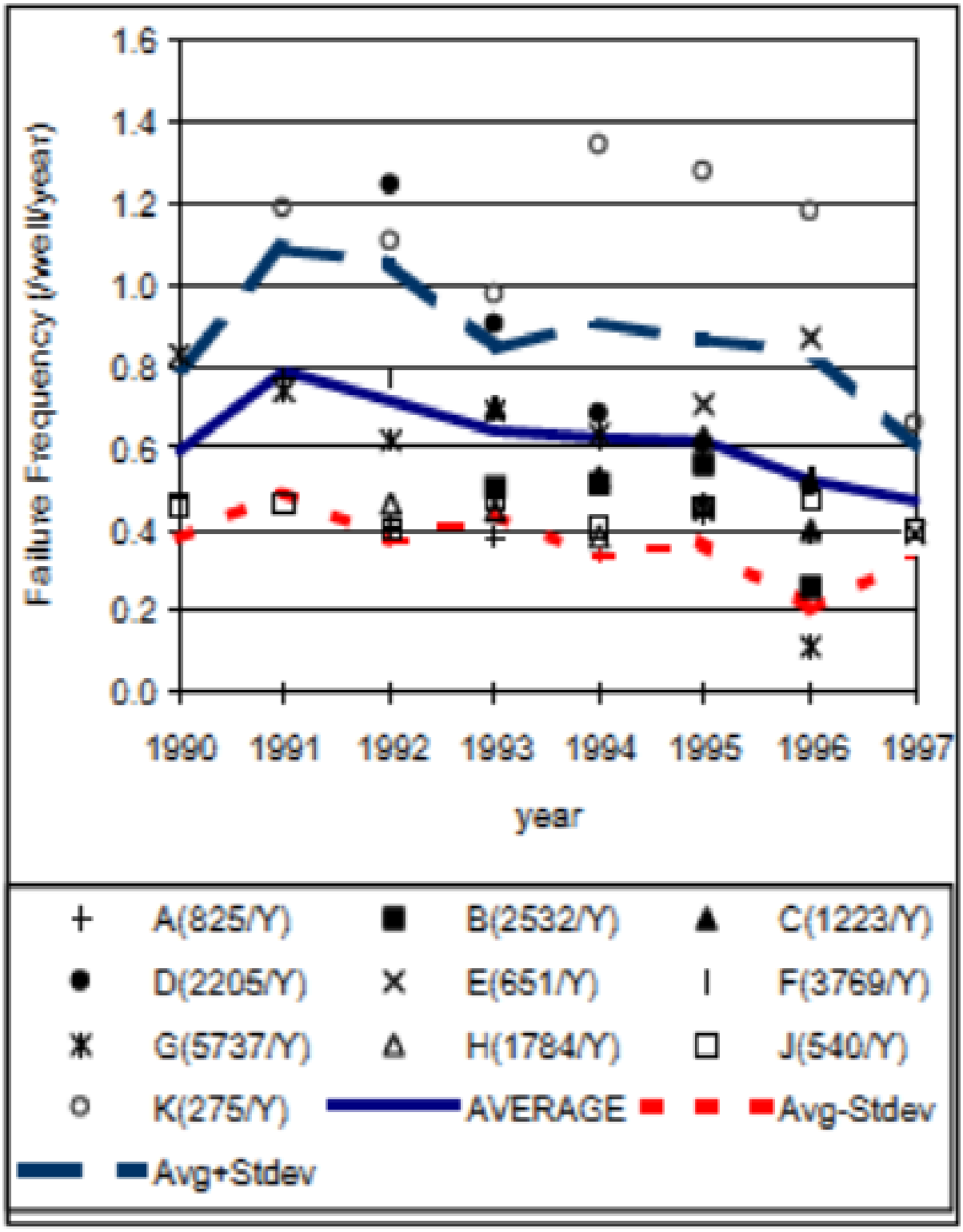
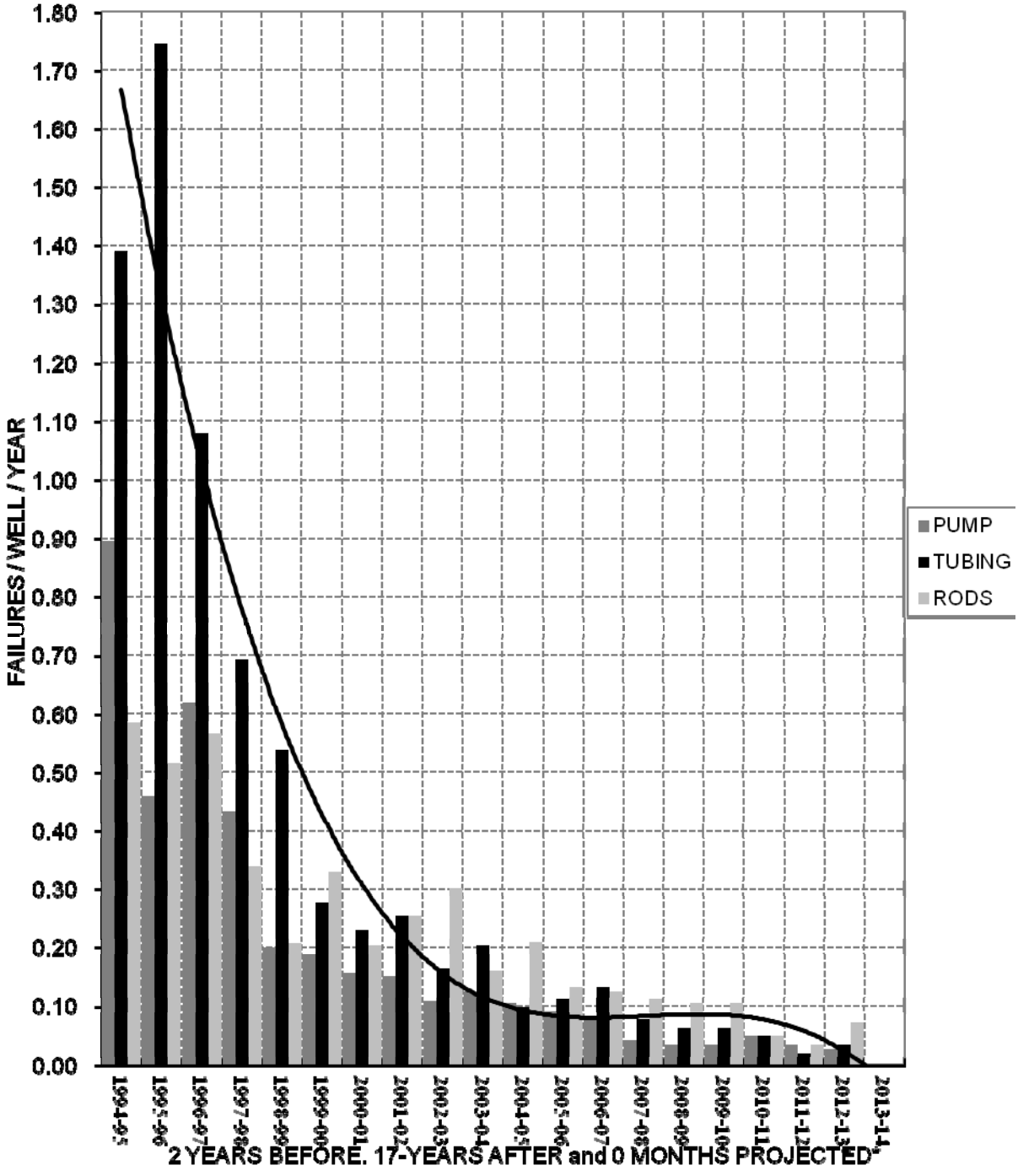
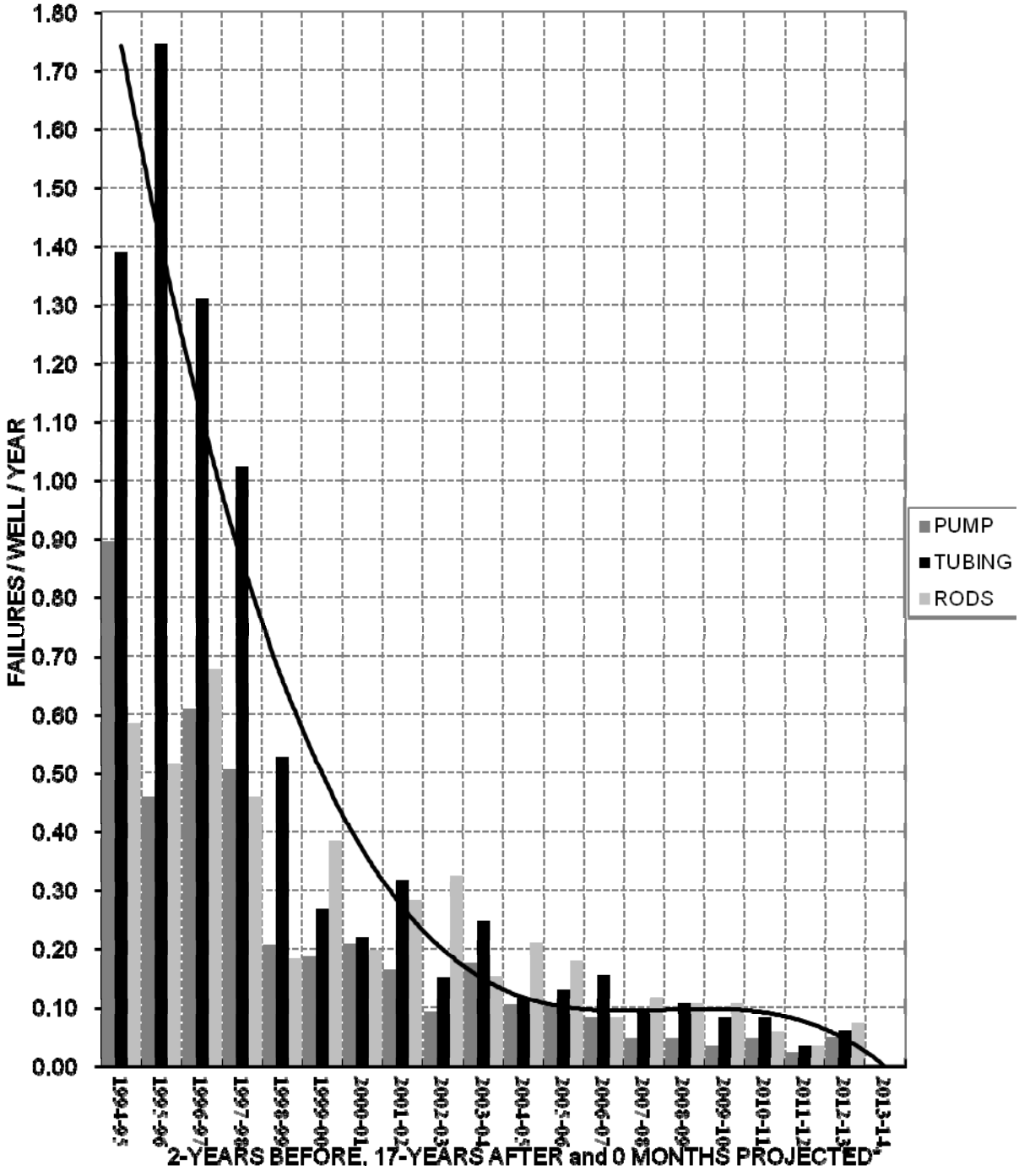


Graph 1, Results of ALEOC – decreasing trends for the failure frequencies for all project operating companies (Ref 1; Figure 2).

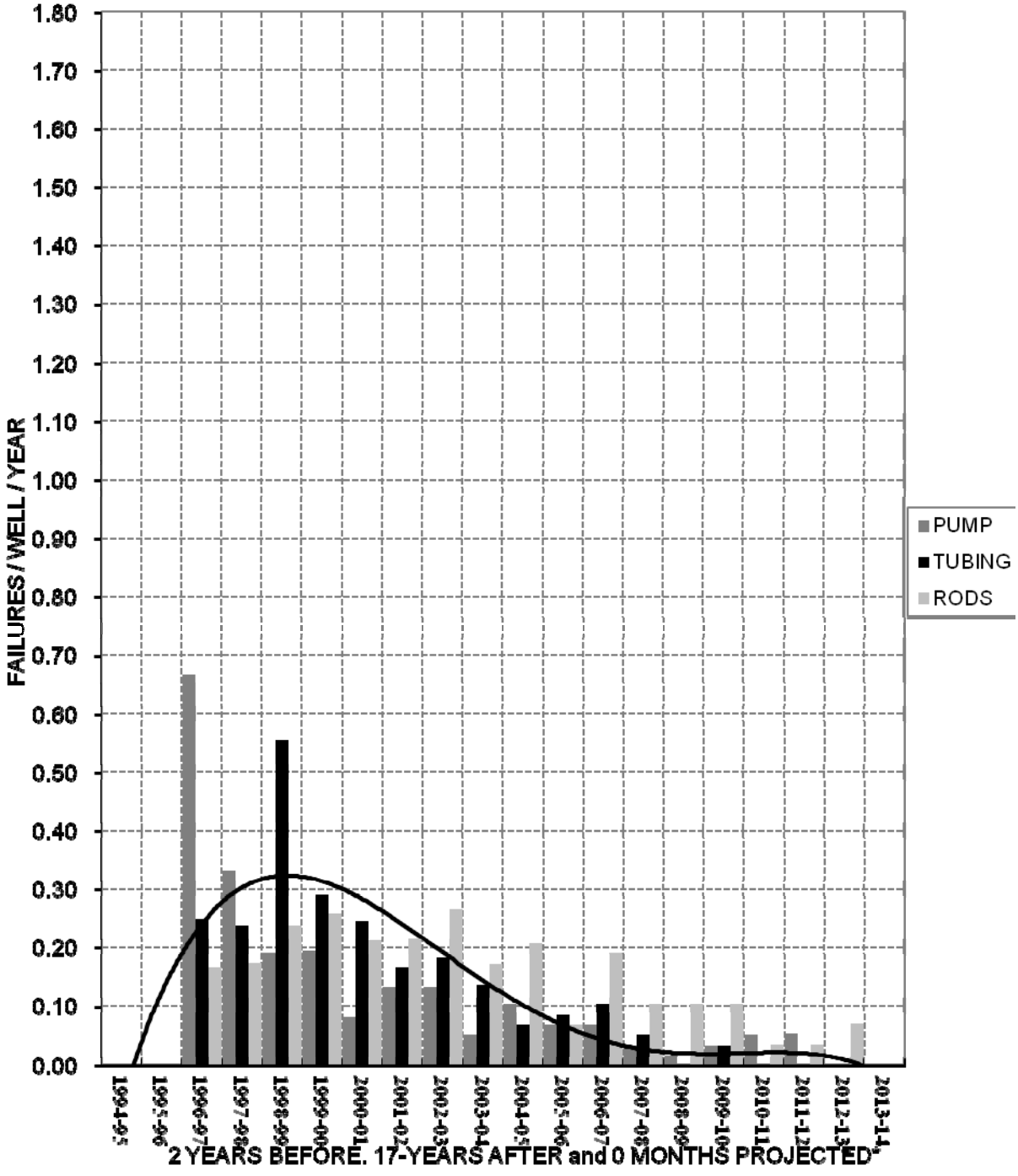
PROGRAM #1 - 150 / 138 "EXISTING" & "NEW" WELLS
TUBING, ROD & PUMP FPWPY - GRAPH 2 (12* MONTHS) 08-17-2013
FLEXBAR / NORRIS / HF / NORRIS PRODUCTION SOLUTIONS



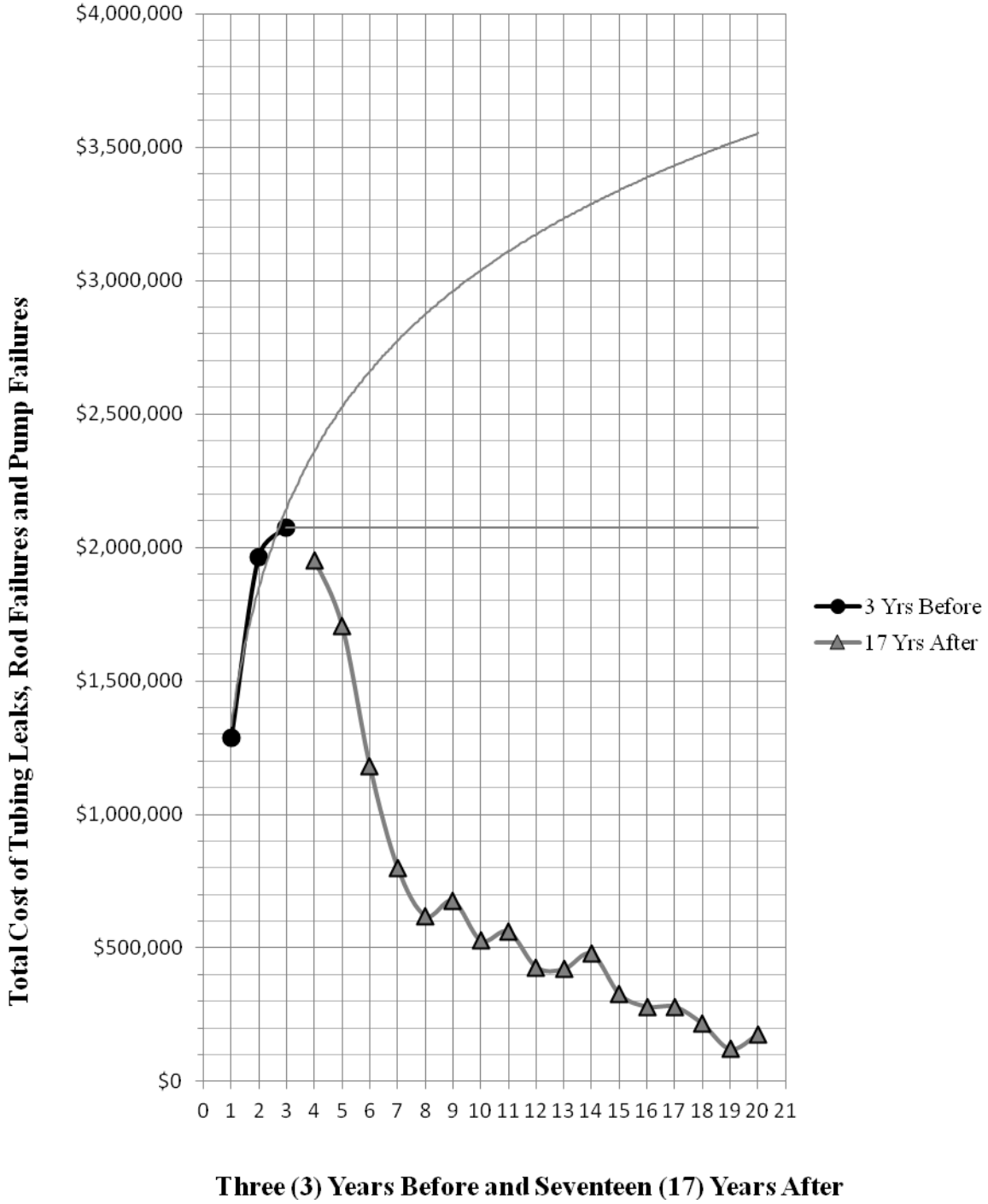
PROGRAM #1 - 87 / 81 "EXISTING" WELLS
TUBING, ROD & PUMP FPWPY-GRAPH 3 (12* MONTHS) 08-17-2013
FLEXBAR / NORRIS / HF / NORRIS PRODUCTION SOLUTIONS



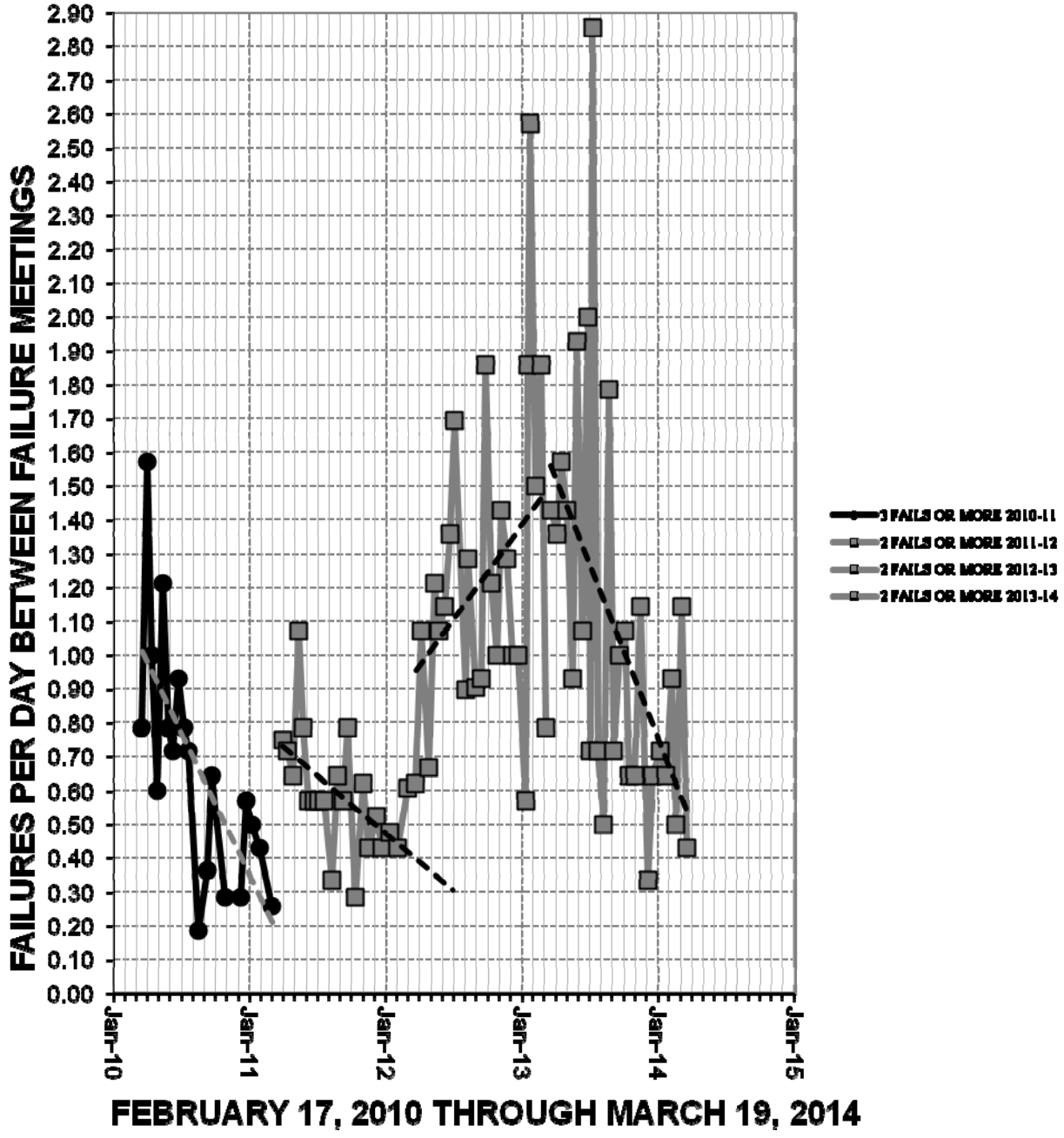
PROGRAM #1 - 63 / 57 "NEW" WELLS
TUBING, ROD & PUMP FPWPY - GRAPH 4 (12* - MONTHS) 08-17-2013
FLEXBAR / NORRIS / HF / NORRIS PRODUCTION SOLUTIONS



17 Year - 150/138 Well Program #1 - Graph 5
Flexbar/Norris/HF/Norris Production Solutions

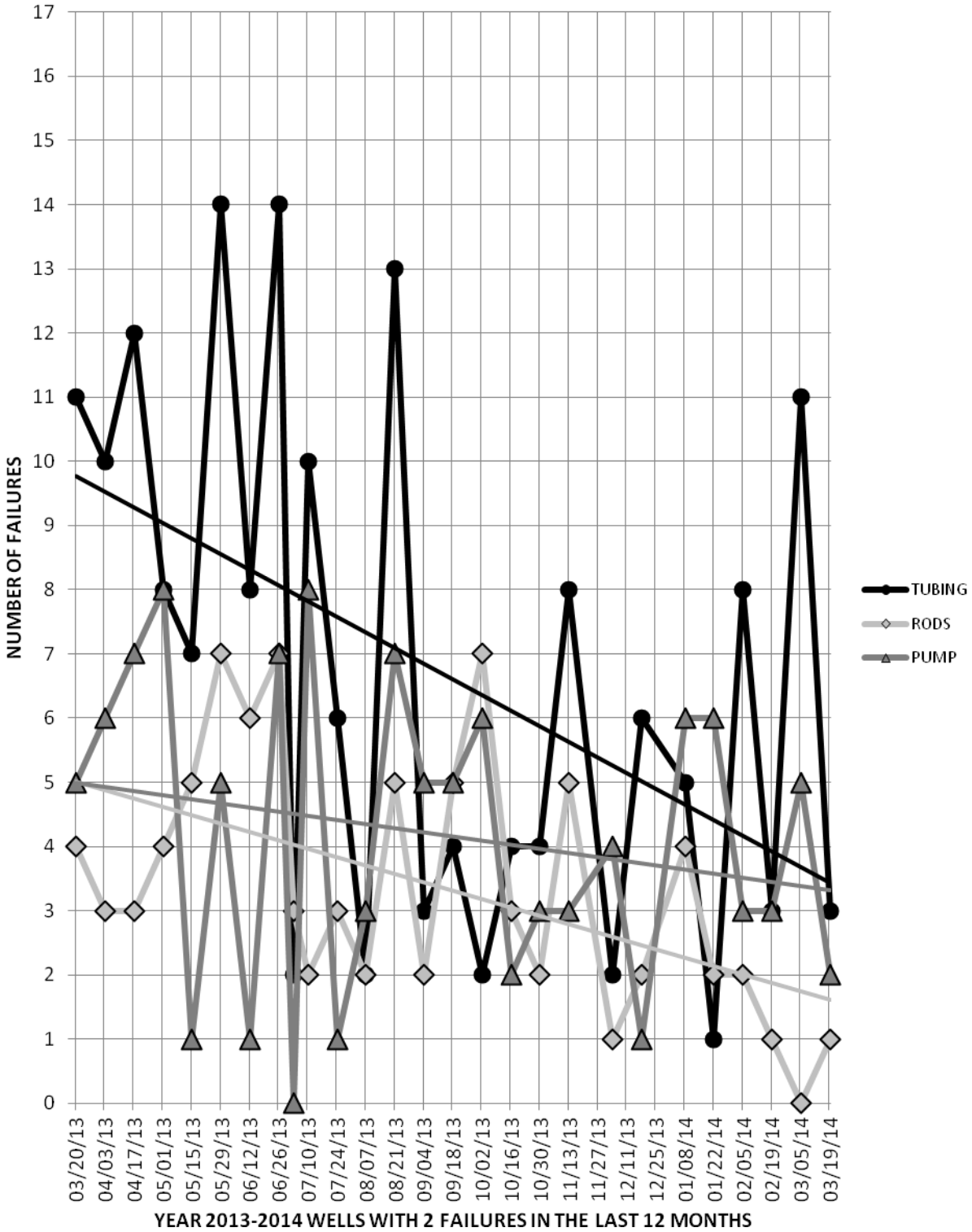


PROGRAM 2 - FAILURE REDUCTION PROGRAM
ALL FOREMAN FAILURE MEETING PERFORMANCE
FLEXBAR / NORRIS / NPS (03-19-2014) GRAPH 6

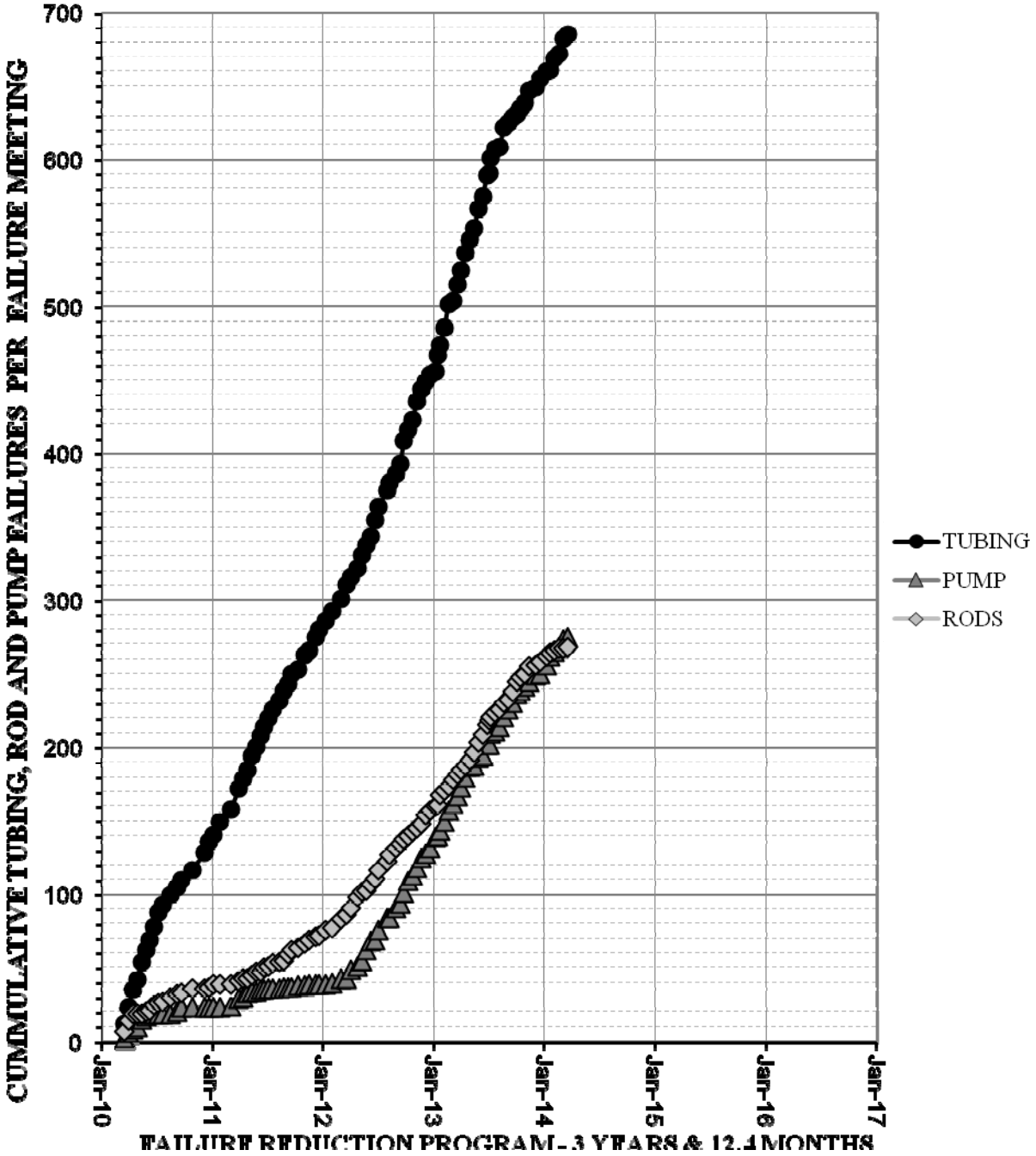


FEBRUARY 17, 2010 THROUGH MARCH 19, 2014

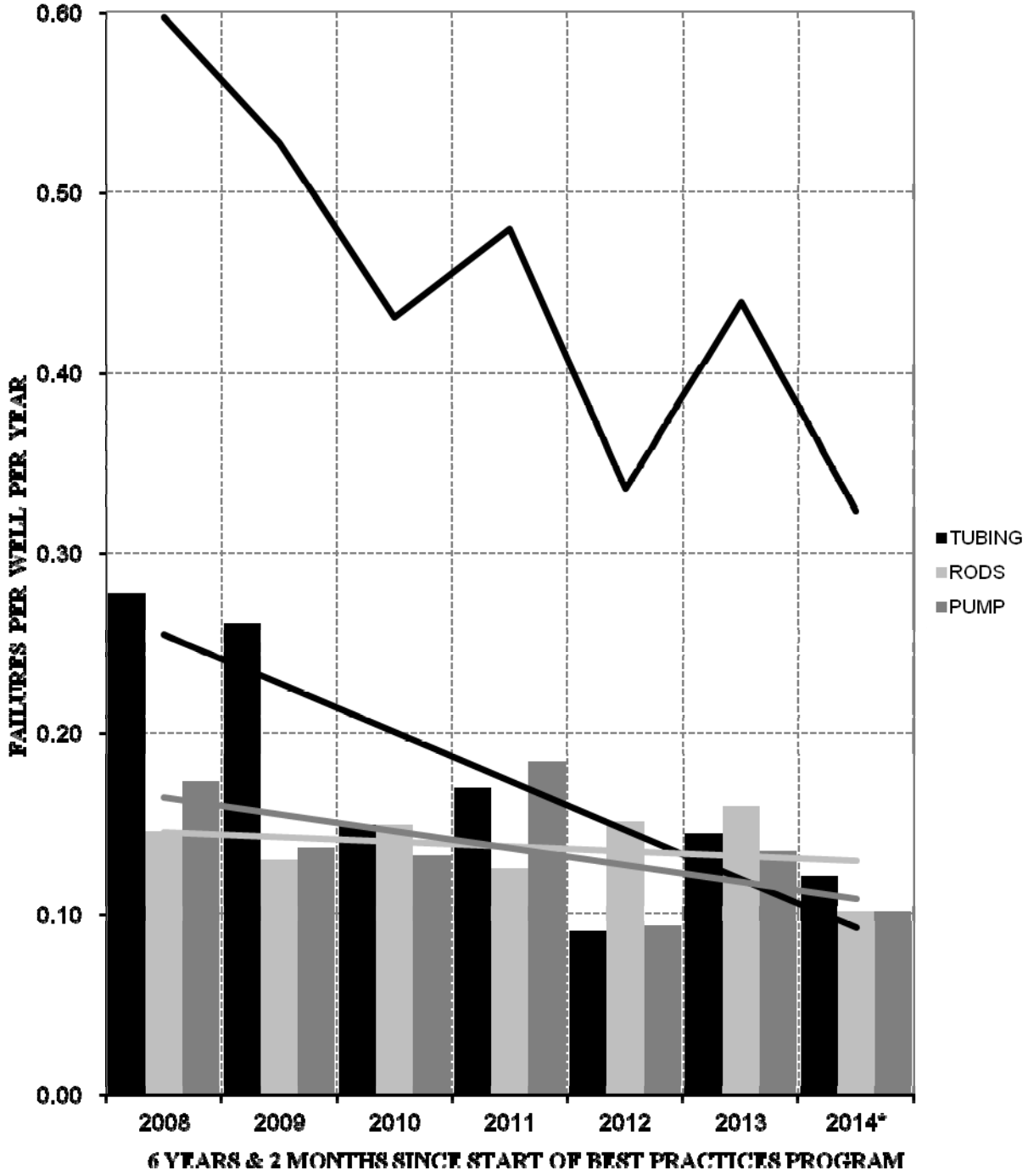
PROGRAM 2 - FAILURE REDUCITON PROGRAM
TUBING, ROD & PUMP FAILURES - GRAPH 7
FLEXBAR - NPS - NORRIS - FLEXBAR (03-19-2014)



PROGRAM 2 - FAILURE REDUCTION PROGRAM
2010-2014 CUMMULATIVE TUBING, ROD & PUMP FAILURES
FLEXBAR / NORRIS / NPS (03-19-2014) - GRAPH 8



PROGRAM #3 - FAILURE REDUCTION PROGRAM - 594 WELLS
TUBING, ROD & PUMP FAILURES (FPWPY)
FLEXBAR / NORRIS / NPS (03-13-2014) - GRAPH #9



PROGRAM #3 - FAILURE REDUCTION PROGRAM
FAILURE COST PER WELL PER YEAR
FLEXBAR / NORRIS / NPS (03-13-14)-GRAPH #10