I – identification of the forces at play (Define the forces and change needed). The change initiated by: Increasing the drilling force sand protection; Weakening the restraining force reducing well activities.

Thus, Well A value is assumed to be the standard value.

Decrements in other wells is indicative of improvement

$\therefore\ R_f =$ Well -A value

$D_f =$ Other well values

If $D_f > R_f$ then improvement ($\propto$) is required

2.3 `Cost Analysis Method

This will involve economic analysis on the effect of introducing sand management strategy on the four well using (Rawlins, 2010):

Increase in oil produced

$$(PO)PO\ after\ \propto - PO\ before\ \propto \quad (4)$$

Percentage increase in oil produced

$$\%\ \text{increase in OP} = \frac{PO\ after\ \propto - PO\ before\ \propto}{PO\ before\ \propto}\frac{x\ 100}{1} \quad (5)$$

Equivalent profit in dollar

Difference in PO after $\propto$ and before $\propto x$CBN oil price (dollar) at a given rate.

2.4 Simple Linear Regression

According to William (2020) simple linear regression is used to model the relationship between two continuous variables, with the objective of predicting the value of an output variable based on the value of an input variable. Simple linear regression is used to establish the relationship between several variables. The Simple Linear Regression model is as expressed in Equation (6)

$$\hat{Y} = \alpha + \beta X \quad (6)$$

where

α= Regression constant

β= Regression coefficient

From Equation (6), to determine α Equation (7) is utilized

$$\alpha = M_Y - \beta M_x \quad (7)$$

where β is determined as

$$\beta = \frac{X - M_X}{Y - M_Y} \quad (8)$$

$$Mx = \frac{\sum X}{n} \quad (9)$$

$$M_Y = \frac{\sum Y}{n} \quad (10)$$

where

M_x = Mean of X values
M_Y = Mean of Y values
X = Unit produced
Y = Defective units
n = Number of parameters

Furthermore, the mean squared error can be calculated as

$$MSE = \frac{(Y - \hat{Y})^2}{n} \quad (11)$$

where

MSE = Mean squared error

$(Y - \hat{Y})^2$ = Square of deviate

2.5 JavaScript

The simple linear regression model was applied on JavaScript which a text-based programming language to facilitate the analysis.

3. `RESULTS AND DISCUSSION

3.1 Results for the Analysis of Total and Cumulative Productivity of Sand

Table 1 shows the result for the analysis of total and cumulative productivity of sand of well A to D for four concurrent year.

Table 1: Total and Cumulative Productivity of Sand in Pounds per Thousand Barrel (pptb)

YEARS (x) / WELLS	1 (x_1)	2 (x_2)	3 (x_3)	4 (x_4)	Cumulative $\sum x$=X	Average $\frac{\sum x}{n}$= Y
A	150	245	746	88	1229	307.25
B	555	115	275	1064	2009	502.5
C	190	226	133	238	787	196.75
D	176	208	76	32	492	123

Table 1 was used to generate cumulative and average values of sand produced in pounds per thousand barrel per well. This showed that Well B had more sand production ad Well D had the smallest production. The cumulative and average values were further examined for exiting relationship using simple linear regression as shown in Table 2.

3.1.1 Simple Linear Regression Analysis of the Marginal Oil Field

The result obtained from the simple linear analysis carried out on the defects on the functional relationship between the average sand production and the cumulative sand production of the marginal field oil well using JavaScript in Appendix is presented in Table 2.

Table 2: Simple Linear Regression Analysis of the Marginal Oil Field

X	Y	X - M_x	Y - M_y	$(X - M_x)^2$	$(Y - M_Y)^2$	$(X - M_x)(Y - M_y)$	Ŷ	Y-Ŷ	$(Y-\hat{Y})^2$
1229	307.25	99.75	24.875	9950.06	618.76	2481.28	307.33	-0.08	0.01
2009	502.5	879.75	220.125	773960.06	48455.01	193654.97	502.49	0.01	0.00
787	196.75	-342.25	-85.625	117135.06	7331.64	29305.15	196.74	0.01	0
492	123	-637.25	-159.375	406087.56	25400.39	101561.72	122.94	0.06	0.00
4517	**1129.5**	**0.0000**	**0.0000**	**1307132.75**	**81805.81**	**327003.12**	**1129.50**	**-0.00**	**0.01**

From the simple linear regression analysis carried out using JavaScript, the regression constant (α) was determined as 0.1633 and the regression coefficient (β) as 0.2502 which is a weak positive linear relationship (Patrick *et al.*, 2018).

Hence, using Equation (6) the simple linear regression Equation becomes

$$\hat{Y} = 0.1633 + 0.2502X \tag{11}$$

In order to evaluate the total productivity of sand and oil Table 3 is presented.as follows

Table 3: Total Productivity of Sand and Oil

Well A Oil (BOPD)	Well A Sand (pptb)	Well B Oil	Well B Sand	Well C Oil	Well C Sand	Well D Oil	Well D Sand
420	150	300	155	100	190	850	176
634	245	336	115	175	226	974	208
800	746	410	275	280	133	120	76
884	88	475	1064	322	238	1124	32

Table 3 shows a corresponding oil production alongside sand. And it is further presented in Figure 1, 2, and 3.

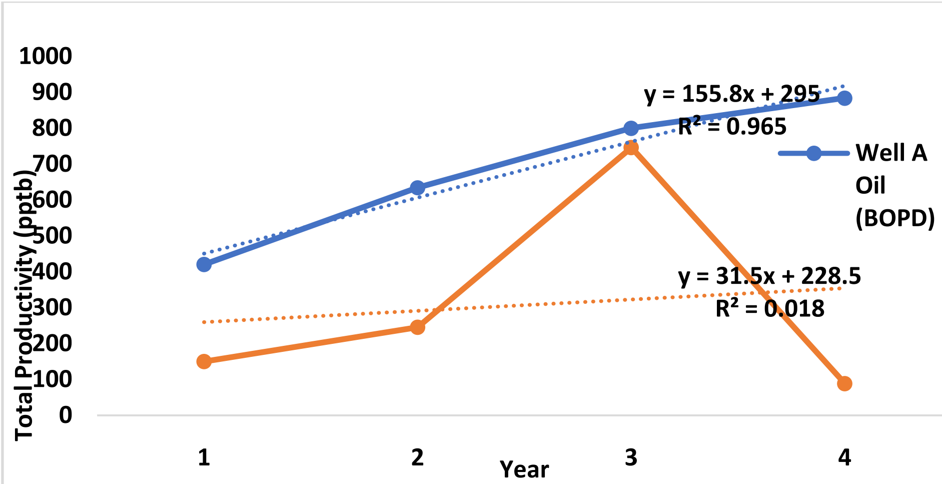

Figure 1: Estimation of Well A Productivity

The coefficient of determination (R^2) shows that the scatter around the regression line is quite small, hence a high R value is obtained. The trend also shows an increment in the oil productivity in well A. This is suggestive of a test for improvement. The sand productivity however, had no defined trend with a poor R^2 value (Patrick *et al.* 2018).

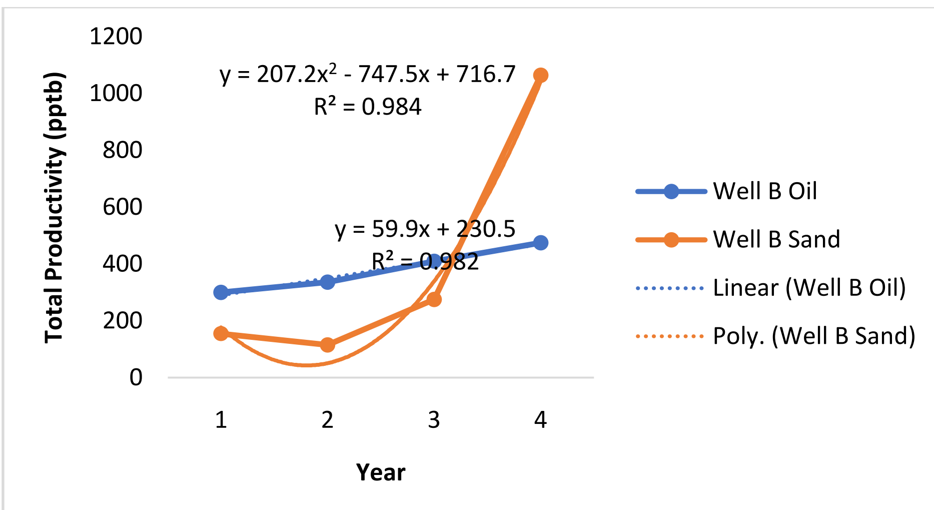

Figure 2: Estimation of Well B Productivity for Oil and Sand

Figur**e** 2 depicts an upshoot in both productivities as the years increased. Though the oil productivity maintained a linear profile, the sand productivity followed a positive polynomial profile. As is expected of a well with few influencing factors, increment in oil rate increases sand production. The R^2 values are also high (Patrick *et al.* 2018).

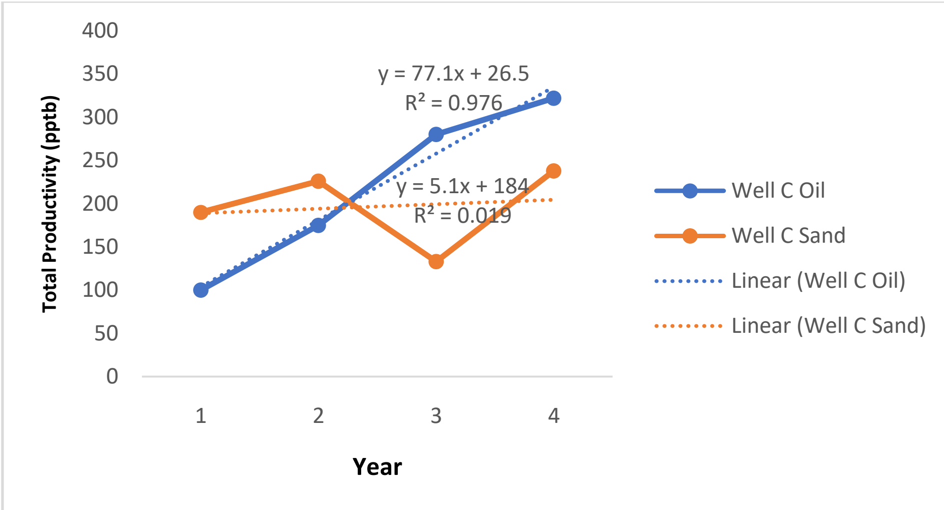

Figure 3: Estimation of Well C Productivity for Oil and Sand

Figure 3 also shows that the trend depicts an increment in the oil productivity in Well C with attendant irregularity in the sand productivity. The R^2 value for the oil productivity shows a good coefficient (Patrick *et al.* 2018).

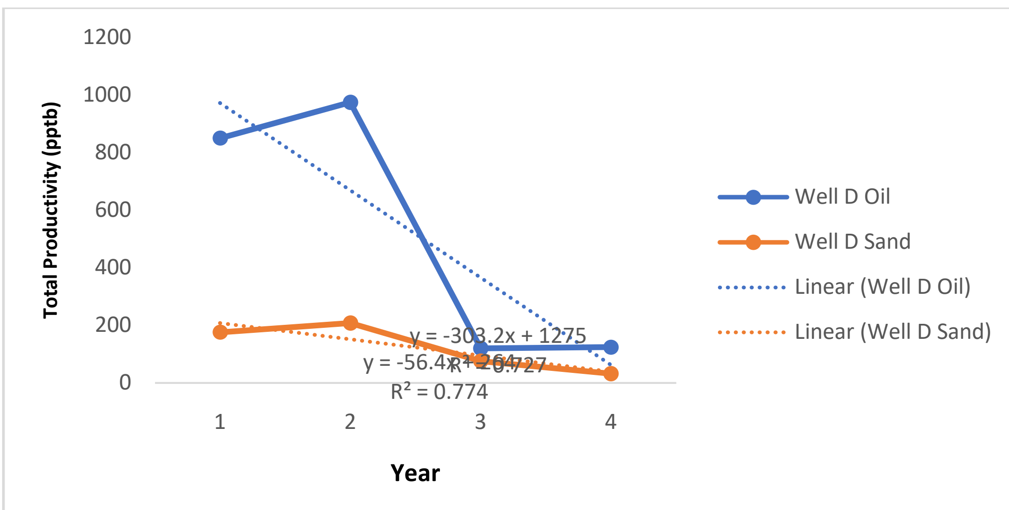

Figure 4: Estimation of Well D Productivity for Oil and Sand

3.1.2 Analysis of Oil Rate

The result for the analysis of oil rate of the wells is presented in Figure 5

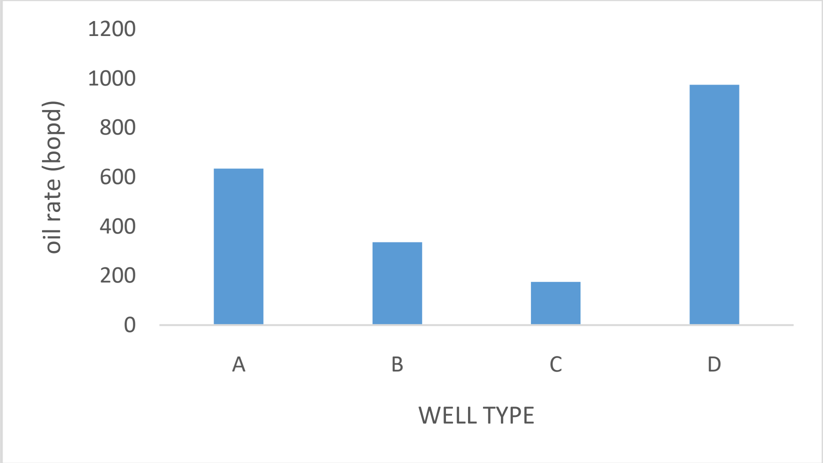

Figure 5: Oil Rate of Various Well

Figure 5 shows the oil rate of various well in the study area. From figure 4.8 well D has the highest oil rate of 974bopd. This is main cause of sand production in this well. There is a critical flow rate for most wells where the frictional drag forces and pressure differential are not higher than the formations compressive strength to cause sand production. This rate can be arrived by gradually increasing the production rate, until sand is been produced. To minimize production of sand operators can choke the flow rate down to critical flow rate where sand production does not occur or where it occurs at an acceptable level.

3.1.3 Analysis of Performance of Well Treatment Type

The analysis of performance of well treatment type using Expandable Sand Screen (ESS) and External Gravel Pack (EGP) is presented in Table 4.

Table 4: Analysis of Performance of Well Treatment Type

WELL	Flow rate ratio of expandable sand screen Y(ESS)	Pseudo-pressure ratio of expandable sand screen X(ESS)	Flow rate ratio of External Gravel Pack Y(EGP)	Pseudo-pressure ratio of External Gravel Pack X(EGP)
A	0.0127	0.9958	0.2032	0.8920
B	0.0132	0.9961	0.1721	0.9169
C	0.0498	0.9688	0.1678	0.9046
D	0.1097	0.9487	0.2012	0.8957

Table 4 shows the analysis of performance of well treatment type using expandable sand screen (ESS) and External Gravel Pack (EGP). It is seen that the gas flow rate ratio(Y) increases from well A (0.0127) to well D (0.0498) when applying ESS whereas the pseudo-pressure (X) ratio increases from well A (0.9958 to well B (0.9961) on ESS. Also, the gas flow rate ratio (Y) reduces from well A (0.2032) to well C (0.1678) when applying EGP and the pseudo-pressure ratio(X) increases from well A (0.8920) to well B (0.9169). The increase in Y value of ESS is an indication of high performance of the wells. The decrease in EGP well performance may be due to debris and loose sand from the formation during production which plugs the pore spaces in the gravel pack. It can also be caused by unclean completion fluid which causes contamination, wrong gravel size selection which can cause sand influx, wrong selection of screen slot to retain the gravel and ineffective placement technique. In other to ascertain whether or not an improvement should be carried out as good management technique, the Lewins force field model is applied as shown in Table 5

Table 5: Lewin's Force Field with %Error

Flow Ratio	Improvement $(\propto) = D_f - R_f$	% Error
0.8921	0.8921 -	std = 0
0.9169	0.9169-09929 = 0.0248	2.7%
0.9046	09046 – 0.8921 = 0.0125	1.4%
0.8957	0.8957 – 0.8921 = 0.0036	0.4%

The Lewins force model, recognizes that improvement can occur, when the percentage error is ≥ 1.0%. This Well B and Well C are to be improved upon

Usually, one of the wells is usually standardized and used as a basis. In this case, well A is the standard well.

Since pseudo pressure depicts the influence of variation of some gas properties already assumed as constants in liquids, it is also proper to base improvement on pseudo pressure. Table 6 contains information on improvement based on pseudo pressure of ESS.

Table 6: Application of Improvement on Pseudo pressure ratio of Expandable Sand Screen

Flow ratio Ratio of ESS	Imp$rovment(\propto)$	% Error
A 0.0927	Standard	0
B 0.0132	0.0132 -00127 = 0.01	1%
C 0.0498	0.0491 – 0.0127 = 0.0311	3%

D	0.1097	0.1097 – 0.0127 = 0.0917	1%

From the percentage error of 1% for well B and D, improvement is required. Well C clearly shows a higher need for improvement

3.1.4 Result of Sand Management Plan

With the application of sand management, the following results were obtained

i) Increase in production benefits: The increased oil production as a result of using this improved sand management strategy has been very encouraging and satisfying. Table 7 indicates the additional oil produced for each well as a result of sand management

Table 7: Effect of Sand Management and Pressure Variation on Well productivity

Well	Oil Rate Before Sand Management (pptb)	Flowing Tubing Head Pressure (FTHP)	Oil Rate Increment on application of Sand Management (BOPD)
A	634	170	250
B	336	108	139
C	175	150	147
D	974	265	150

3.1.5 Cost Analysis

The result of the cost analysis is presented in Table 8.

Table 8: Cost of Existing Strategy and Improve Strategy

Well	Oil rate	Oil price	Existing Equivalent price in dollars	Improve equivalent price
A	634bopd	$62.81	$39821.54	$55524.04
B	336bopd	$62.81	$21104.16	$29834.75
C	175bopd	$62.81	$10991.71	$20224.78
D	974 bopd	$62.81	$61176.94	$70598.44

4. CONCLUSION

After careful examination of the productivity data for wells A, B, and C gave a high R^2 value depicting an increment in well productivity for both sand and oil. It was however not used to determine whether an intervention was needed for well D. Evaluation of the data obtained from the marginal oil well was carried out to ascertain the effective sand techniques in oil well production of the marginal oil field using simple linear regression, and Lewins forcefield model. The simple linear regression analysis carried out for possible sand management data analysis gave a weak positive regression coefficient of 0.2505. This allowed the application of sand management.

The sand control technique was evaluated using the flow rate ratio and pseudo pressure ratio. The increased flow rate ratio for the ESS screening technique from the standard Wells A to C depict that an action plan was required. Lewins force field model was applied to predict improvement on sand management technique. Decision value according to the force field model showed the application of improvement at ≥1% error.

Application of the sand management technique gave an increment of $15702.5 for Well A, $8730.59 for Well B, $9233.7 for Well C and $9421.5 for Well D. The cost of improvement before and after, established a profit of 39.4% for Well A, 41.3% for Well B, 84% for Well C, 15.4% for Well D. Oil rate also increased with increase in flowing tubing head pressure (FTHP).

From the detailed analysis carried out, it is recommended that should incorporate the use the use of machine learning such as Artificial Neural Network, Random Forest, and Support Vector Machine.

5. ACKNOWLEDGEMENTS

The authors would want to acknowledge the staff of the Department of Mechanical Engineering of Rivers State University, Nigeria, for their technical support. Also, we appreciate Engr. R. K. C. Amadi, and Mr. Orokor, Allwell Chiyonu for their technical support.

REFERENCES

Aborisade, O. M. (2011). *Practical Approach to Effective Sand Prediction, Control and Management.* Masters Dissertation. Department of Petroleum Engineering, African University of Science and Technology.

Al-Awad, M. N. (2001). The Mechanism of Sand Production Caused by Pore Pressure Fluctuations. *Journal of Oil & Gas Science and Technology.* 56 (4), 339-345.

Appah, D. (2001). New Gravel Pack Technique Reduces Sand Production in Niger Delta Wells. *Oil and Gas Journal*.3(5), 1-6.

Brar, G. S. Aziz, K., (2000). Analysis of Modified Isochronal Tests to Predict the stabilized Deliverability Potential of Gas Wells without using Stabilized Flow Data. *Journal of Petroleum Technology.* 30 (1): 297–304

Nouri, A., Vaziri, H., Belhaj, H., & Islam, R. (2003). *A Comprehensive Approach to Modeling Sanding During Oil Production. A Paper Presented at the SPE Latin American and Caribbean Petroleum Engineering Conference.*

Qui, K., Marsden, J. R., Alexander, J., Retnanto, A., Abdelkarim, O. A. & Shatwan, M. (2006). Practical approach To Accuracy in Sanding Prediction. *A Paper Presented at the SPE Asia Pacific Oil and Gas Conference and Exhibition*, 11-13 September, Adelaide.

Syed, T. H., Shen, L., Tayyaba, A., Muhammad, J. H., Syed, H. H., & Muhammad, A. (2016). *Journal of Innovation & Knowledge.* 6(2), 1-7.

Vaziri, H., Barree, B., Xiao, Y., Palmer, I. & Kutas, M. (2002). What is the Magic of Water in Producing Sand? *A Paper Presented at the SPE Annual Technical Conference and Exhibition.*

Weingarten, J. S. & Perkins, T. K. (1995). Prediction of Sand Production in Gas Wells: Methods and Gulf of Mexico Case studies. *Journal of Petroleum Technology*: 7(3), 13-21.

William, N. (2020). *Statistics for Engineers and Scientist. Fifth Edition.* McGraw Hill, New York.

Zhang, J., Rai, C. S., & Sondergeld, C. H. (2011). Mechanical Strength of Reservoir Materials: Key Information for Sand Prediction. *Paper Presented at the SPE Annual Technical Conference.* Trondheim.