AV Improving Infill Development Decision Making with Interval Estimation*

By

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Abstract

Following partial completion of both primary and secondary development in a given field, it becomes necessary to determine whether continued drilling should be pursued in the same field. The usual approaches for deciding whether to continue drilling (Swanson's mean or estimates based on lognormal methods) can fail to account for variation and uncertainty. To better inform this decision, we propose implementing statistical confidence intervals (with an accompanying certainty level) for relevant features of interest. Closed form intervals and maximum likelihood based intervals for the average ultimate recovery for all wells in a field, the percent of wells in a field having ultimate recovery values above a certain benchmark value, and other important features of interest are considered. Confidence intervals appropriate for both the lognormal and Weibull distribution are given. The proposed methods are illustrated with real data from 64 Devonian Richfield wells in the Beaver Creek field, Michigan basin

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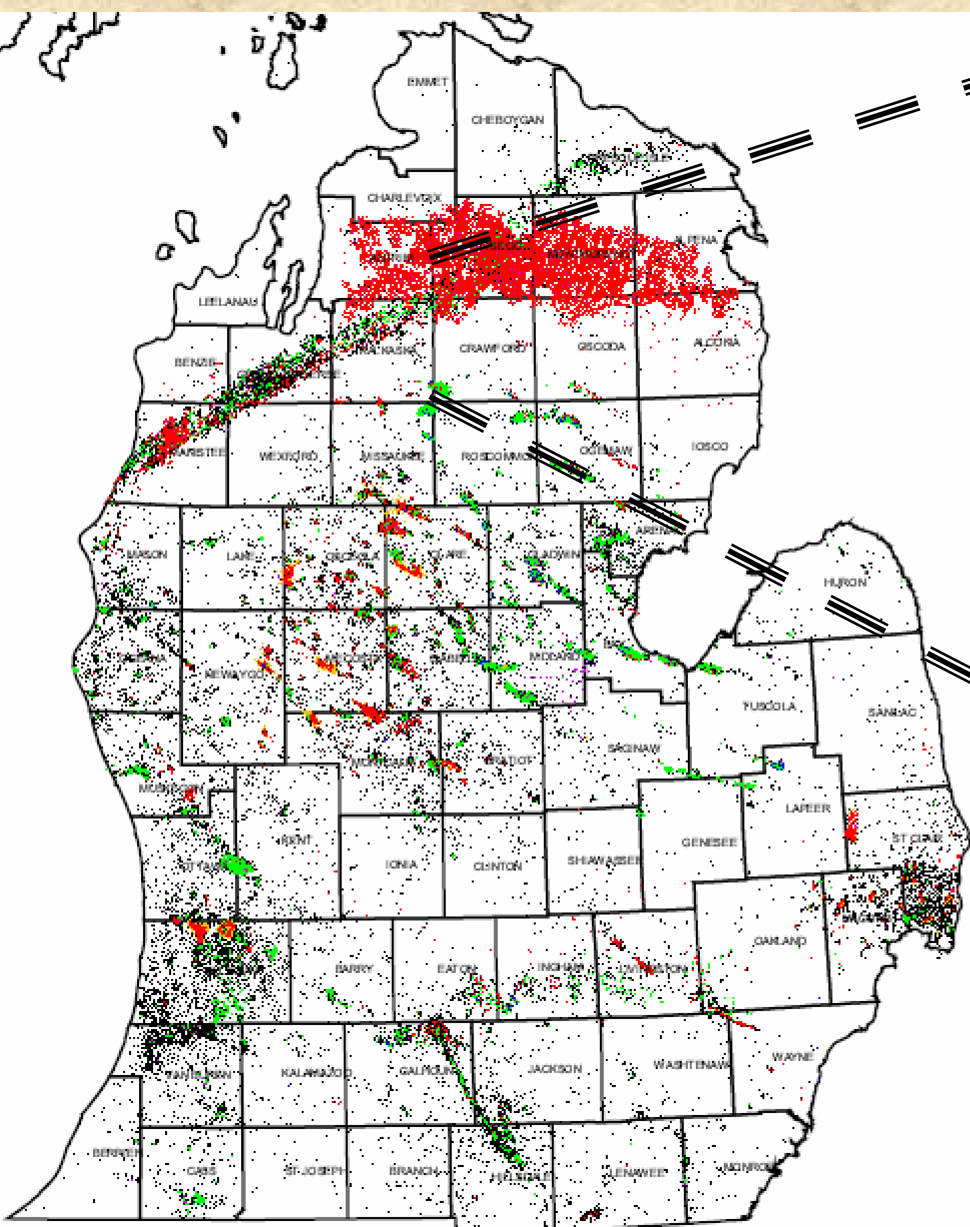
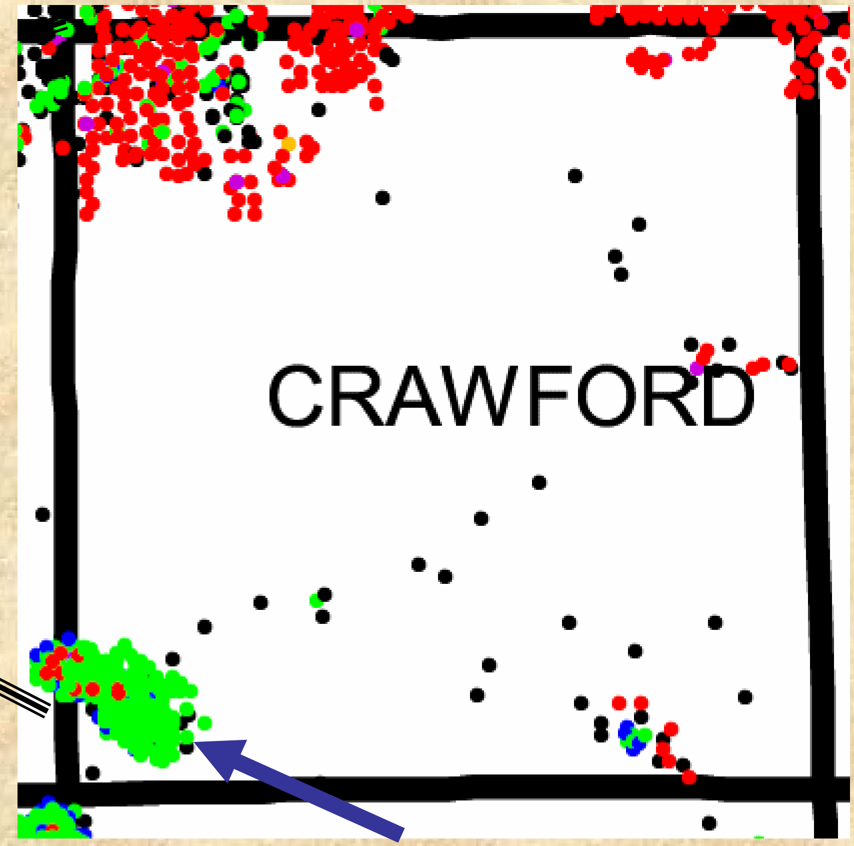
Index Map; LP of Michigan; Location of the Study Area





Oil and Gas Well Legend

- Oil Wells — 13,185
- Gas Wells — 14,142
- Dry Holes — 22,407
- Disposal Wells — 1,087
- Injection Wells — 810
- Other Wells — 813

Study Area; Beaver Creek Field

(Courtesy, Michigan DEQ, 2008)

Operational History

- A case study utilizing an available tool to help reach a decision
- Five years of 20 acre Richfield Dolomite down-spacing; with poorer than expected results; prematurely terminated down-spacing in 1991
- Property put up for sale in 1994
- Divestiture process revealed true reasons for sub-par performance

  1. Inconsistent stimulations
  2. Program wells were in high primary recovery areas; drainage
  3. Program wells drilled in secondary recovery areas; swept

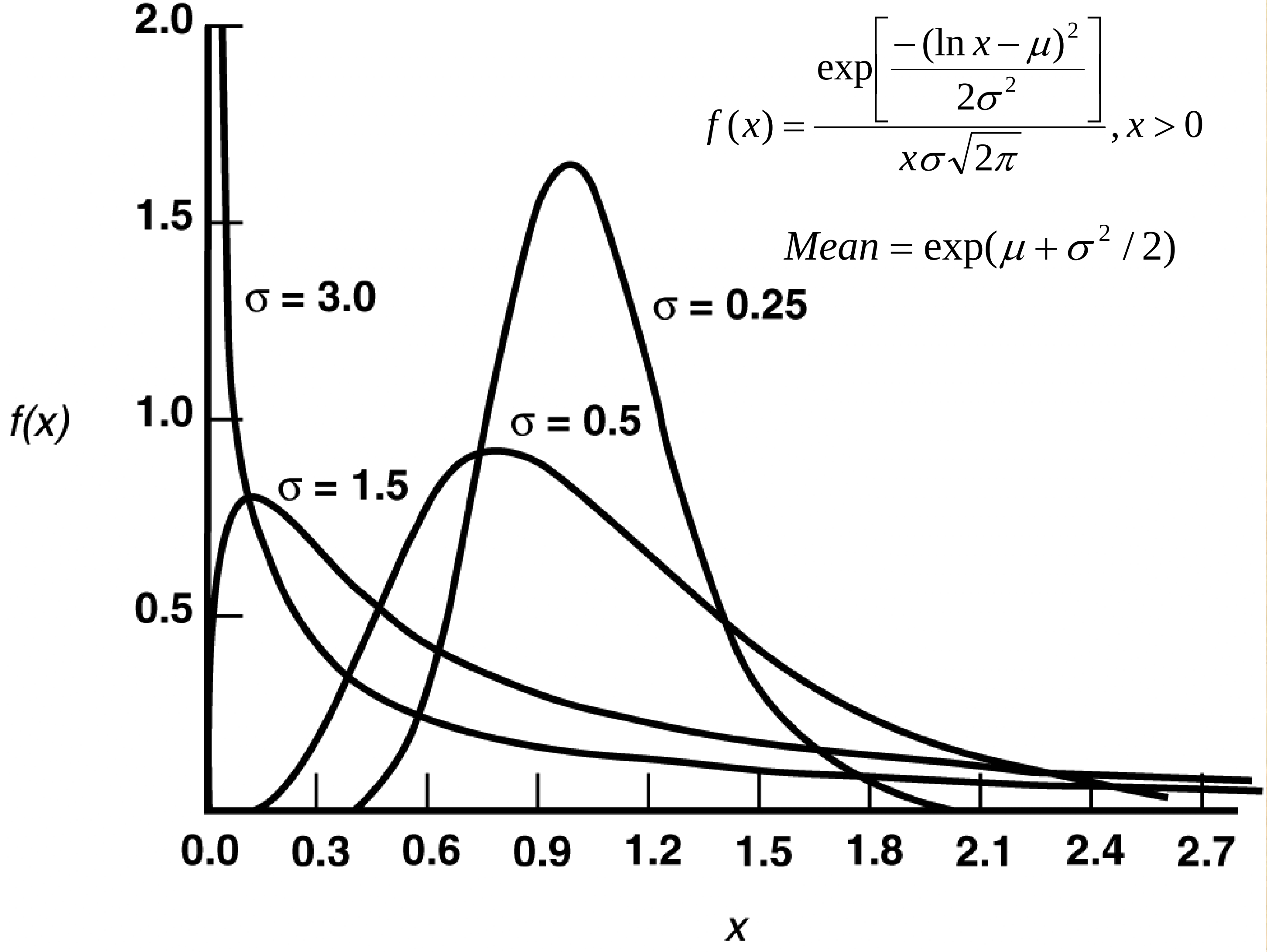
- New review of asset involved application of the Weibull statistical method which lead to a more accurate and informed picture of possible recoveries.

Purpose of Study

- Should the data have been interpreted differently?
- 20 acre infill program was not meeting expectations because incorrect stimulation and poor well placement.
- Is there a tool to help optimize decision making?

- Swanson’s mean or estimates based on lognormal methods
- Fail to account for variation and uncertainty
- Statistical confidence intervals
- Closed form intervals
- Maximum likelihood based intervals
- Average ultimate recovery for all wells in a field
- Percent of wells in a field having ultimate recovery values above a certain benchmark value
- Other important features of interest are considered.
- Real data from 64 Devonian Richfield wells in the Beaver Creek field, Michigan basin.

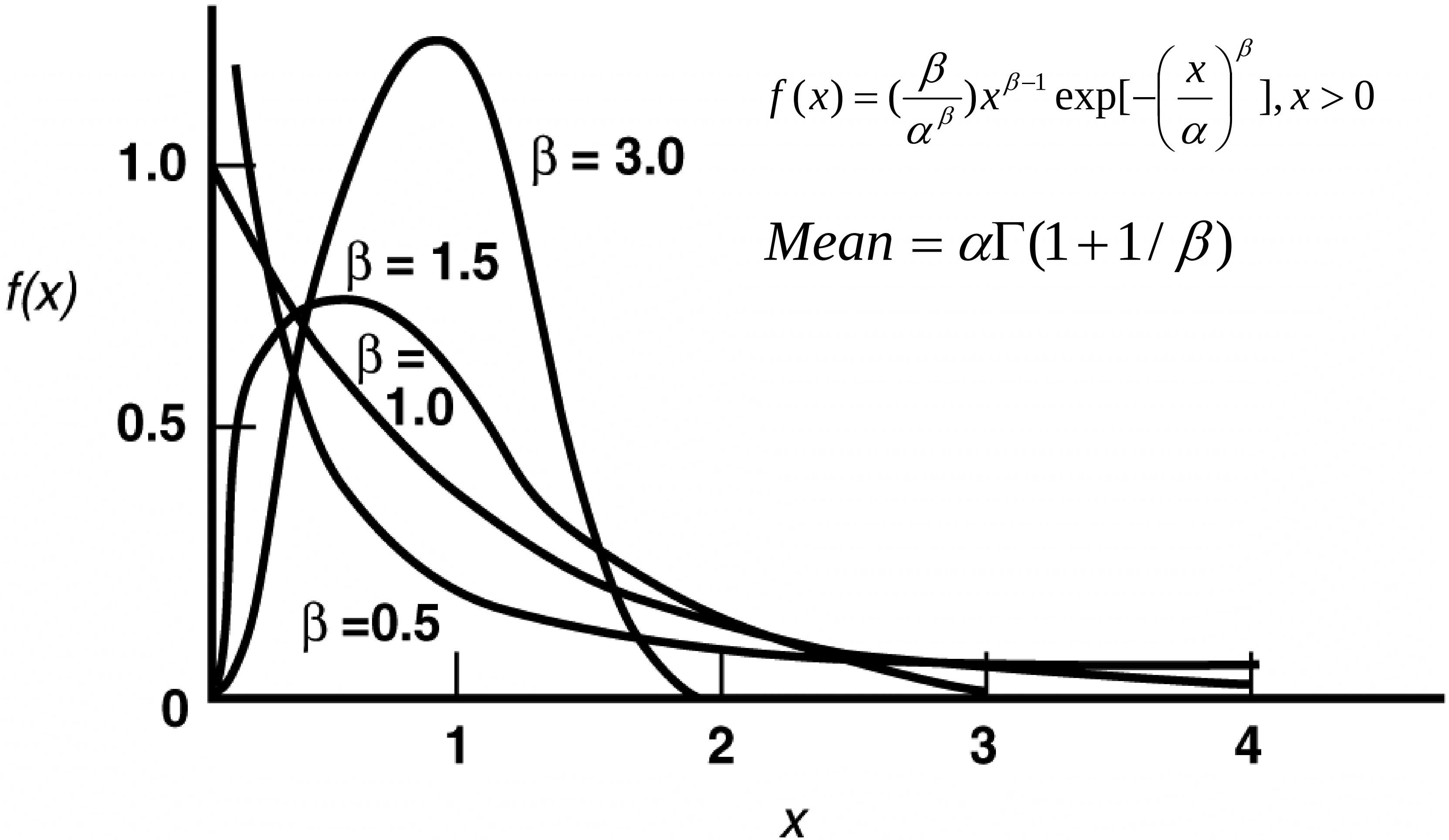
Lognormal Distribution
location parameter $\mu = 0$ or scale $\exp(\mu)$
selected shape parameter σ values



$$f(x) = \frac{\exp\left[\frac{-(\ln x - \mu)^2}{2\sigma^2}\right]}{x\sigma\sqrt{2\pi}}, x > 0$$

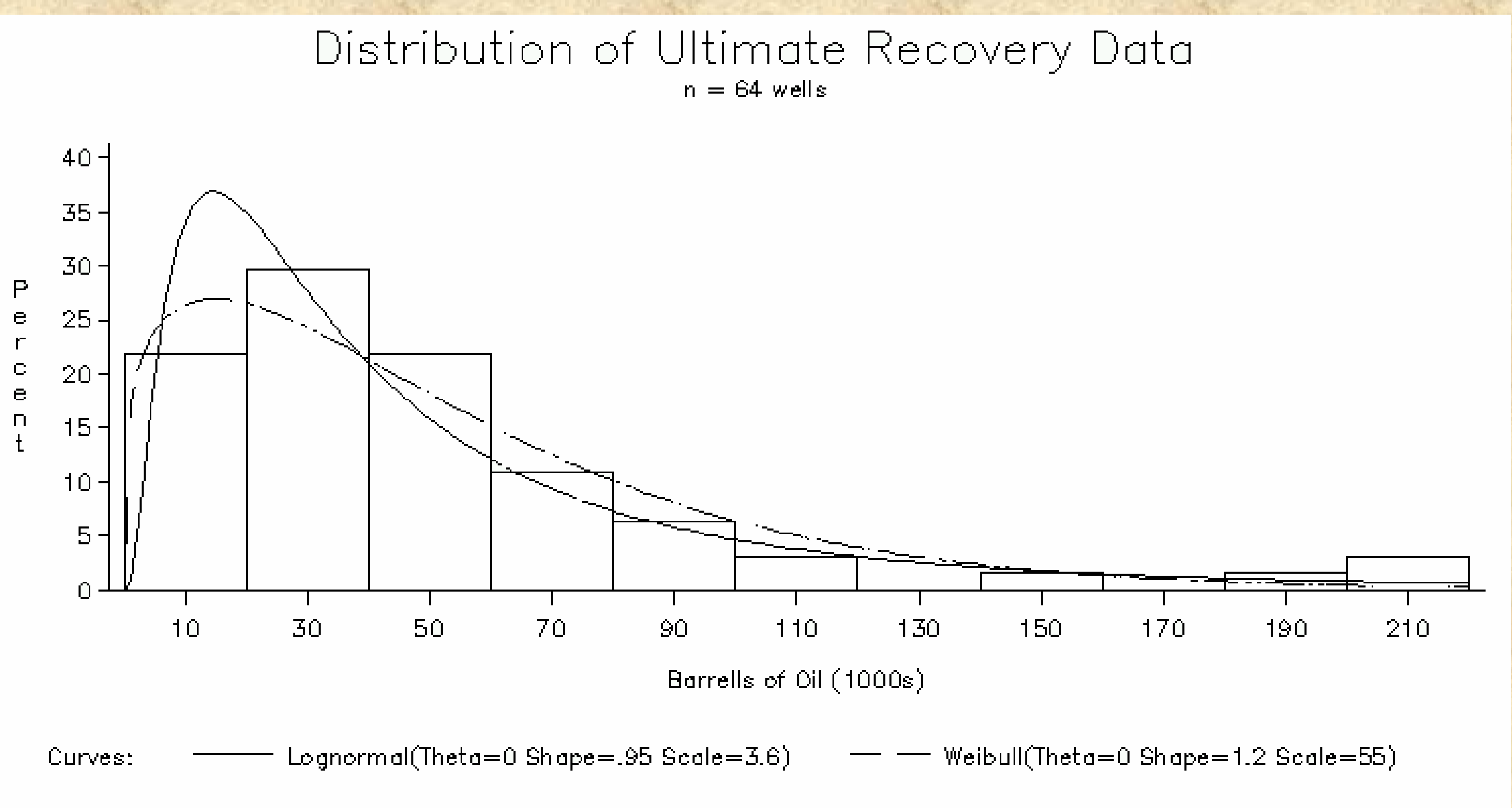
$$Mean = \exp(\mu + \sigma^2 / 2)$$

Weibull Distribution
scale parameter $\alpha = 1$
selected shape parameter β values



$$f(x) = \left(\frac{\beta}{\alpha^{\beta}}\right) x^{\beta-1} \exp\left[-\left(\frac{x}{\alpha}\right)^{\beta}\right], x > 0$$

$$Mean = \alpha\Gamma(1 + 1/\beta)$$


Distribution of Ultimate Recovery Data
n = 64 wells
Percent
0
5
10
15
20
25
30
35
40
10
30
50
70
90
110
130
150
170
190
210
Barrells of Oil (1000s)
Curves:
Lognormal(Theta=0 Shape=.95 Scale=3.6)
Weibull(Theta=0 Shape=1.2 Scale=55)

Usual Statistics

- Swanson’s Lognormal dependent mean is 55.615.
- Swanson’s Distribution independent mean is 48.765.

95% Confidence Intervals for Characteristics of Interest Assuming a Weibull or Lognormal Distribution

Quantity to be estimated	Lognormal	Weibull	Restriction/Method
μx	(40.21, 62.39)	(40.21, 62.39)	$n > 30$
	(42.12, 73.18)	(42.24, 62.83)	ML, $n > 30$
Median	(28.21, 45.25)	no closed form	$n > 1$
	(23.39, 44.97)	(32.62, 51.81)	ML, $n > 30$
X (single observation)	(5.31, 240.1)	no closed form	$n > 1$
	(0, 185.86)	(0, 133.89)	ML, $n > 30$

95% Confidence Intervals for Characteristics of Interest Assuming a Weibull or Lognormal Distribution

Quantity to be estimated	Lognormal	Weibull	Restriction/Method
P(X > xo=41)	(.3476, .5402)	(.404, .603)	n lognormal>20 n Weibull > 100
	(.3473, .5399)	(.3982, .5957)	ML, n > 30
Lower One-sided for P(X > xo=41)	(.3624 to 1)	(.4125 to 1)	n lognormal>20 n Weibull > 100
	(.362 to 1)	(.415 to 1)	ML, n > 30

*Note: All confidence intervals are at the 95% confidence level.
ML corresponds to the maximum likelihood method and n is sample size.

- Estimate Ultimate Recovery (1000s barrels) for the n=6 new wells
- 14 68.3 55.3 82.4 46.7 25.7

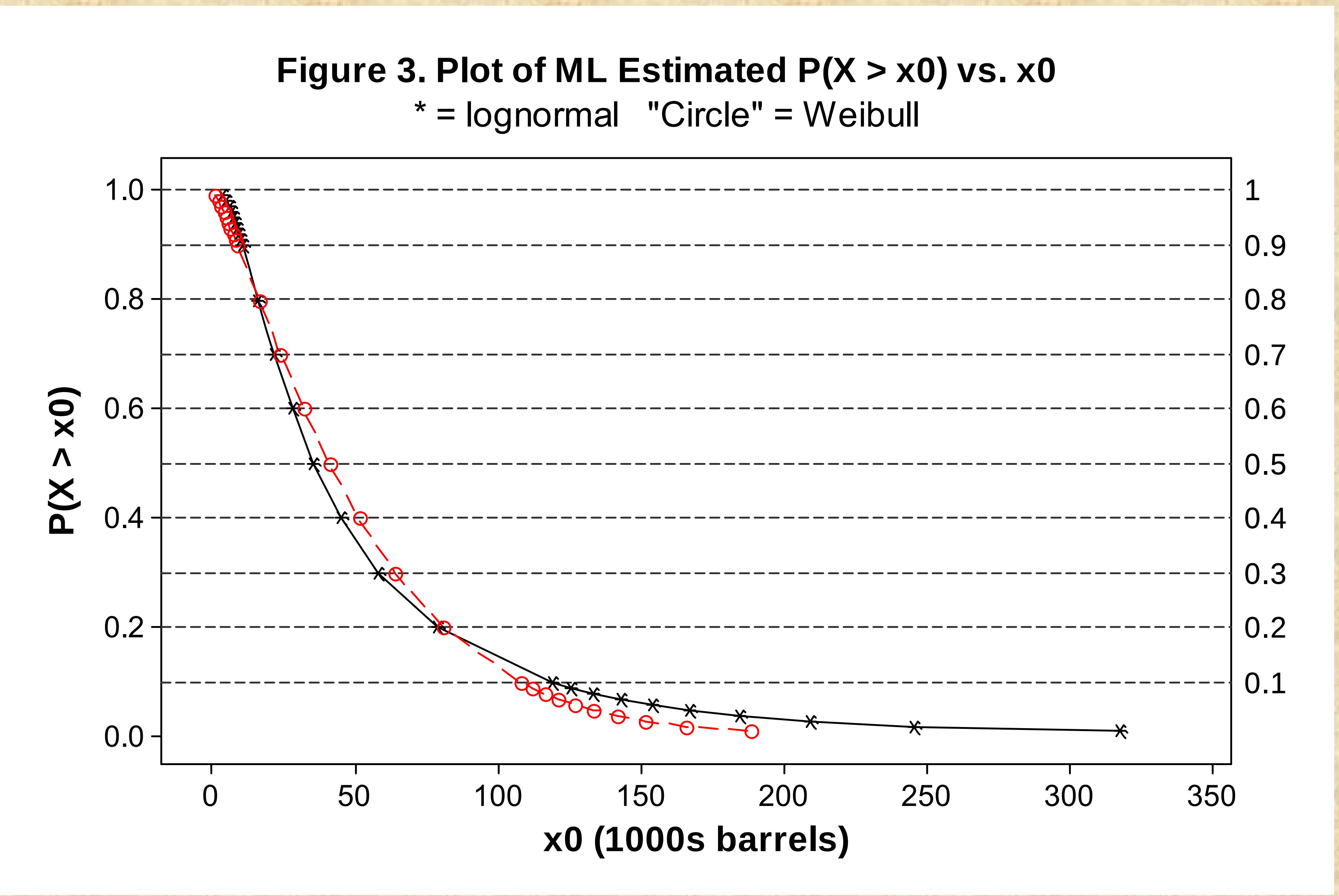


Figure 3. Plot of ML Estimated P(X > x0) vs. x0
* = lognormal "Circle" = Weibull
P(X > x0)
1.0
0.8
0.6
0.4
0.2
0.0
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
50
100
150
200
250
300
350
x0 (1000s barrels)

Additional References

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