RemTech 2006

Beginning With the End in Mind: When to Shut Down a Remedial System?

By (in no particular order):

Yong Li, Scott Digel, and Elwyn Lyons

O'CONNOR ASSOCIATES

RemTech 2006

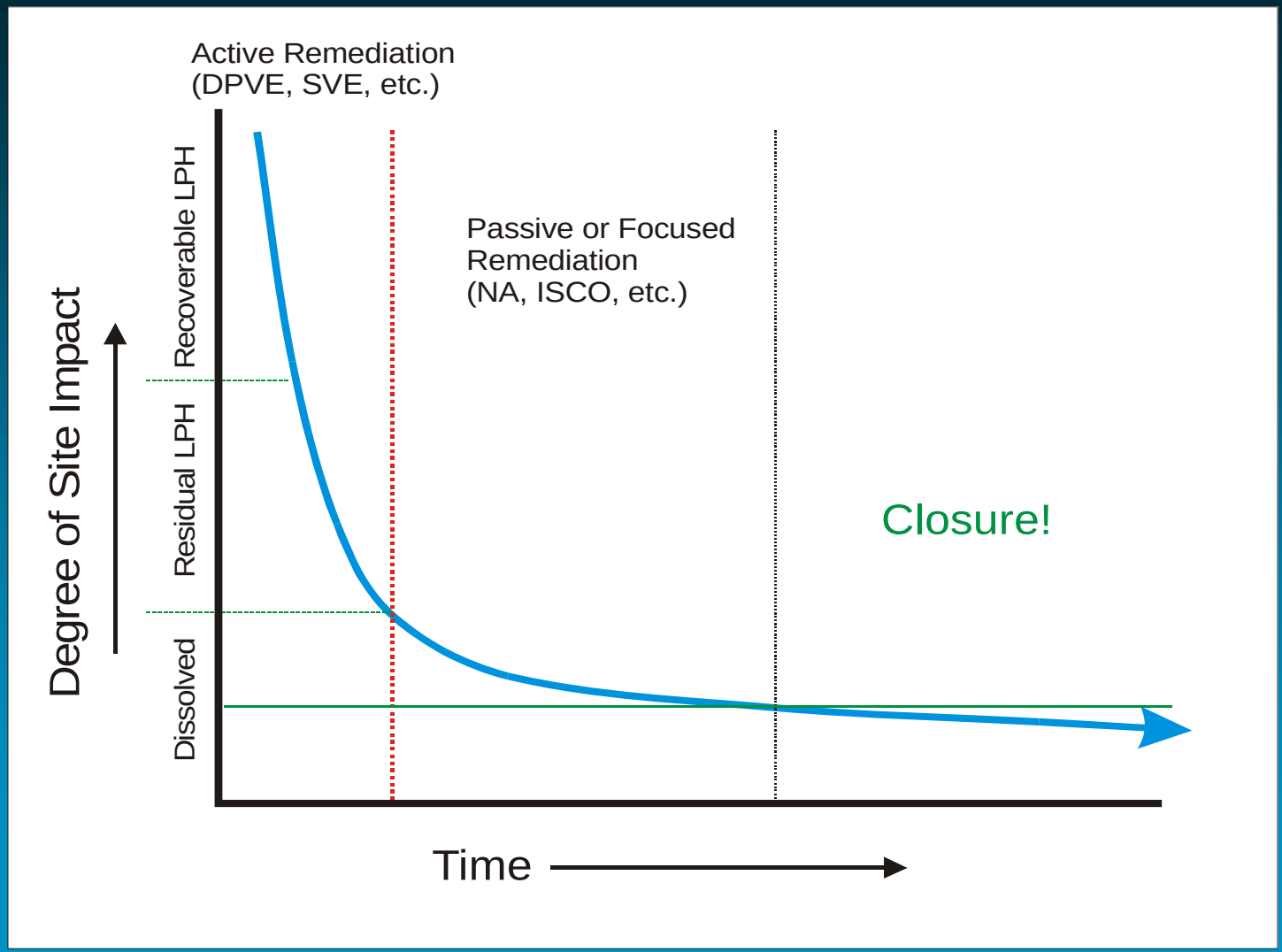
DISCLAIMER:

This talk is about a journey that isn't over yet!

Things That We Already Know...

1. Projects follow a life cycle during which a variety of different remediation and risk management strategies may be appropriate
2. Active remediation using some sort of system (DPVE, Air Sparging, etc.) is typically appropriate early in the life cycle
3. Systems are expensive to operate
4. You usually won't achieve site closure with active remediation alone

Simplified Project Life Cycle



O'CONNOR ASSOCIATES

So…

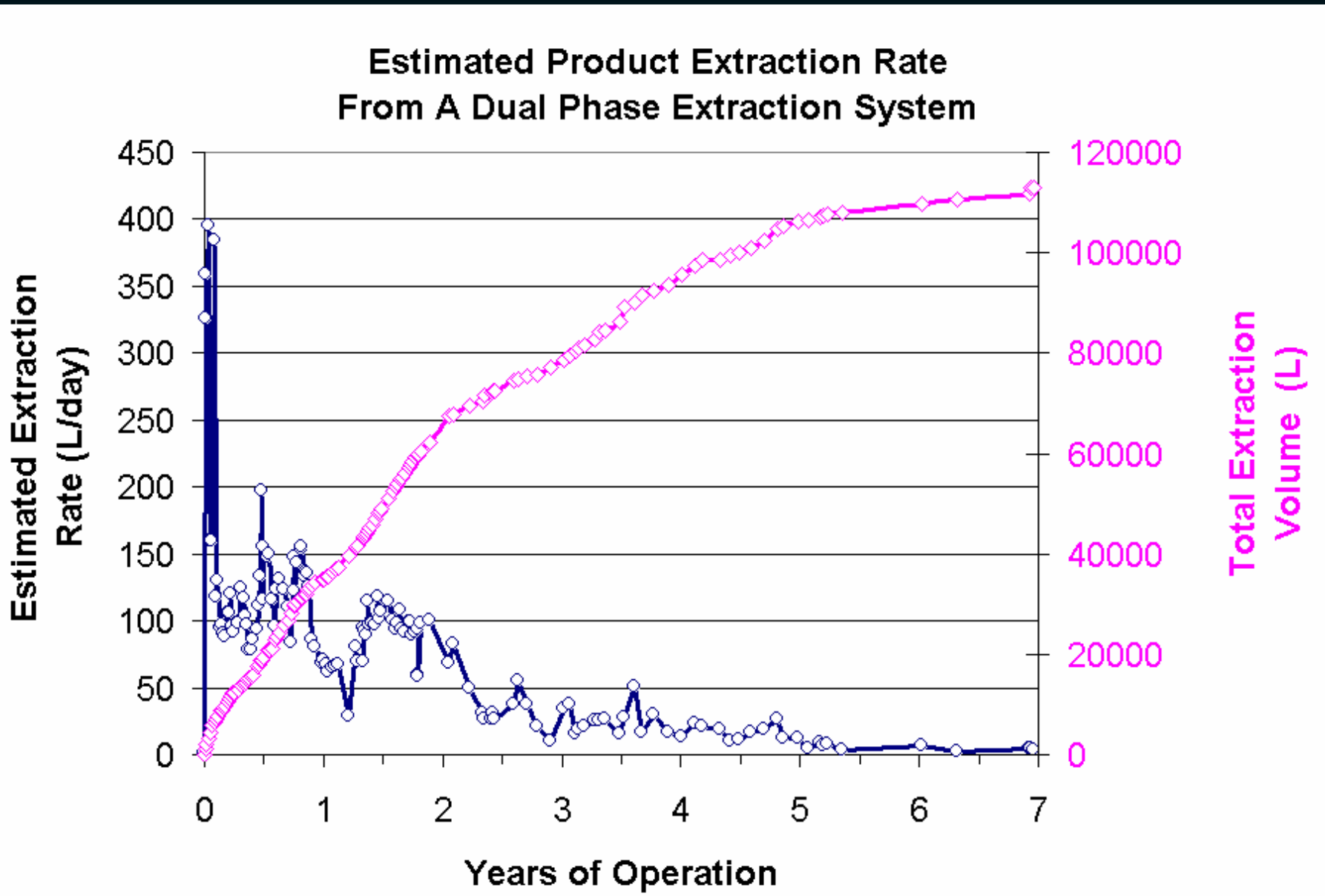
WHEN and WHY should you shut a system off and how can you try to answer these questions before you turn it on?

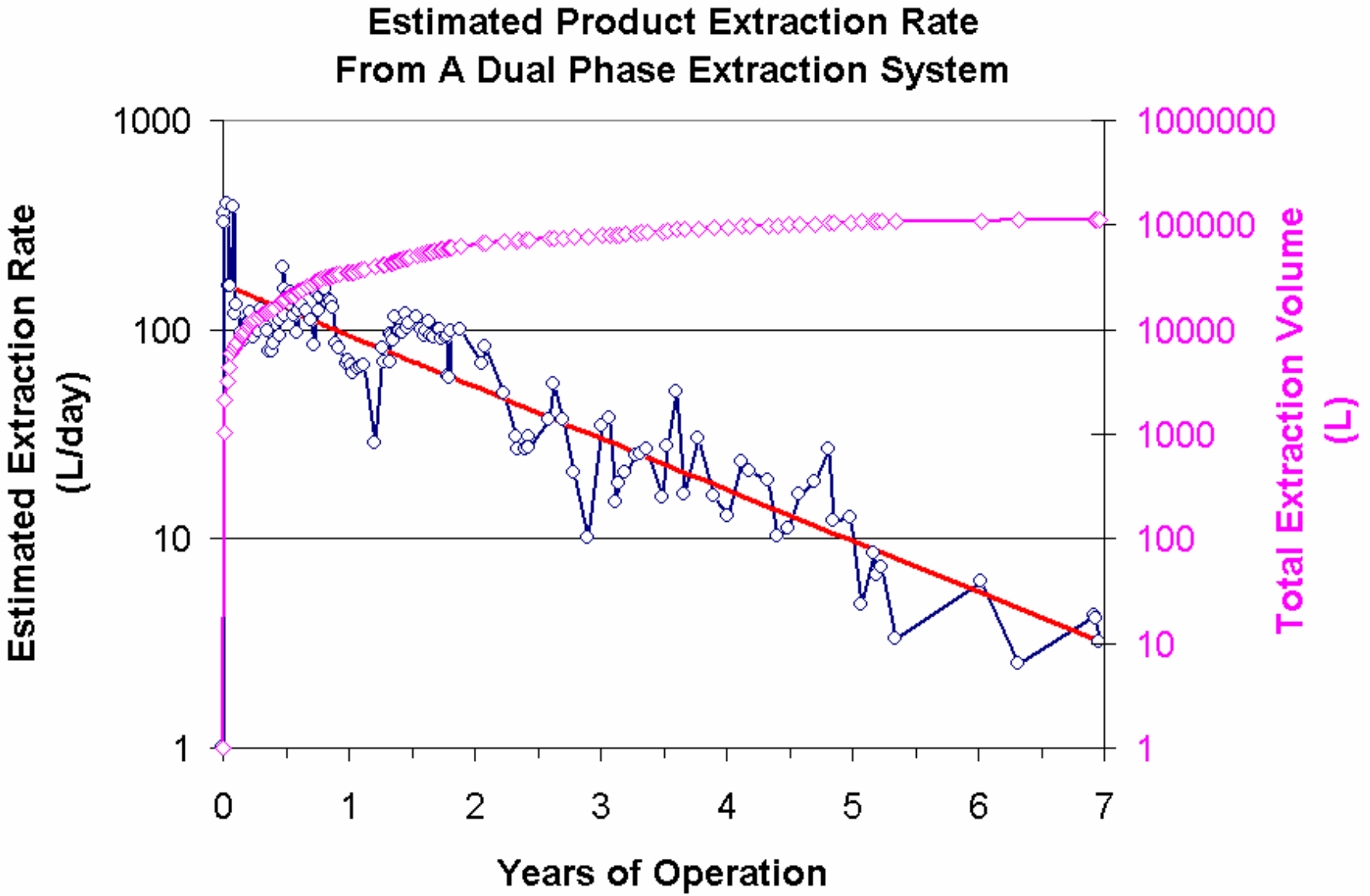
3 Approaches:

- Install and hope to figure it out on the fly [the old way]
- Assess, design, determine empirical criteria and then install [experience-based]
- Assess, design, determine empirical and quantitative criteria and then install [experience-based and predictive]

Understanding System Performance

- Developing an understanding can be complex and site-specific, but general trends exist
- Extraction rates typically show exponential decline
- Irregularities are introduced by modification of the system or its' operation


Estimated Product Extraction Rate
From A Dual Phase Extraction System
Estimated Extraction Rate (L/day)
Total Extraction Volume (L)
Years of Operation
450
400
350
300
250
200
150
100
50
0
120000
100000
80000
60000
40000
20000
0
0
1
2
3
4
5
6
7


Estimated Product Extraction Rate
From A Dual Phase Extraction System
Estimated Extraction Rate (L/day)
Total Extraction Volume (L)
Years of Operation
1000
100
10
1
1000000
100000
10000
1000
100
10
1
0
1
2
3
4
5
6
7

Why the Exponential Decline?

Conservation of Mass:

$$V\frac{dC}{dt} = -aQC$$

where

V = total volume affected by extraction $[L^3]$

C = concentration of extractable contaminant $[M / L^3]$

Q = extraction flux $[L^3 / T]$

a = constant

Why the Exponential Decline?

Solution of the CoM Equation:

$$C = C_0 \times e^{-\alpha t}, \text{ where:}$$

$$\alpha = \frac{aQ}{V} \; [1/T]$$

Extraction rate changes with time:

$$R = QC$$

$$= \text{contaminant extraction rate } [M/T]$$

$$R = R_0 \times e^{-\alpha t}$$

Why the Exponential Decline?

A Dual Porosity Model Can Describe the Curve:

$$R = R_0 \times e^{-\alpha t}$$

for early stages (advection, large pores)

$$R = R_0 \times e^{-\beta t}$$

for later stages (diffusion, small pores)

$\alpha >> \beta$

Other Contributing Factors:

- Contaminant migration towards extraction wells
- Degradation, attenuation

Irregularity Is Normal

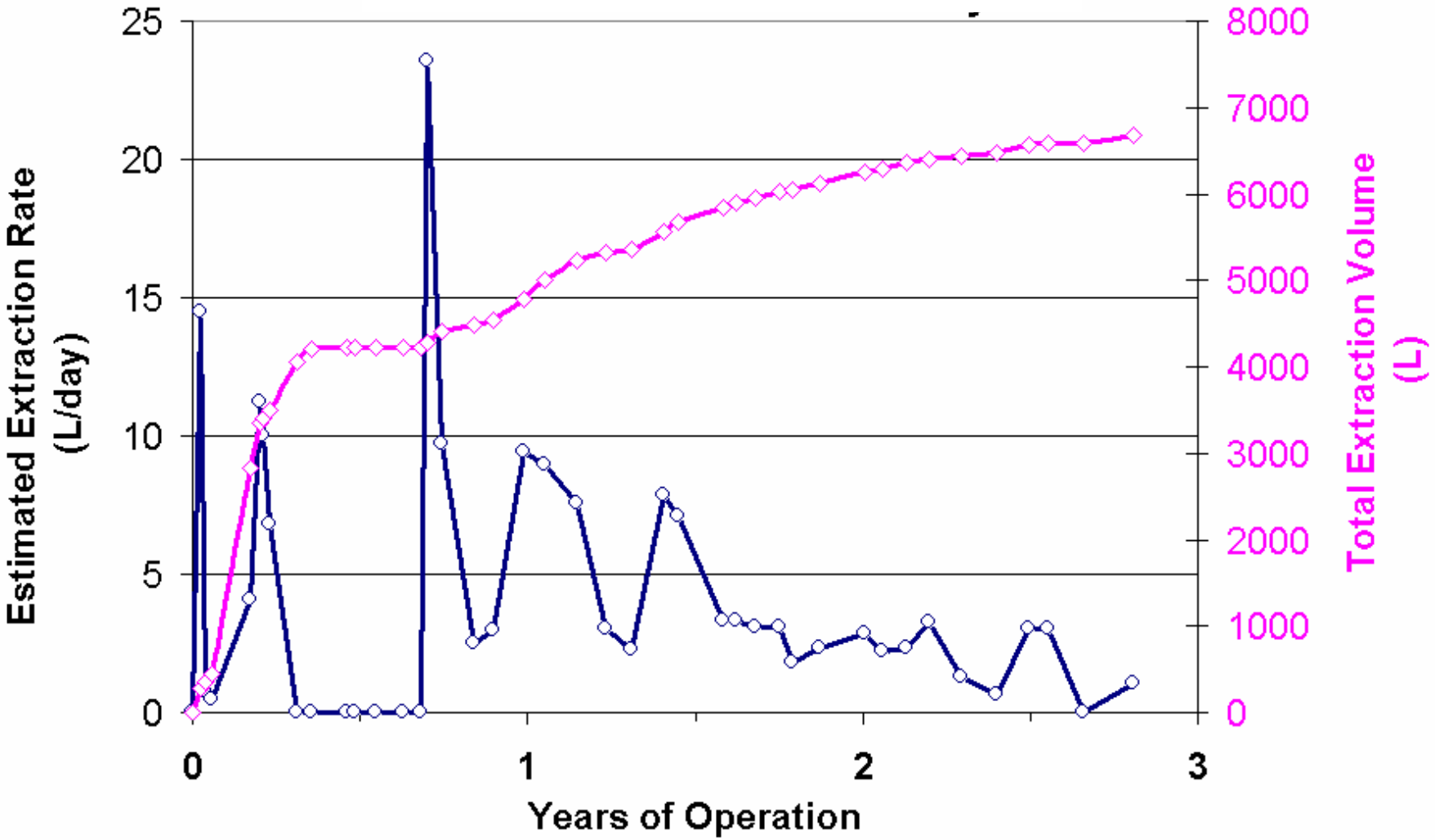
And may be due to:

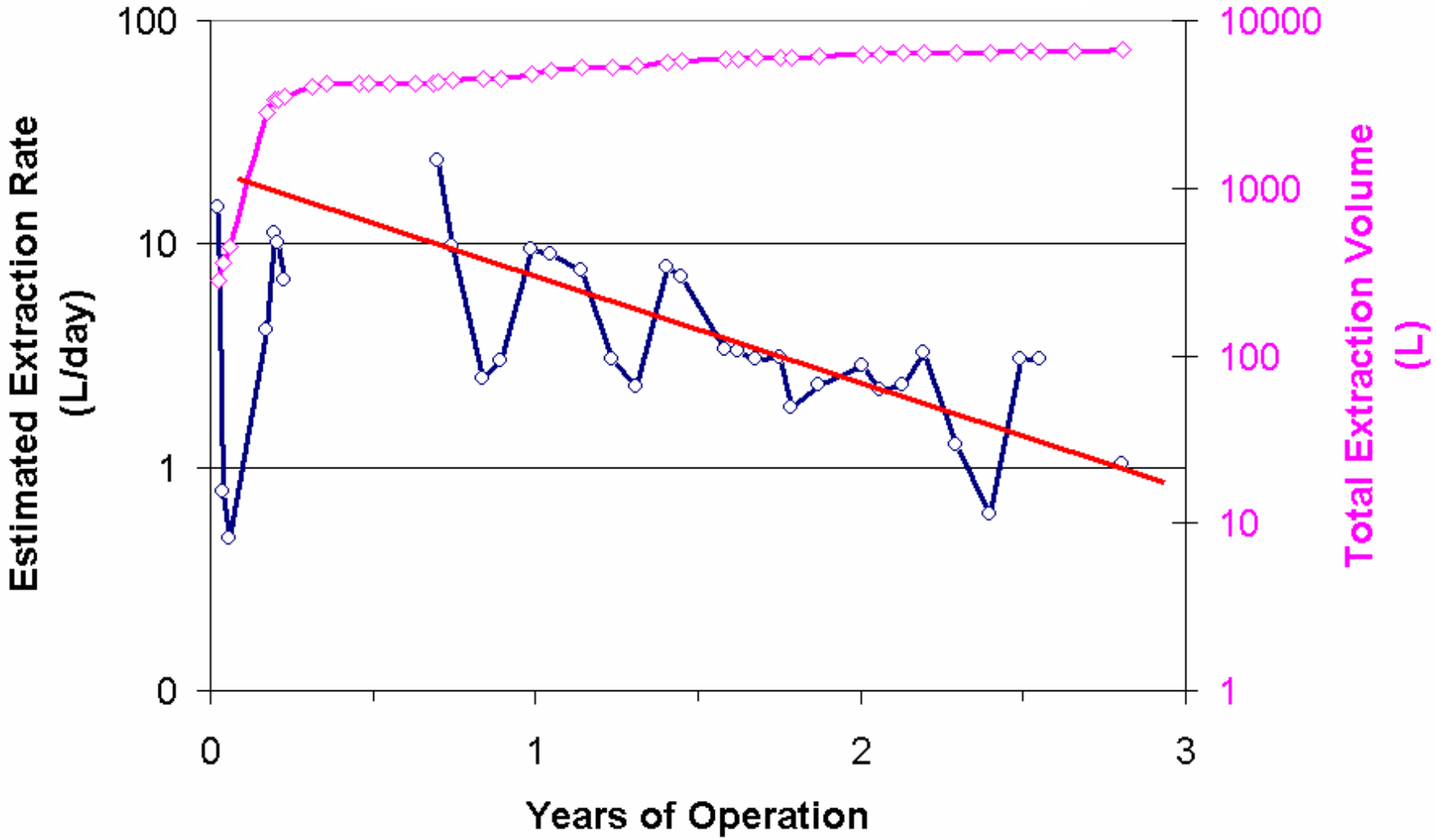
- **Changes in system configuration**
- **“Pulse” operation to improve system efficiency**
- **System maintenance difficulties**

But:

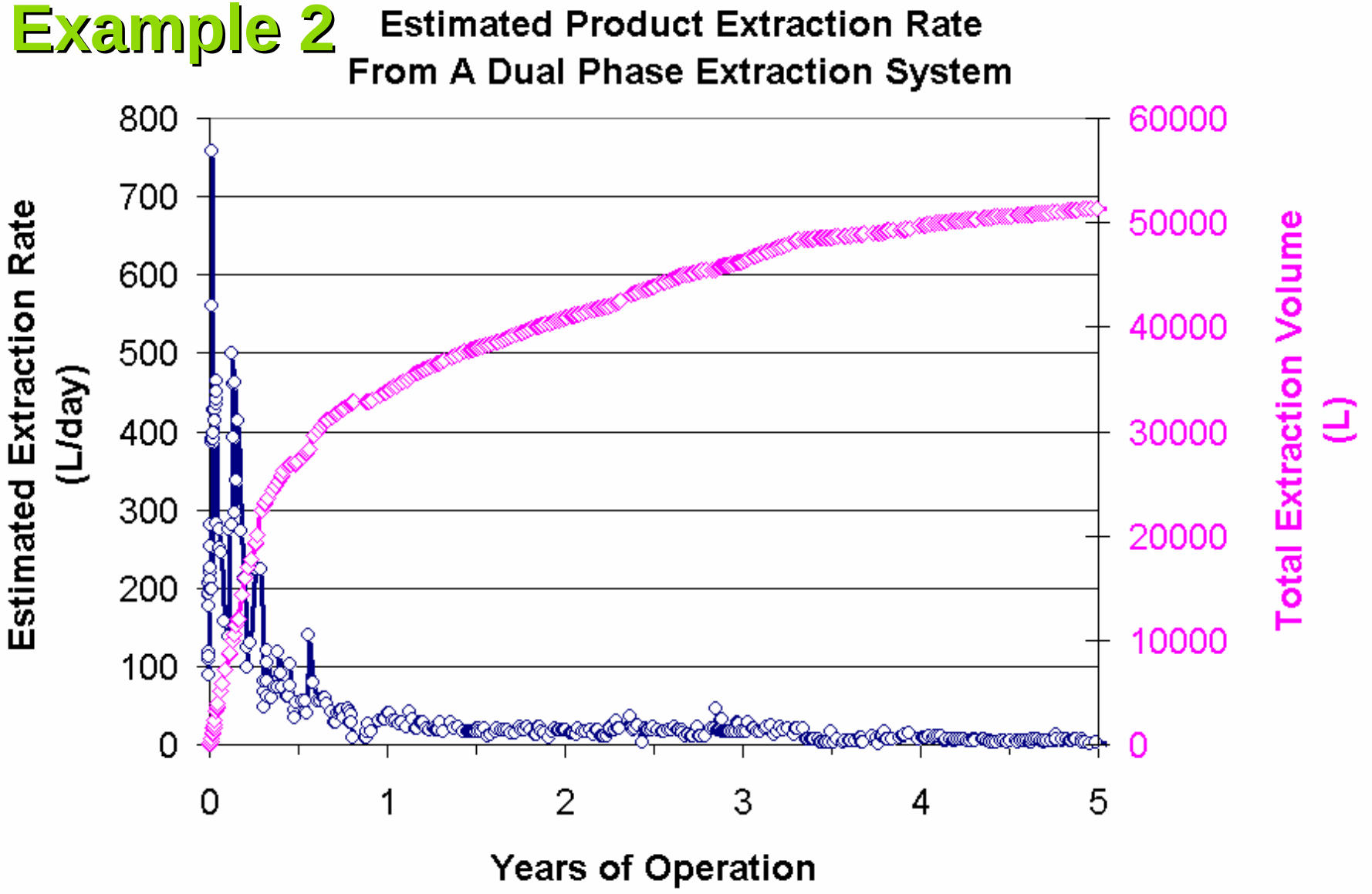
Exponential declines resume

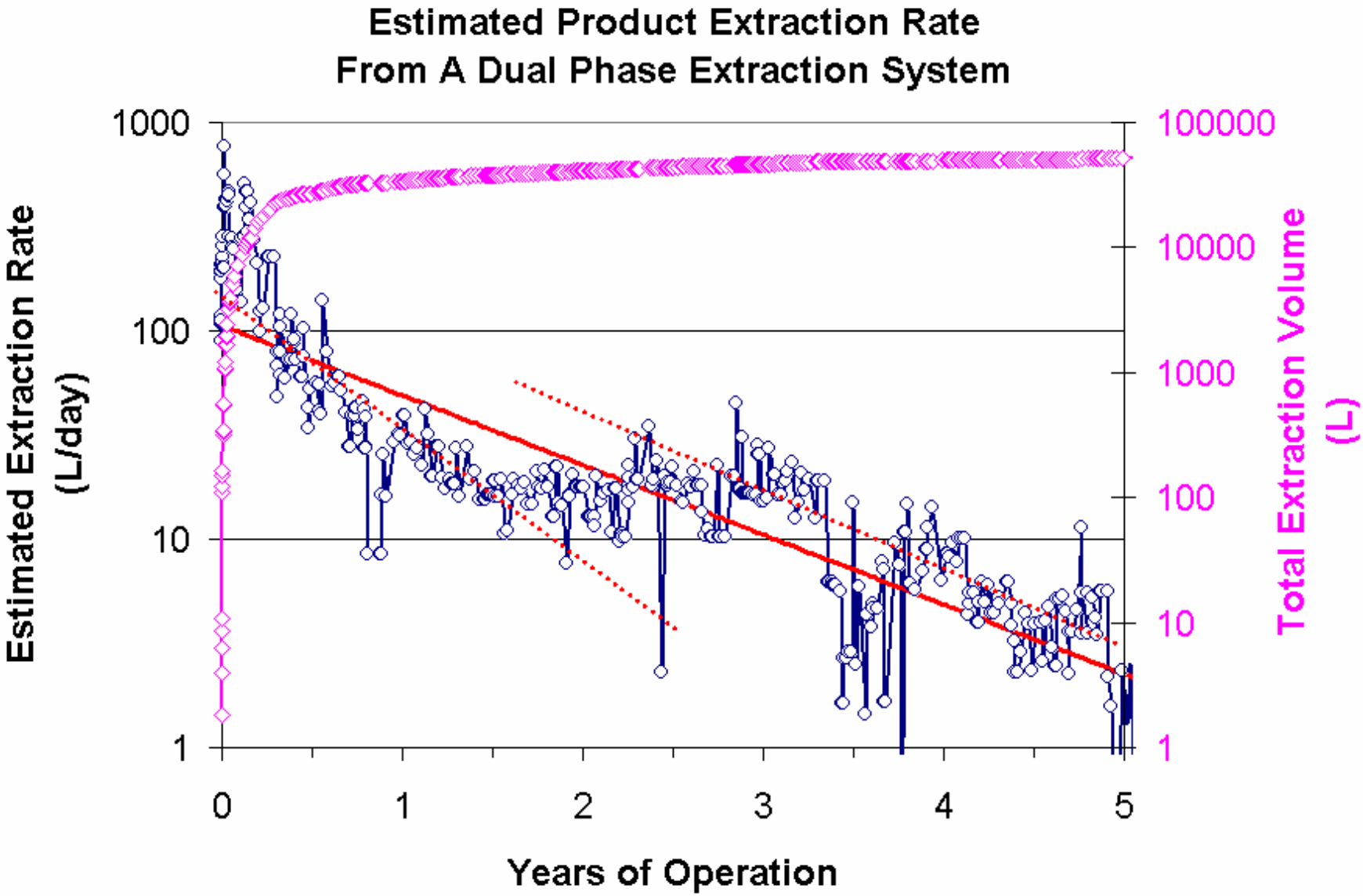
Example 1


Estimated Extraction Rate (L/day)
25
20
15
10
5
0
0
1
2
3
Years of Operation
8000
7000
6000
5000
4000
3000
2000
1000
0
Total Extraction Volume (L)


100
10
1
0
10000
1000
100
10
1
0
1
2
3
Estimated Extraction Rate (L/day)
Total Extraction Volume (L)
Years of Operation

Example 2


Estimated Product Extraction Rate
From A Dual Phase Extraction System
Estimated Extraction Rate (L/day)
Total Extraction Volume (L)
Years of Operation
800
700
600
500
400
300
200
100
0
60000
50000
40000
30000
20000
10000
0
0
1
2
3
4
5



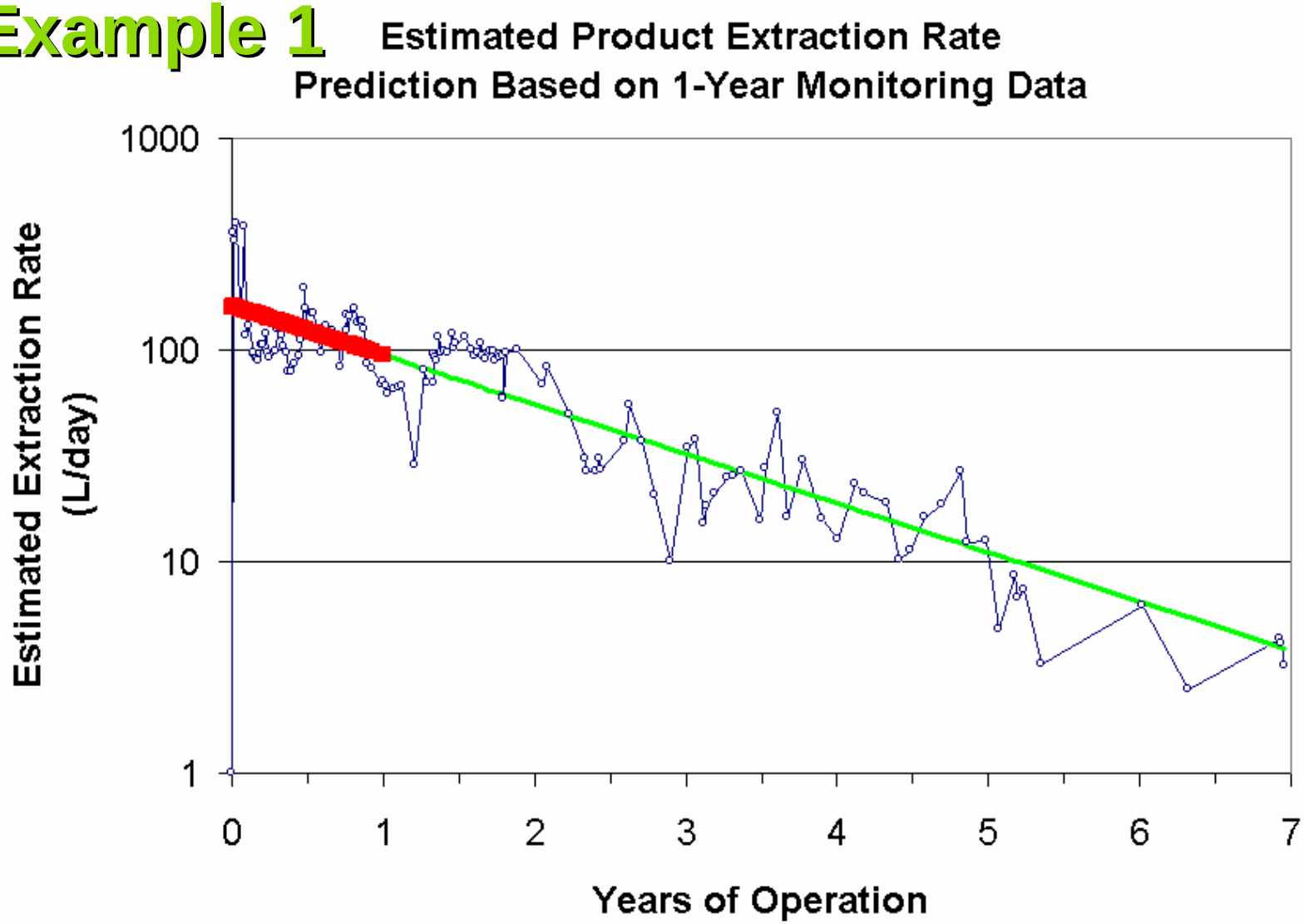
Can We Predict Early On ?

Yes:

- **Use short-term monitoring data to predict long-term trends**
- **Select “representative” data set(s)**
- **Modify predictions when additional data are available**

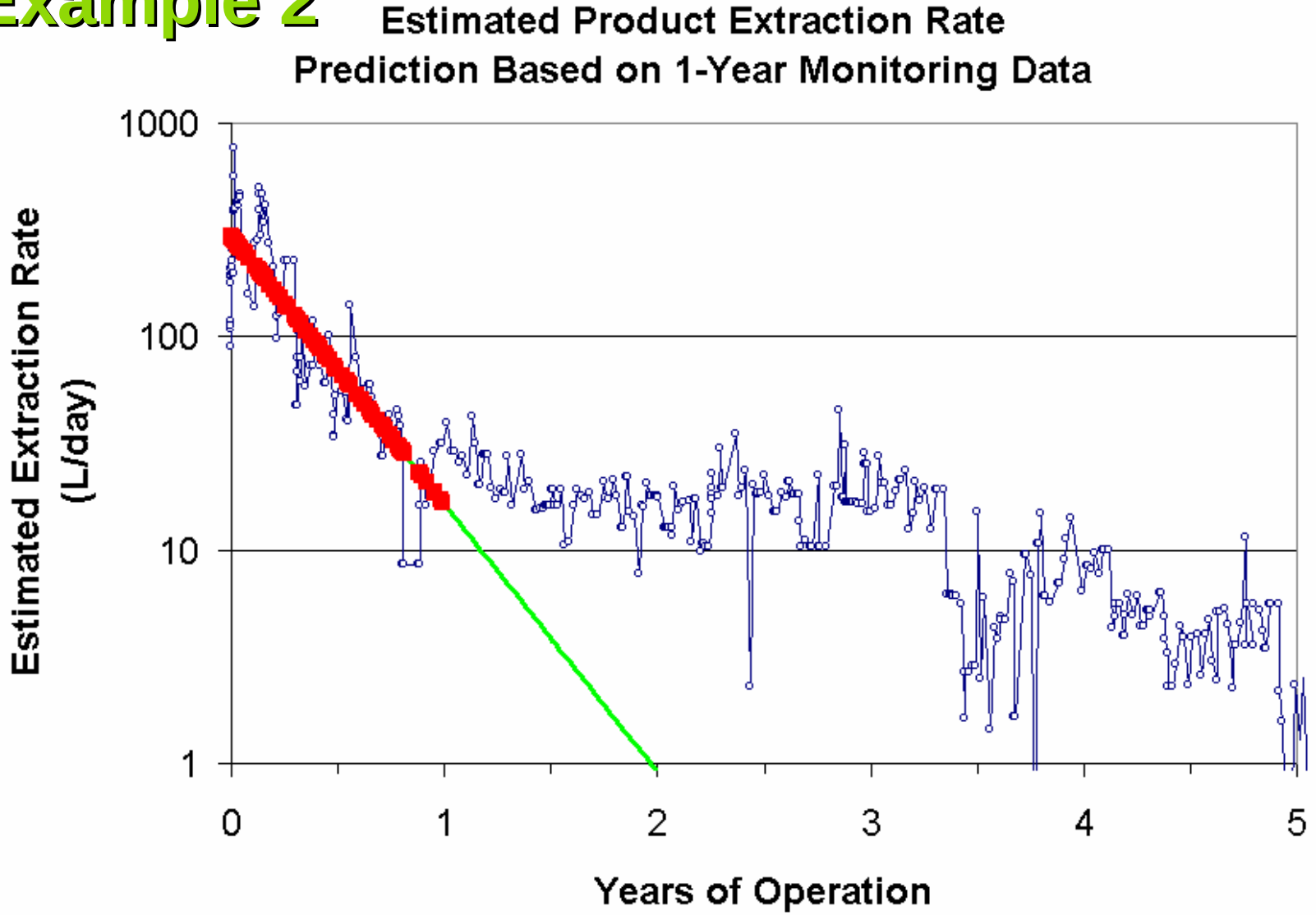
But there will be uncertainties and we may underpredict the system lifespan!

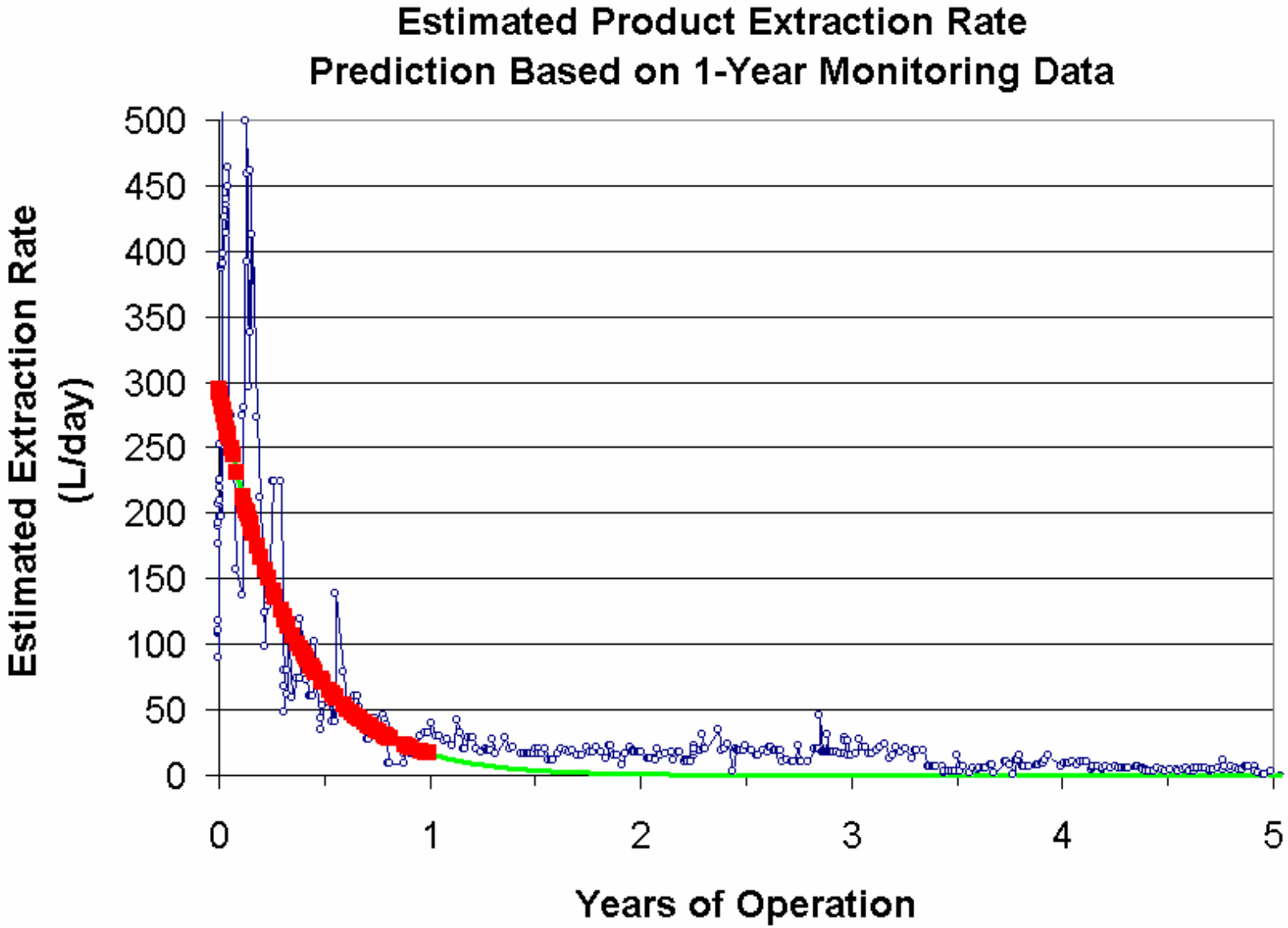
Example 1



O'CONNOR ASSOCIATES

Example 2


Estimated Product Extraction Rate
Prediction Based on 1-Year Monitoring Data
Estimated Extraction Rate (L/day)
1000
100
10
1
0
1
2
3
4
5
Years of Operation



O'CONNOR ASSOCIATES

Can We Predict Beforehand?

Possible, but with UNCERTAINTIES

- **Experience-based (e.g. rapid decline in first few months, slow changes for a few years)**
- **Modelling (SVE, Air Sparging, MPE). Promising but expensive.**
- **Experience-based with quantitative estimation**

What Do We Need to Know?

Assume that system performance can be approximated by an exponential curve, then estimate:

- **Initial extraction rate (pilot test)**
- **Rate of decline (early stage, later stage, system type, and site conditions)**
- **Rebound effects (difficult)**

Shut Down at 2 L/day or 10 L/day ?

Situation-specific, but assessable:

- **Remaining time to remediate at asymptotic extraction rate >> desired clean-up time frame and system operation modifications show little improvement**
- **Site becomes clean, or data show that system is not affecting site conditions**
- **More efficient remedial options are available**

A System Shut-down Decision Matrix

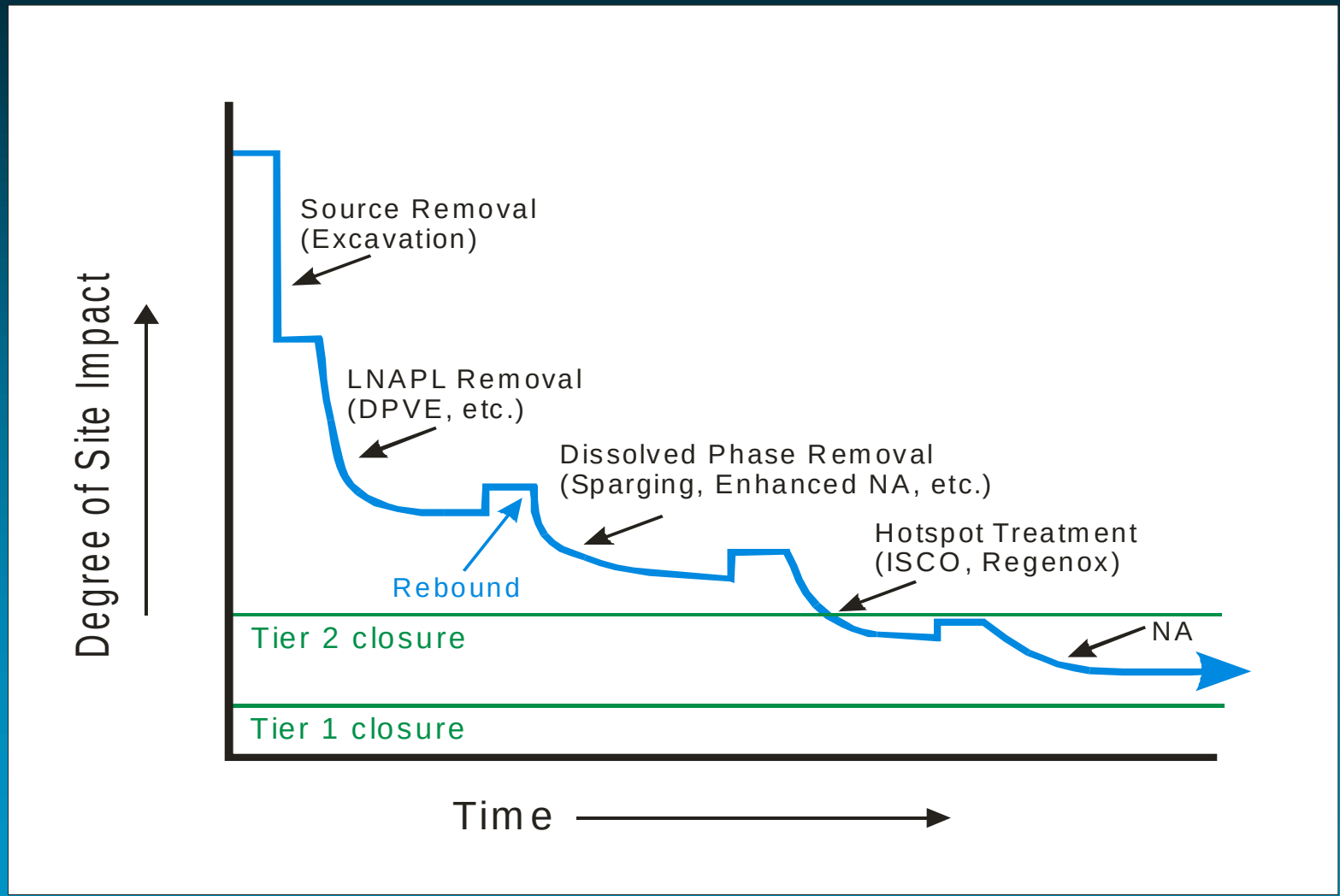
Must:

- **Monitor and and asses system operation**
- **Monitor and assess site conditions**

Bottom Line

Is continued operation of the system improving the site conditions?

A Long-term Vision of Site Clean-up



Closing Comments

- Right now, it can be difficult to predict when to shut the system off
- System performance is complex, but general trends exist
- Worth trying to anticipate the trends based on tests, early observations, and experience
- Exponential curves are simple and useful tools to describe system performance

Closing Comments (continued)

- Decision to shut down a system should be made based on both system performance evaluation and site monitoring.
- Multiple remedial actions will be taken at different stages of site clean-up.

THANK YOU!

O'CONNOR ASSOCIATES