

Ageing Pump Efficiency

The hidden cost thief?

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CTO - Derceto



**Distribution Systems
Symposium & Exposition**

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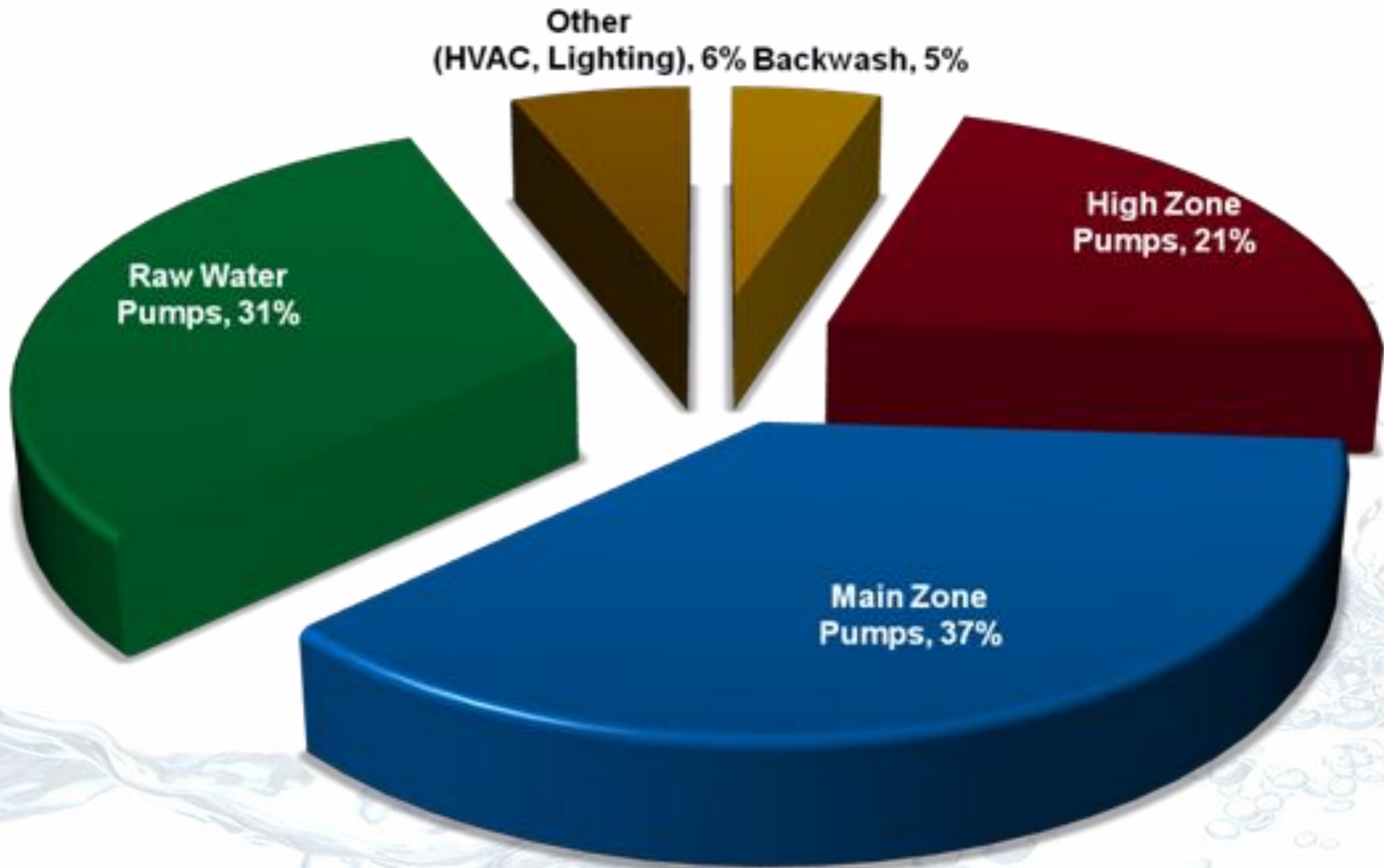
Background Information

- “The more than 60,000 water systems and 15,000 wastewater systems in the United States are among the country’s largest energy consumers, using about 75 billion kWh/yr nationally —3 percent of annual U.S. electricity consumption.”

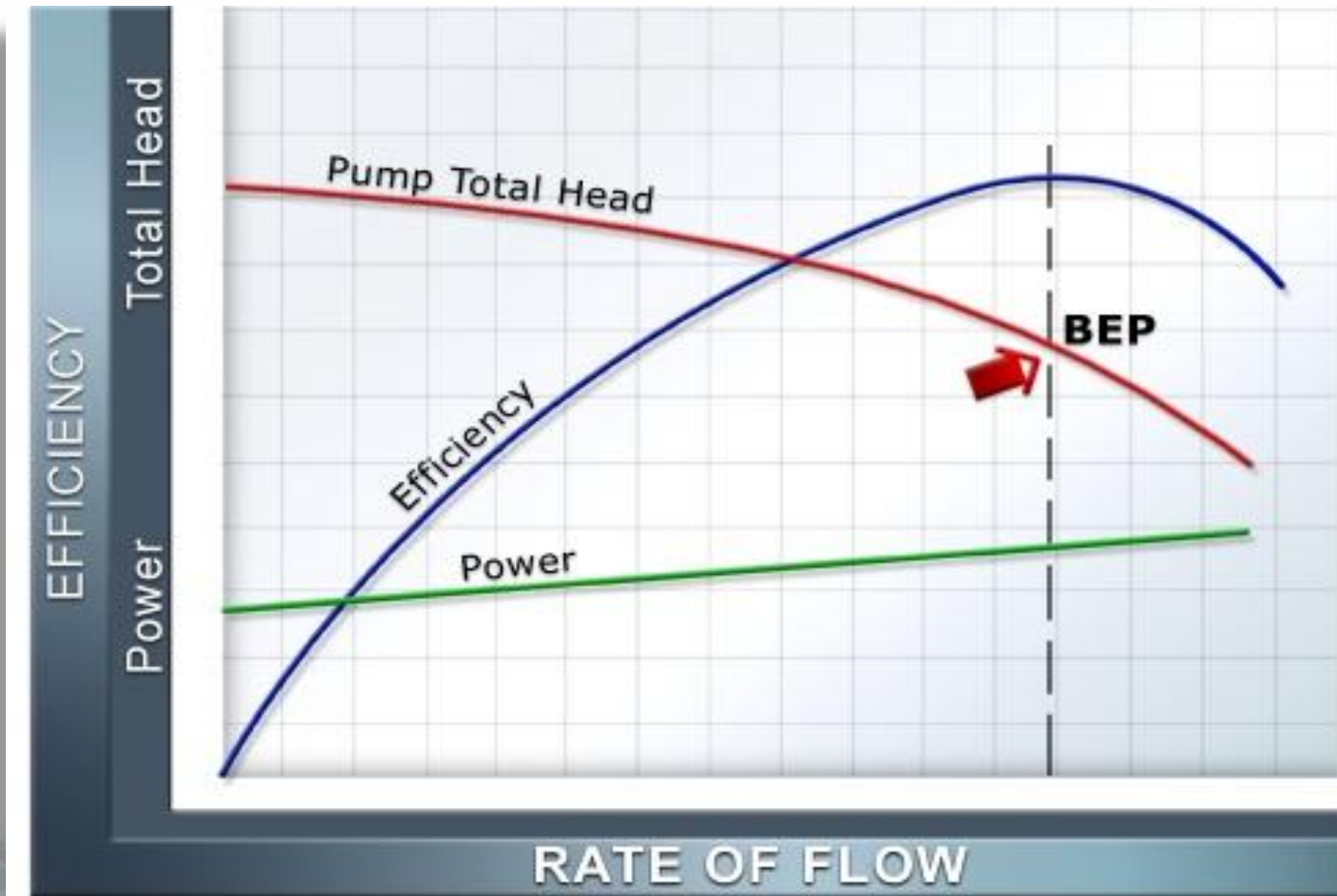
*Electric Power Research Institute,
Energy Audit Manual for Water/Wastewater Facilities,
(Palo Alto: 1999), Executive Summary*

- That’s \$10 billion in energy costs per year!

Typical Energy Use in Water Utilities



Best Efficiency Point



The Affinity Laws

- H = head
- G = gallons/min
- S = Pump speed
- P = Power (HP)
- D = Impellor Diam.
- $G_2 = G_1 (S_2/S_1)$ or $G_2 = G_1 (D_2/D_1)$
 - Flow increases linearly
- $H_2 = H_1 (S_2/S_1)^2$ or $H_2 = H_1 (D_2/D_1)^2$
 - Head increases by the square of speed
- $P_2 = P_1 (S_2/S_1)^3$ or $P_2 = P_1 (D_2/D_1)^3$
 - Power increases by the cube of speed

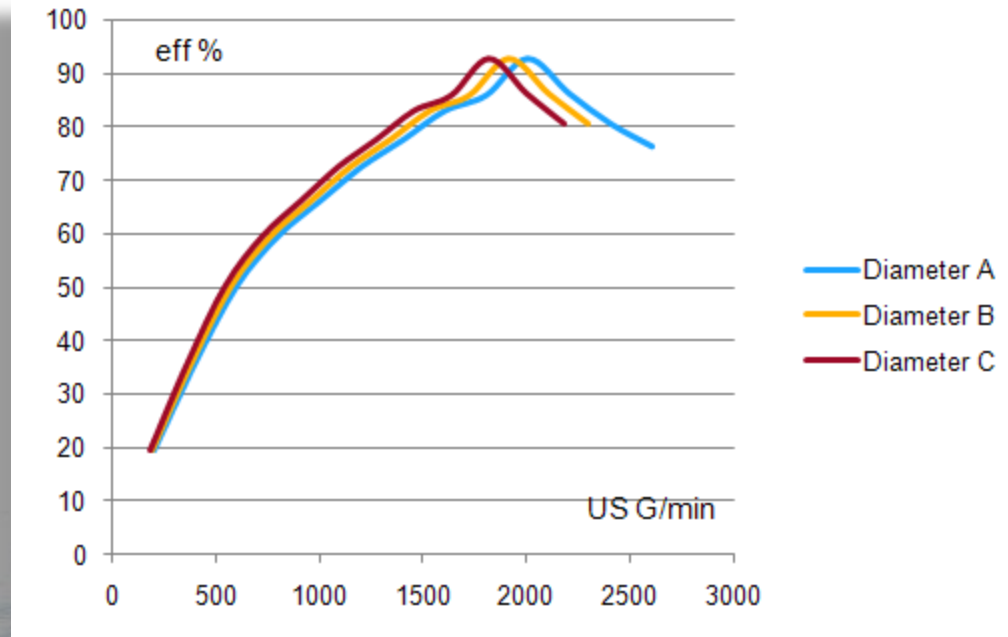
What do the affinity laws predict?

$$eff_2 = \frac{HP_{out_2}}{HP_{in_2}} = \frac{Head_2 * Flow_2 * \frac{8.33}{33000}}{HP_{in_1} * \left(\frac{speed_2}{speed_1}\right)^3}$$

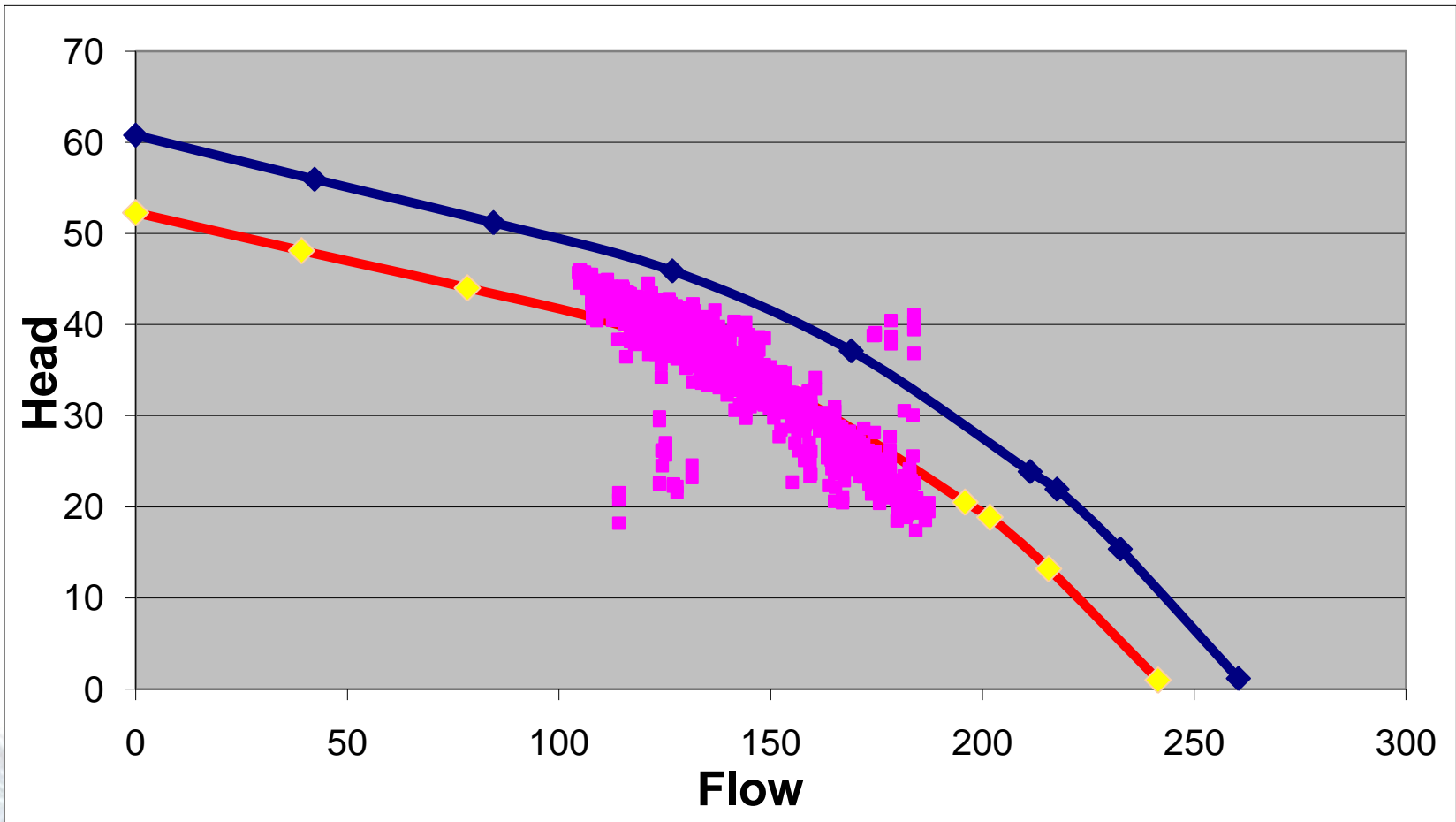
$$= \frac{Head_1 * \left(\frac{speed_2}{speed_1}\right)^2 * Flow_1 * \left(\frac{speed_2}{speed_1}\right)^2 * \frac{8.33}{33000}}{HP_{in_1} * \left(\frac{speed_2}{speed_1}\right)^3}$$

$$= \frac{Head_1 * Flow_1 * \frac{8.33}{33000}}{HP_{in_1}} = eff_1$$

➔ Peak Eff₁ = Peak Eff₂

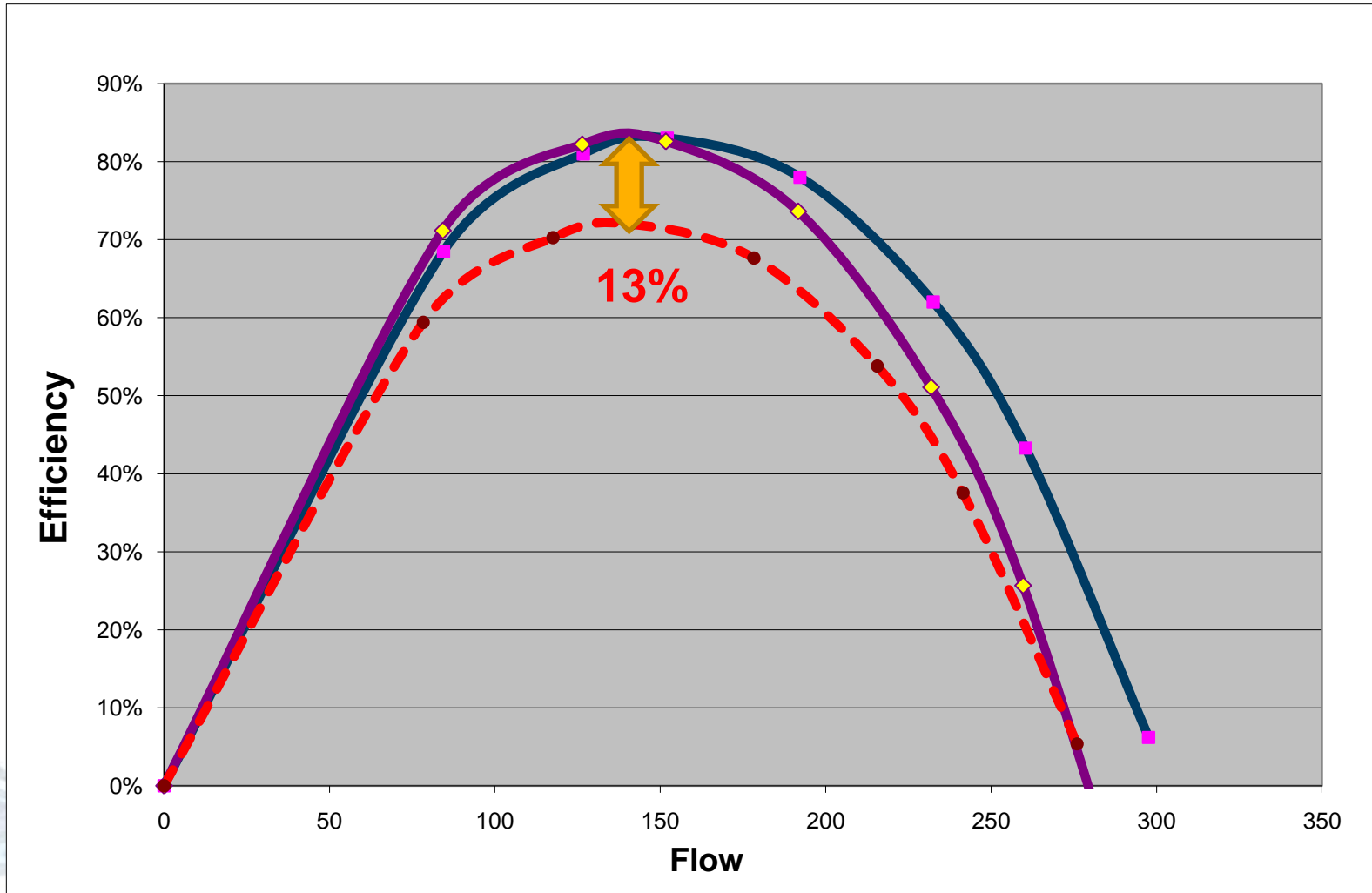


But water pumps don't wear...

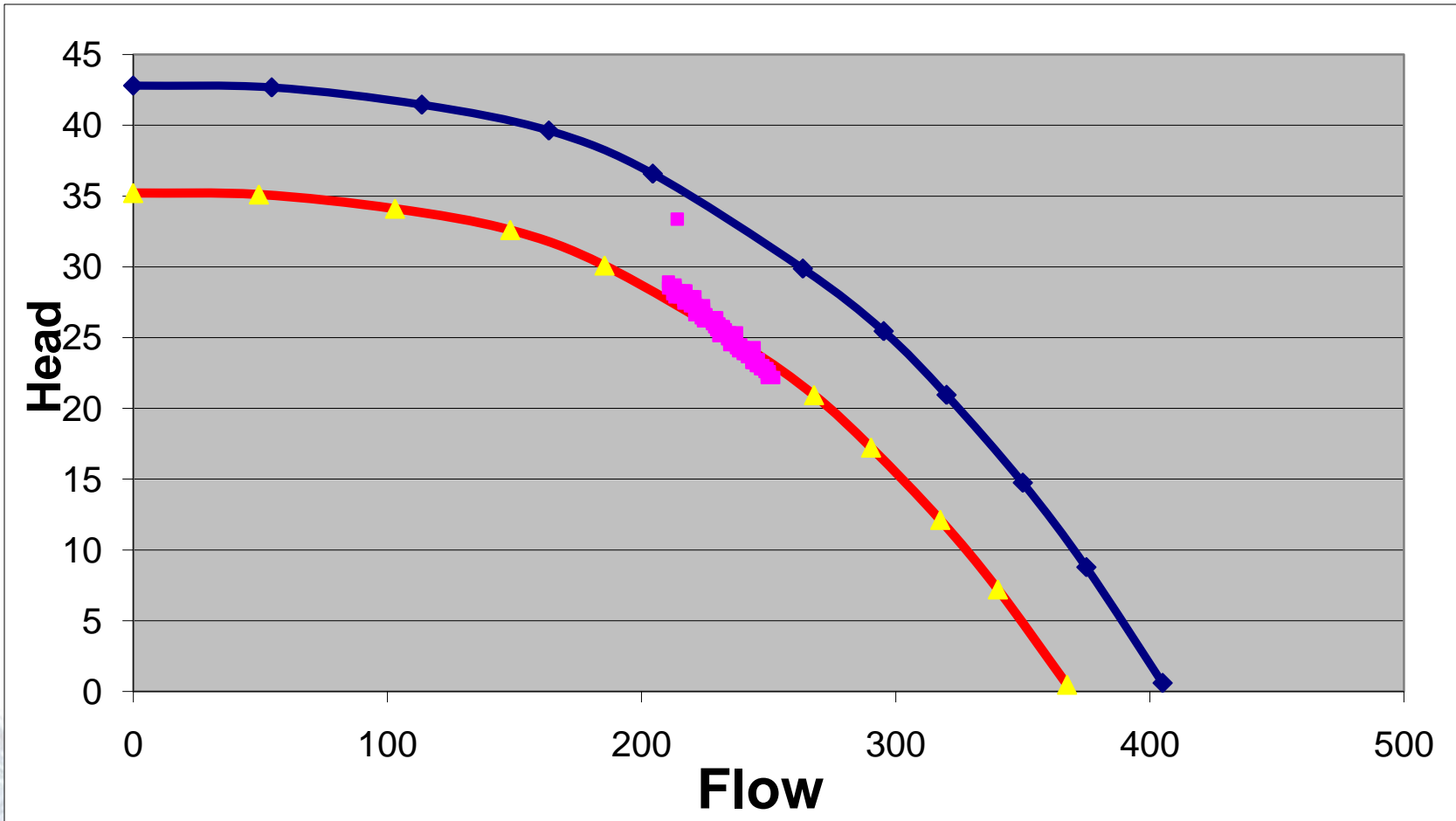


- Pump installed 2000

But water pumps don't wear

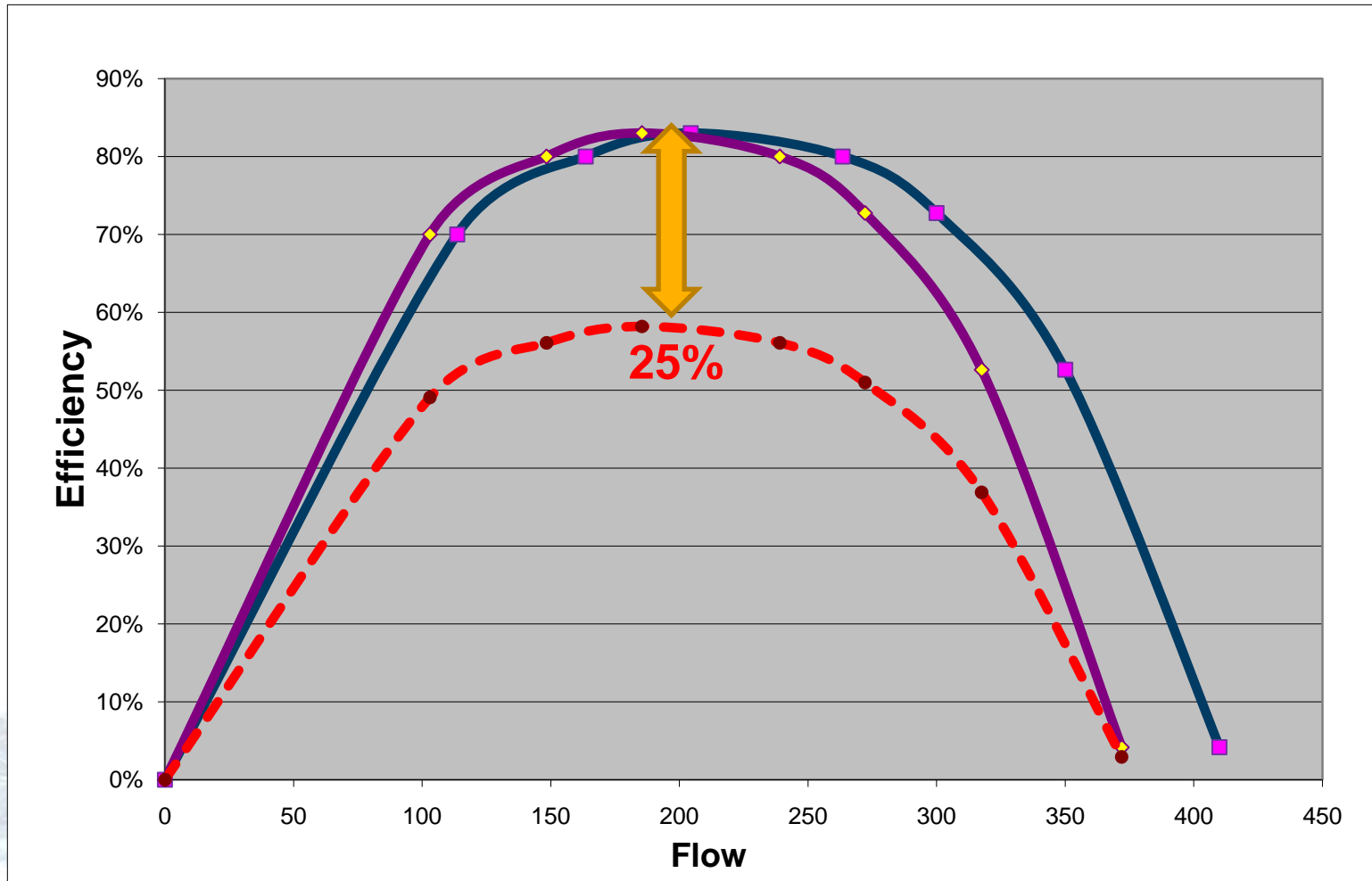


And an older pump...

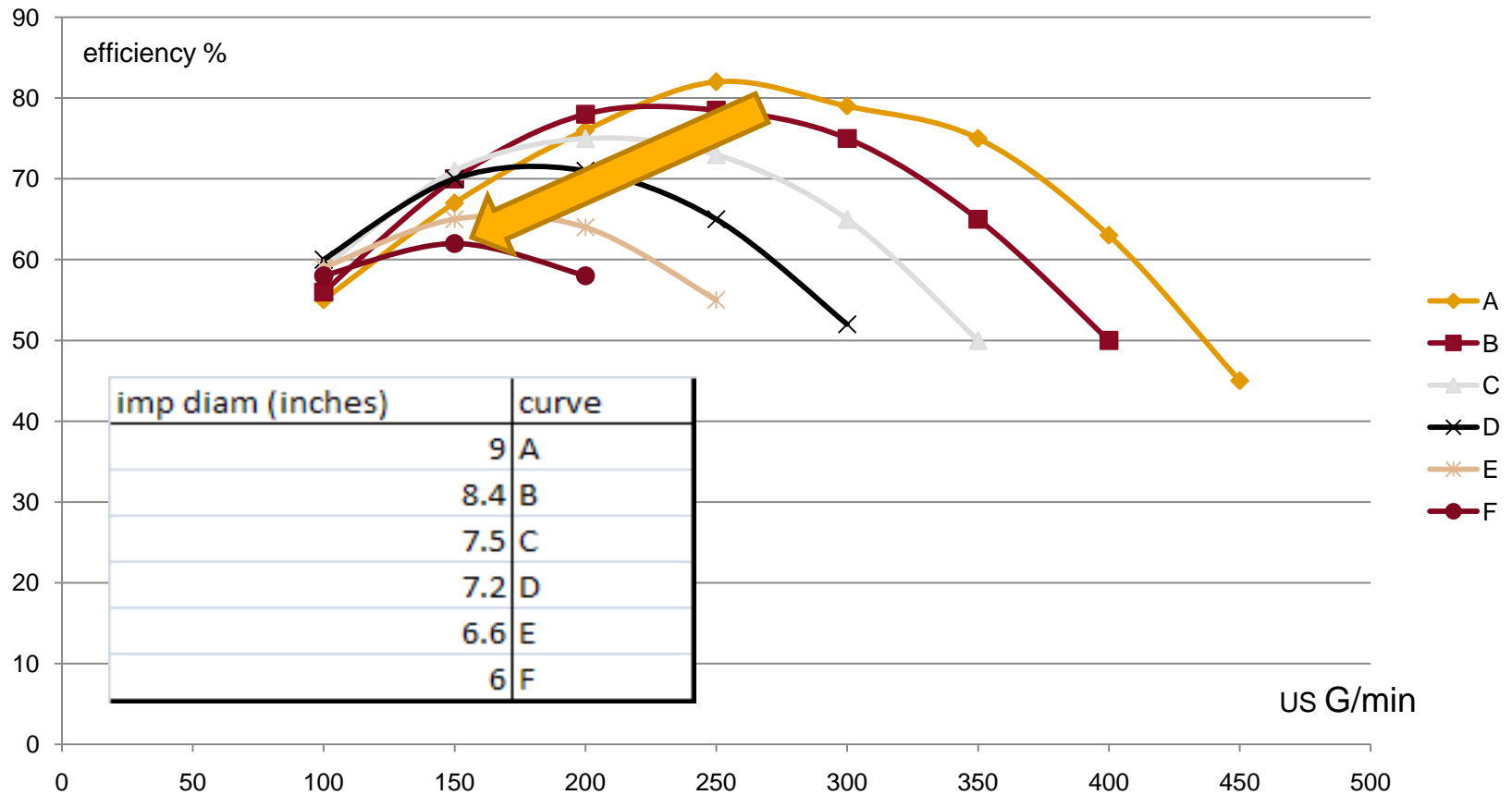


- Pump installed 1988

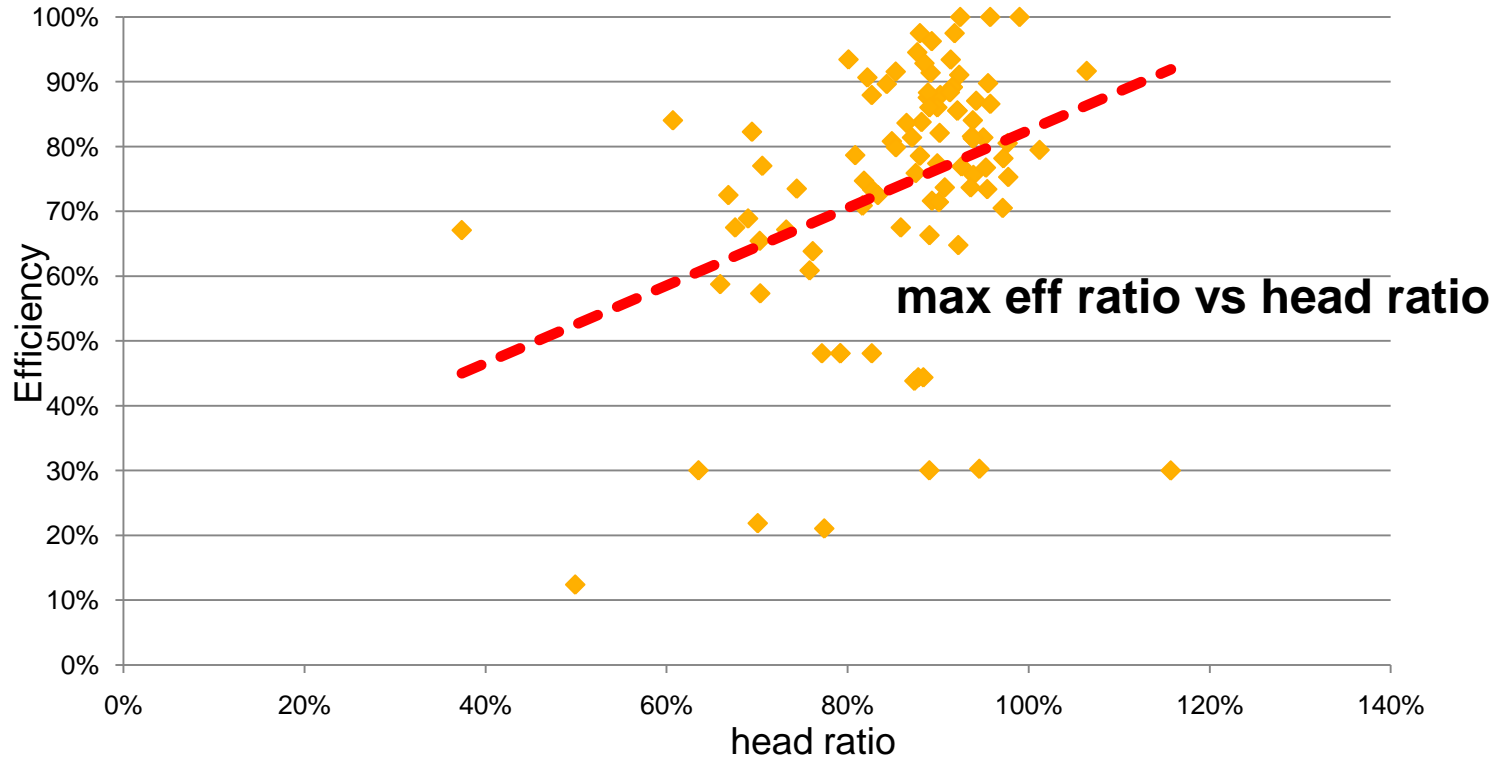
..with its efficiency



Impellor size change has similar outcomes



Real Efficiency of a Pump

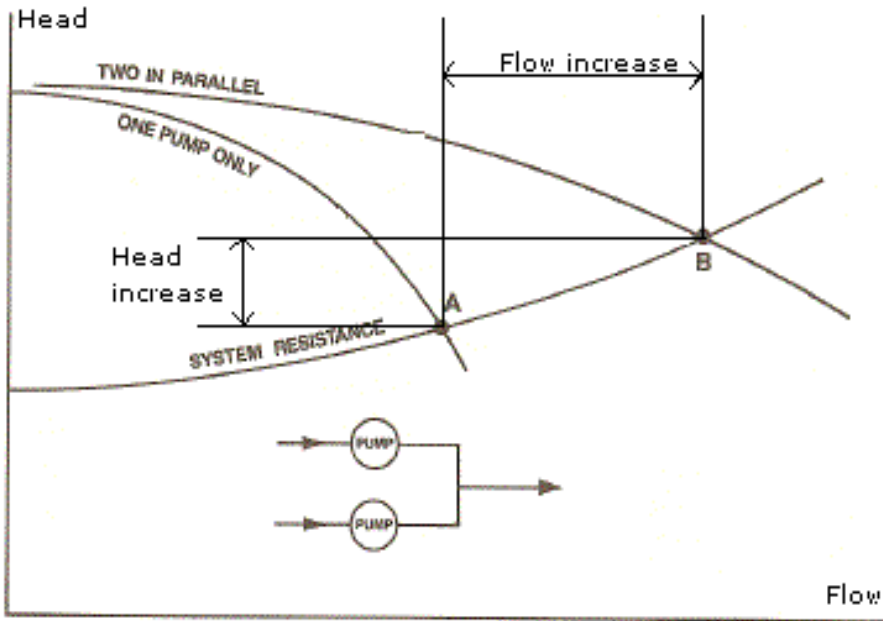


- Results obtained with 95 pumps, still poor correlation
- UK based WRC working on similar study with 4000 pumps; results expected in December

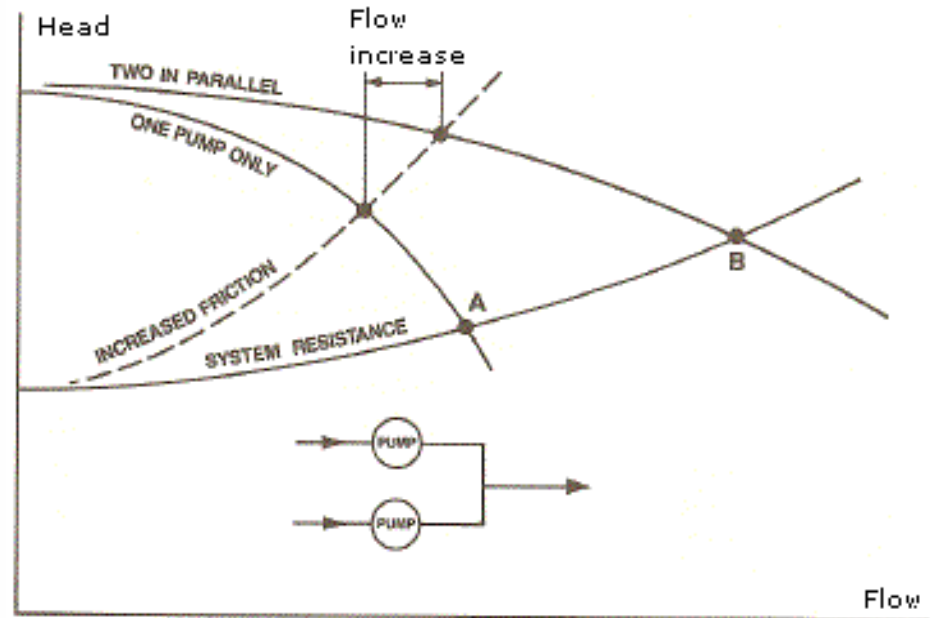
So water pumps do wear!

- A quick rule of thumb;
 - **1% deterioration on head/flow curve per year**
- Though it tends to be faster for the first few years, e.g. MCWA found 10% drop in the first 6 years
- ..and slower towards the end as pumps are corroded, pitted, have tuberculation and reach around 40% efficiency

Parallel Pumps' Efficiency



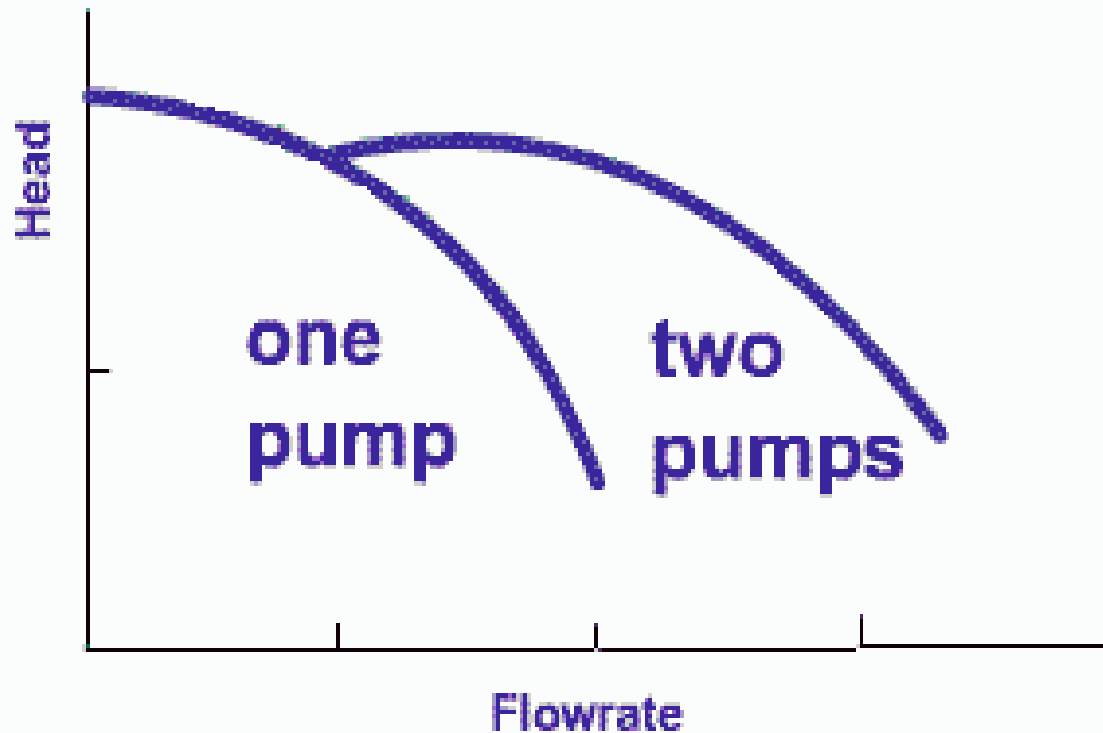
- Low system curve



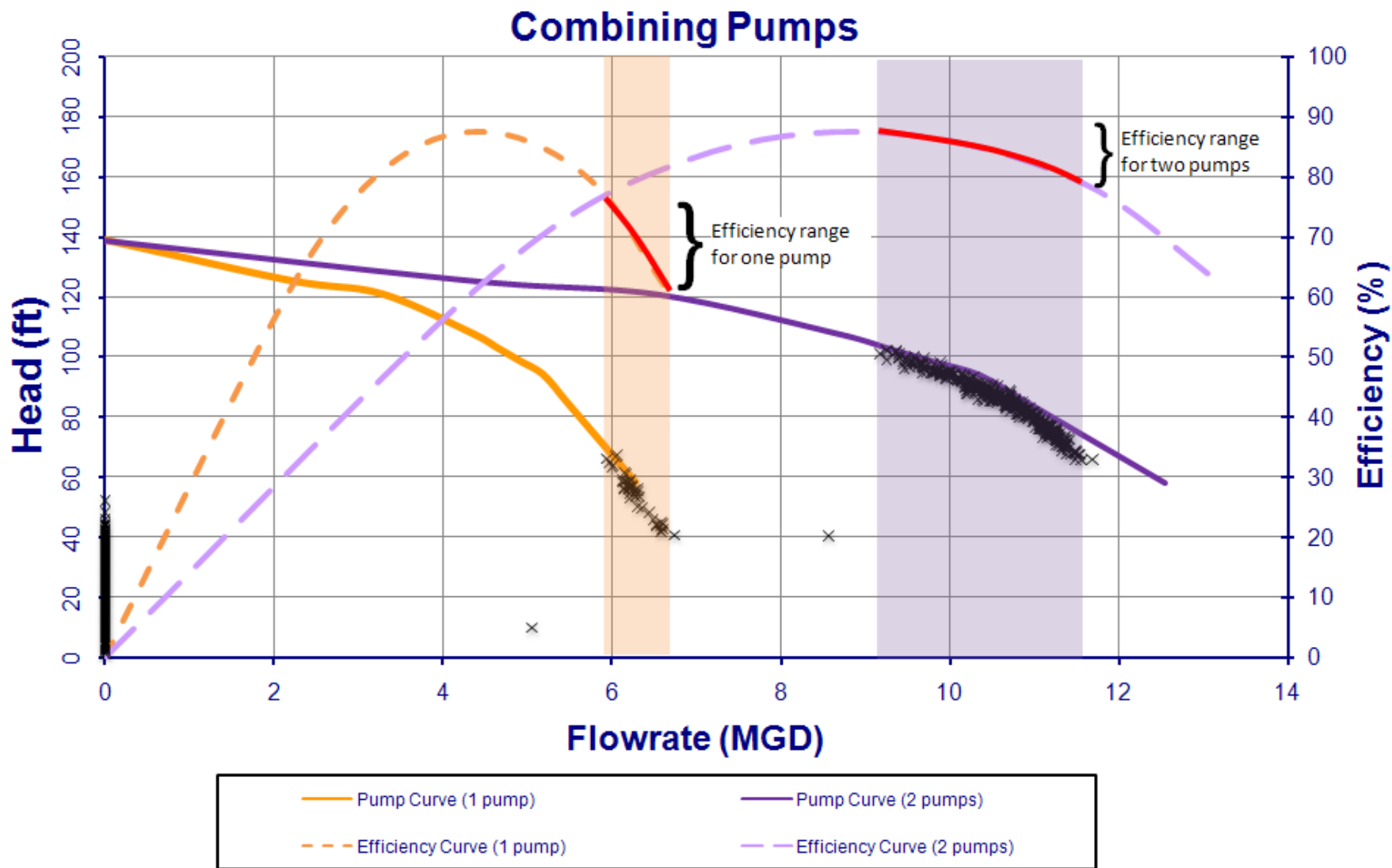
- High system curve.

Parallel Pumps' Efficiency

- Non identical pumps:



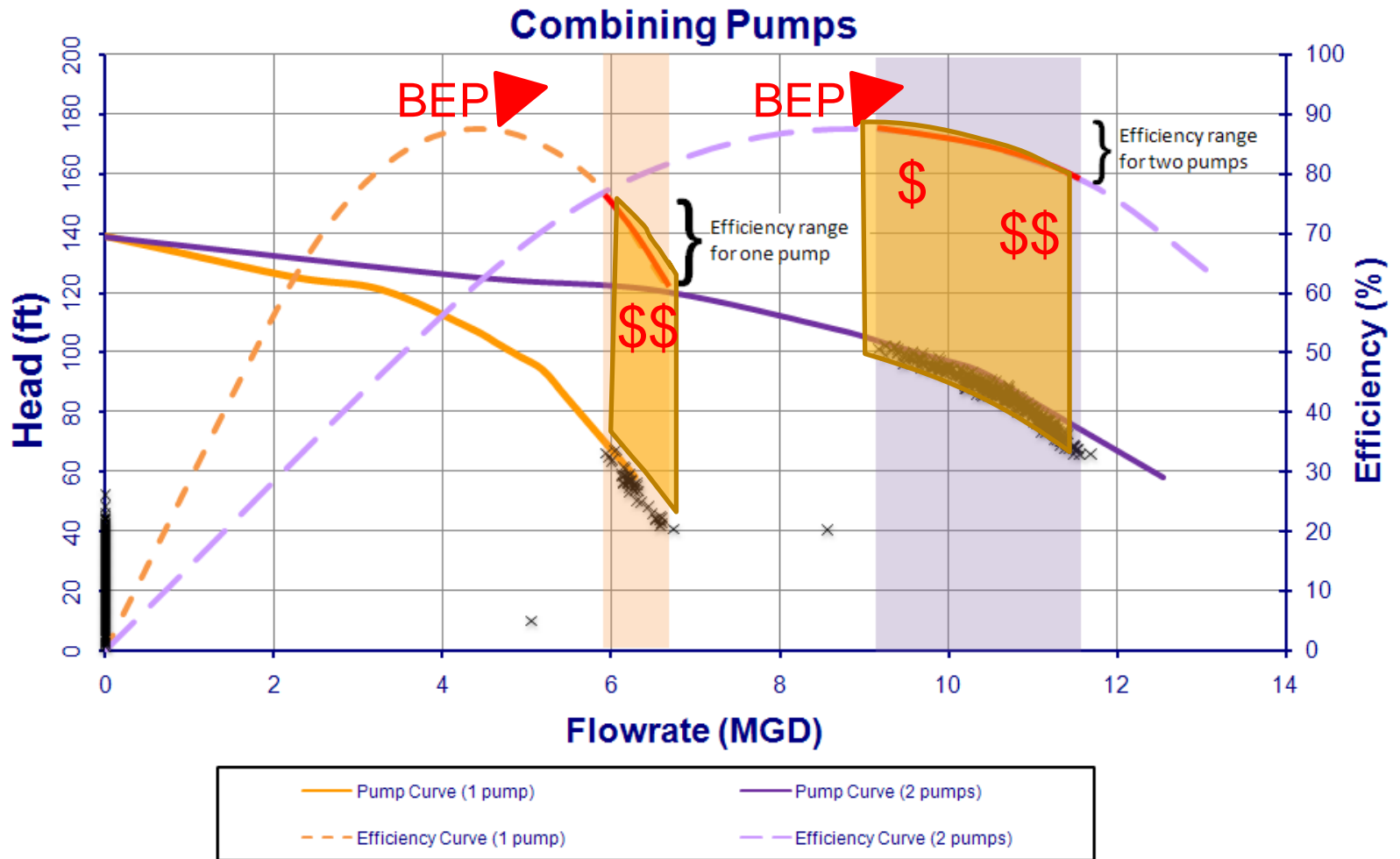
How do real pumps operate?



What does efficiency mean?

- 3 ways of calculating “efficiency”
 - Power in / Power out (Pump station)
 - Weighted Average Efficiency (Average value of each pump’s efficiency weighted by the flow), should be the same value as Power in / Power out (Pump station)
 - Volume of water moved per energy unit spent
- The last way allows the comparison of the different solutions (Pump1, Pump2 or Pump1 // Pump2) in terms of kWh spent

Best Efficiency Point - reality



Parallel Pumps' Efficiency

- 1 pump: 6.3MGD @ 50', efficiency 70%
- 2 pumps: 10.4MGD @ 90', efficiency 85%

So running two pumps makes them run efficiently, but look at the lifts.

Calculating actual energy required to deliver the water, which is really what matters:

1 pump used 223 kWh/MG

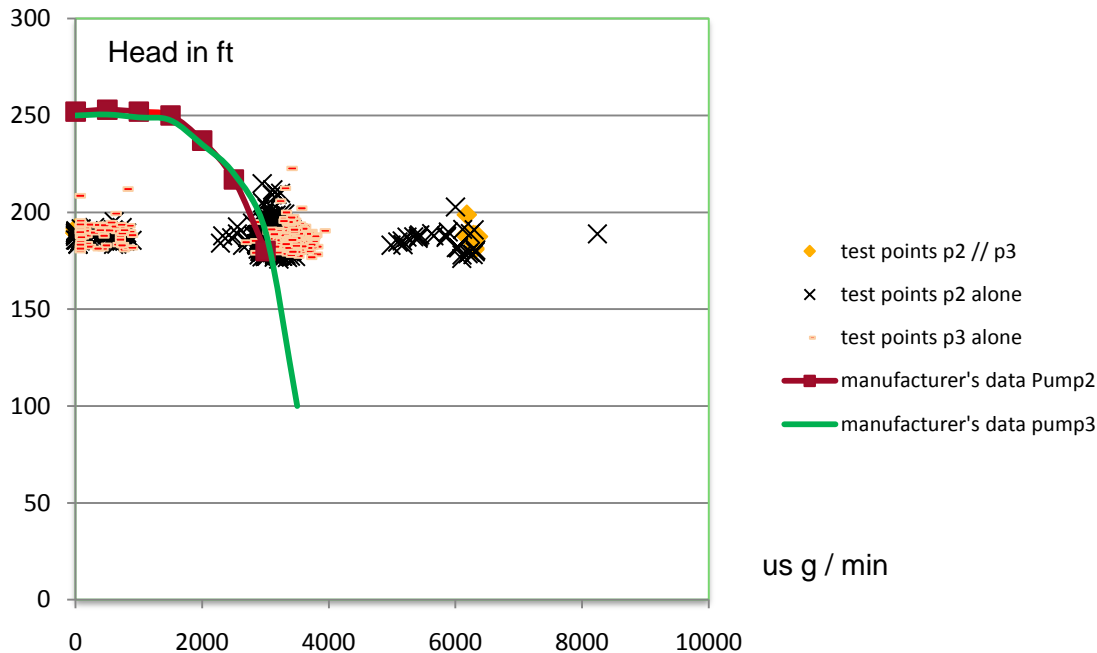
2 pumps used 332 kWh/MG, 50% more energy used.

Parallel Pumps' Efficiency

- For example, if running one pump alone in a given pump station has a ratio of 250 gallons per kWh and running two pumps in parallel is equivalent to 300 gallons per kWh, running two pumps will be more efficient.
- This ratio could be calculated by dividing the flow at operating point by the input power for this flow (volume/energy \Leftrightarrow flow/power).
- The solution with the biggest ratio is the one that carries more water per energy unit spent.

Parallel Pumps' Efficiency

- Case 1: two identical pumps

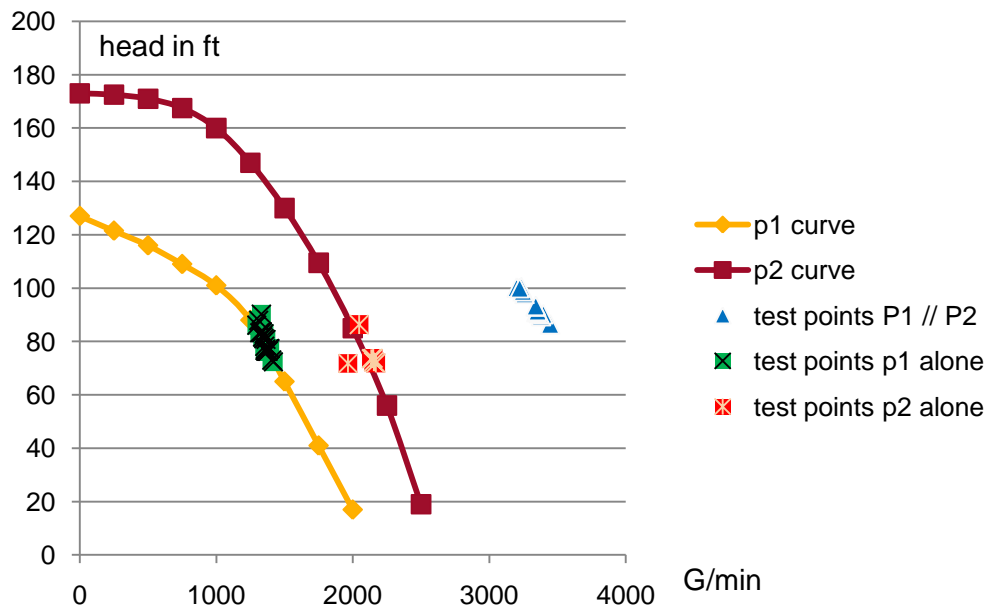


Overall pump station efficiency	80.55%
Pump 2 or Pump 3 efficiency running alone	77.78%
Pump 2 or Pump 3 alone	16.98 G/(HP x min)
Pump 2 and Pump 3 run together	17.09 G/(HP x min)

- Here it is more energy efficient to run the two pumps in parallel, the pumps will also run closer of their BEP.

Parallel Pumps' Efficiency

Case 2: Pump 1 and Pump 2 (Two Non-identical Pumps)



Overall pump station efficiency	69.23%
P1's efficiency while running alone	68.4%
P2's efficiency while running alone	57.6%
P1's efficiency while p1 // p2	73.68%
P2's efficiency while p1 // p2	66.62%
Pump 1 alone	33.9 G/(HP x min)
Pump 2 alone	30.4 G/(HP x min)
Pump 1 // Pump 2	31.9 G/(HP x min)

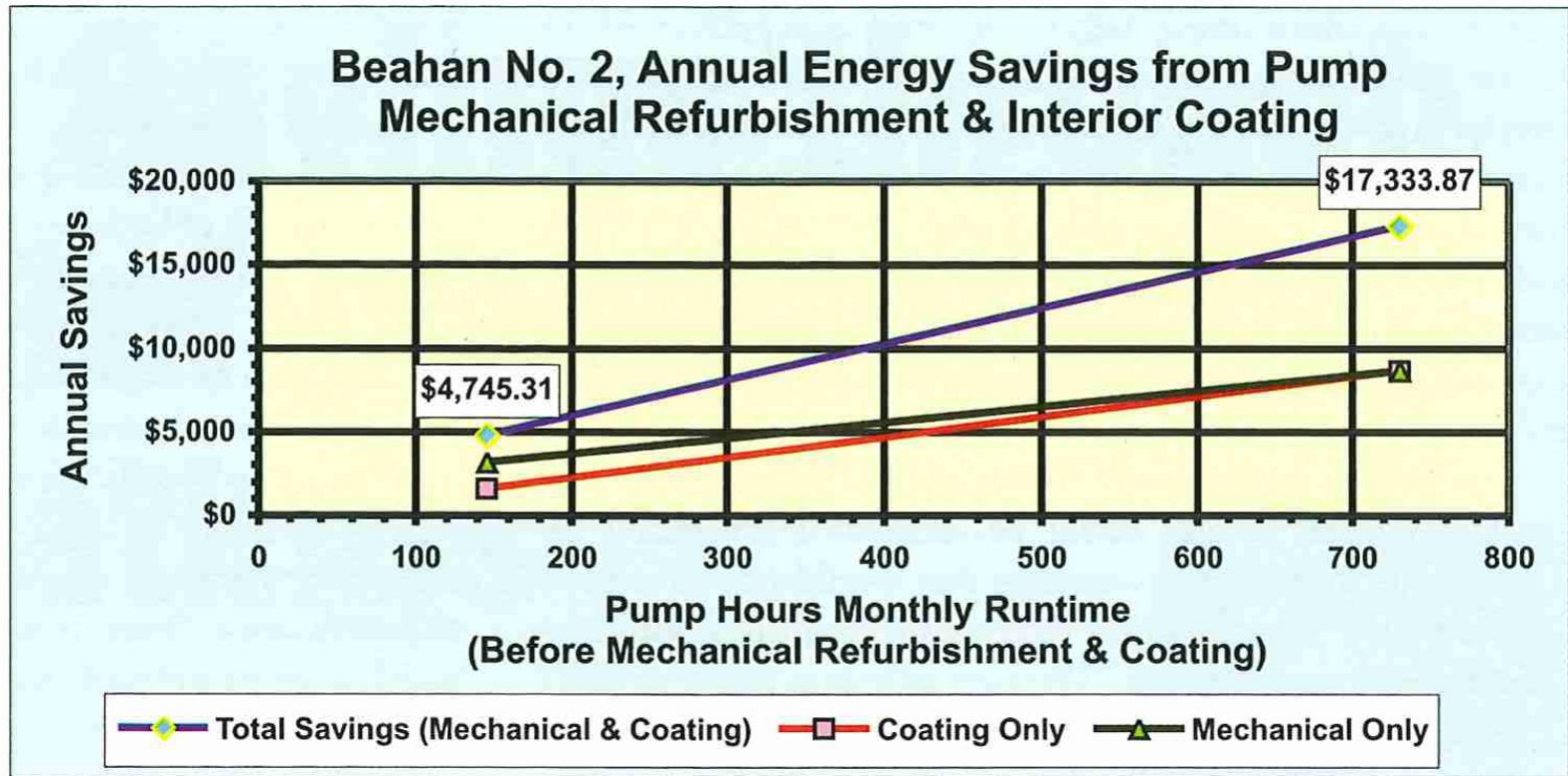
- Here it is more energy efficient to run the Pump 1 only or both pumps in parallel but never use Pump 2 alone

Case Study 1: Austin TX Power Plant

- Reported by Department of Energy¹ in 2005
- Two 1000-horsepower cooling water pumps
- Tested in 1978, at 88% efficiency
- Tested in 2005; 50% and 55% efficient
- New impellers, diffusers, shrouds and shafts
- Retested, now both at 85% efficiency
- Increased generation capacity due to more cooling
- Saved 43,000 tons CO₂ so far
- Annual savings of \$1.2m per year, 11 month payback

1. **US Department of Energy (DOE)**, 2006. Pumping System Improvements Save Energy at Texas Power Plant. Energy Matters, Spring, 2006.

Case Study 2: Monroe County (NY)



- Pump efficiency in 2000 was 88%, by 2006 it was 77.8%
- Refurbishment plus coating took it back to 88%

Case Study 2: Monroe County (NY)

“We never thought that roughness of internal pump surfaces could be costing us so much money...” ...“and there was very little information available documenting the effects of internal corrosion on a pump’s overall efficiency. After running tests on pumps in our distribution system, our engineers were shocked to find that many were operating 15% to 25% below the manufacturer’s specifications”

Paul Maier

– Monroe County Water Authority.

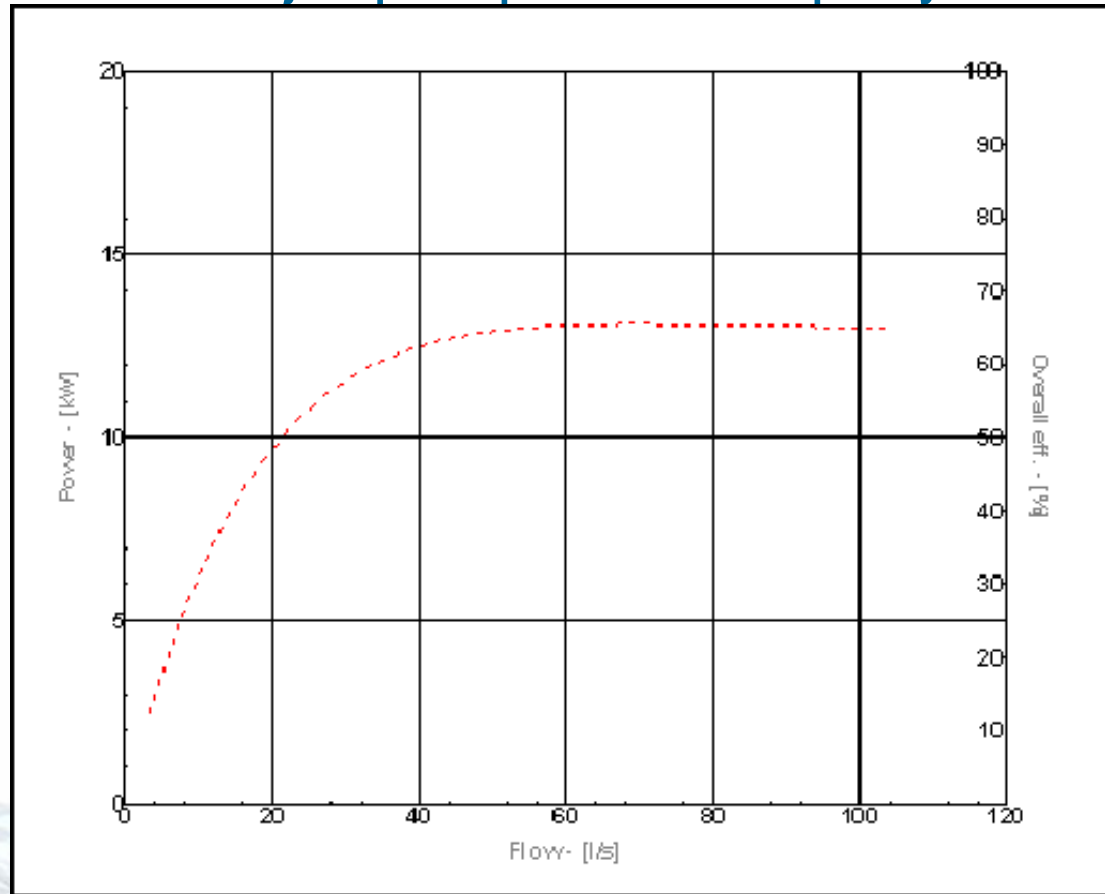


Variable Speed Drives

- Affinity laws say that changing impeller diameter and rotational speed has the same effect
- According to Schneider Electric's manual, variable speed drive allows pump to be driven at “high efficiency no matter what speed is used”
- A presentation from the website www.energymanagertraining.com says that reducing the speed of the pump of 50% results in a 1 or 2% reduction of the efficiency
- According to Haestad's Advanced water distribution modelling and management the affinity laws are right

Variable Speed Drives

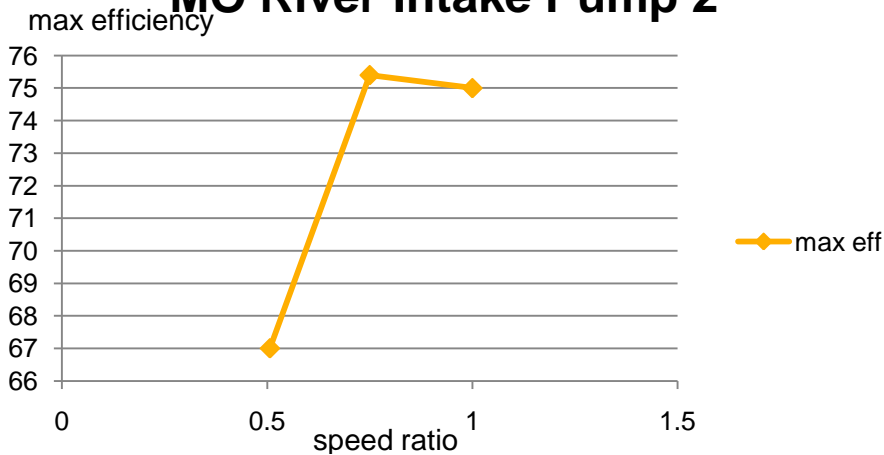
- This is from a major pump test company



Variable Speed Drives

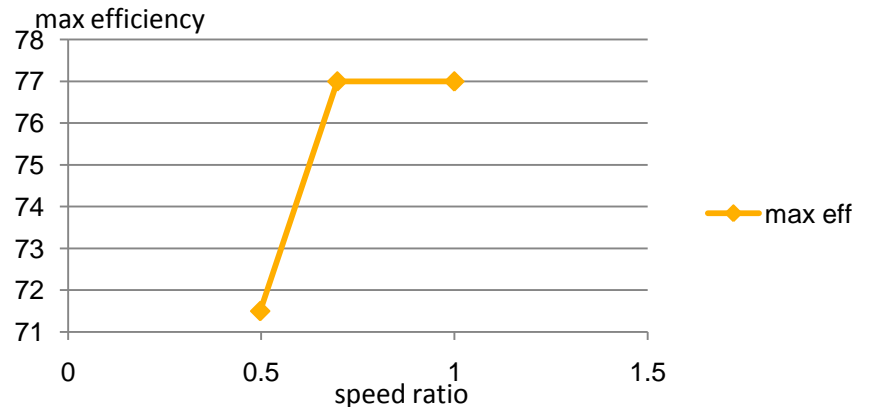
- Data from two large VSD pumps give the following result:

MO River Intake Pump 2



- It seems that the affinity laws are right for 70% to 100% speed only

Missouri Settled Pump 2



AQUADAPT - Key Software Modules



Water Utility
SCADA System

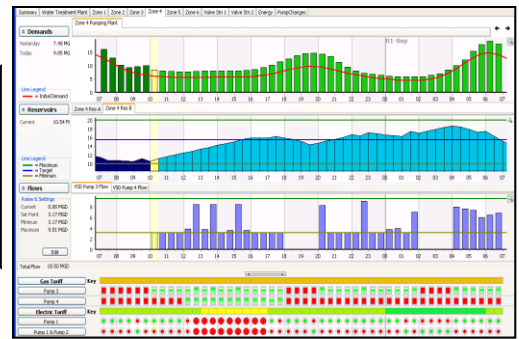
OPC

SCADA Interface

Current day / real-time

Operator Panel

PC on LAN



Primary Database
(Live Server)

Data Cleaner

Solver/Scheduler

Application Manager

Operations Simulator

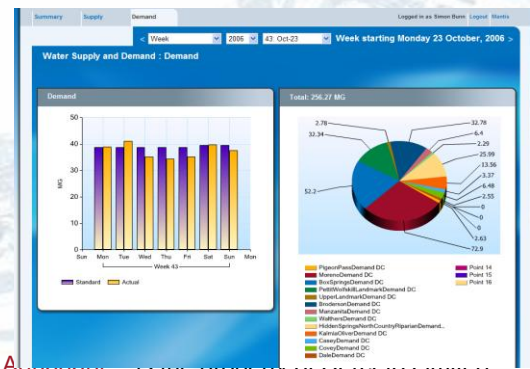
Historian
(B/U Server)

PC on LAN



Dashboard

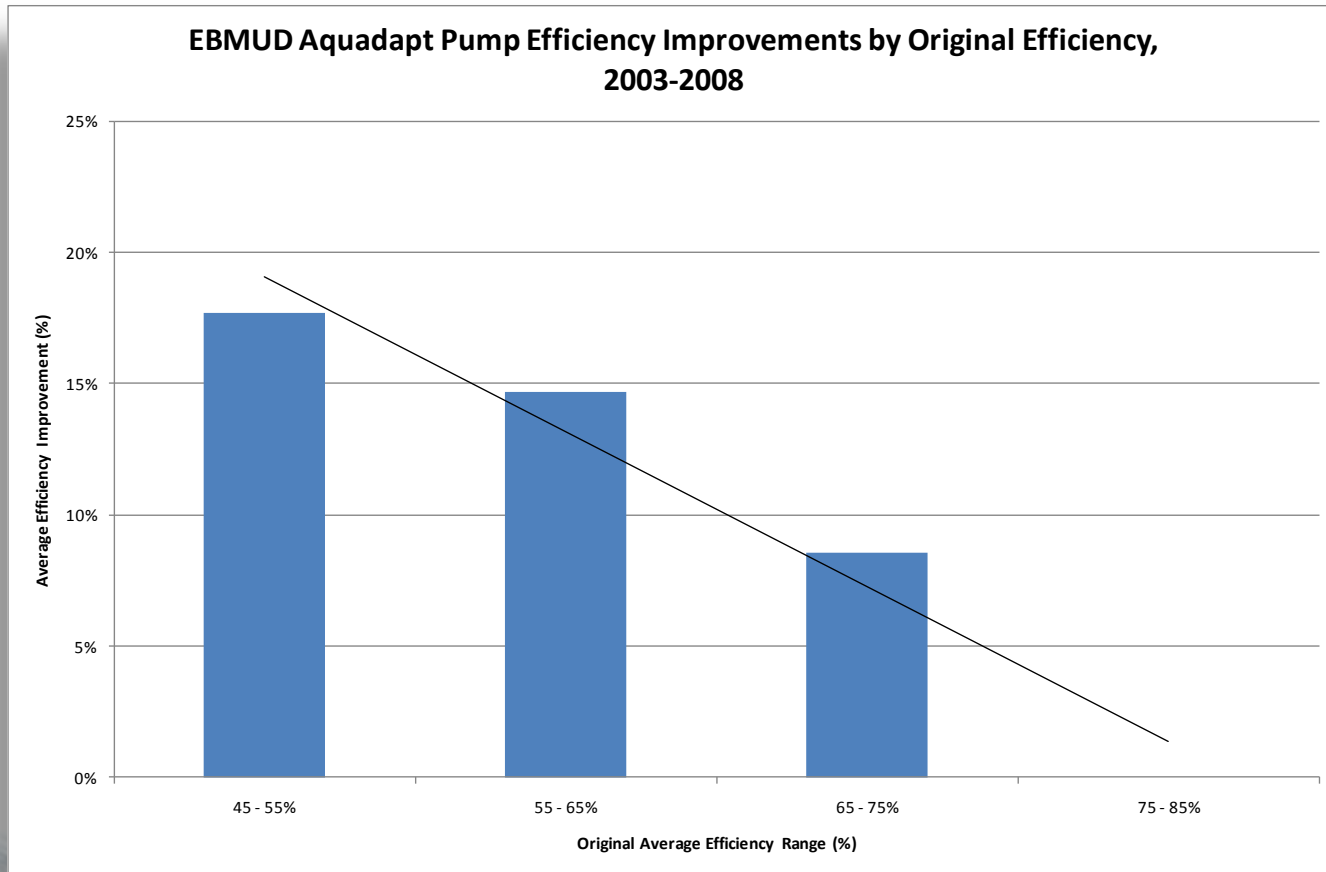
PC on LAN



Derceto®

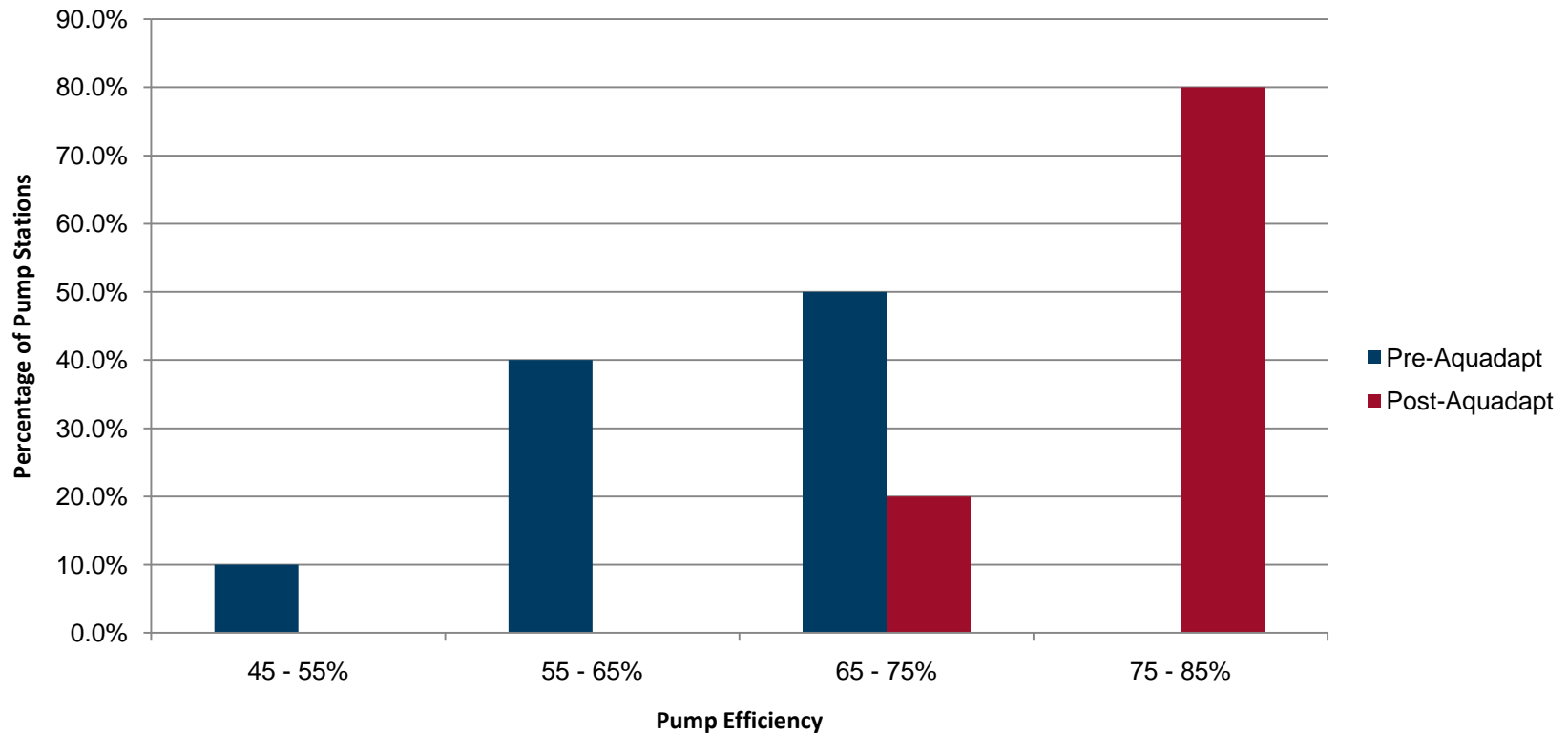
Limited, Reg. USPTO, Reg. IPONZ, Reg. OHIM. Aquadapt is the property of Derceto Limited.

Case Study 3: East Bay MUD



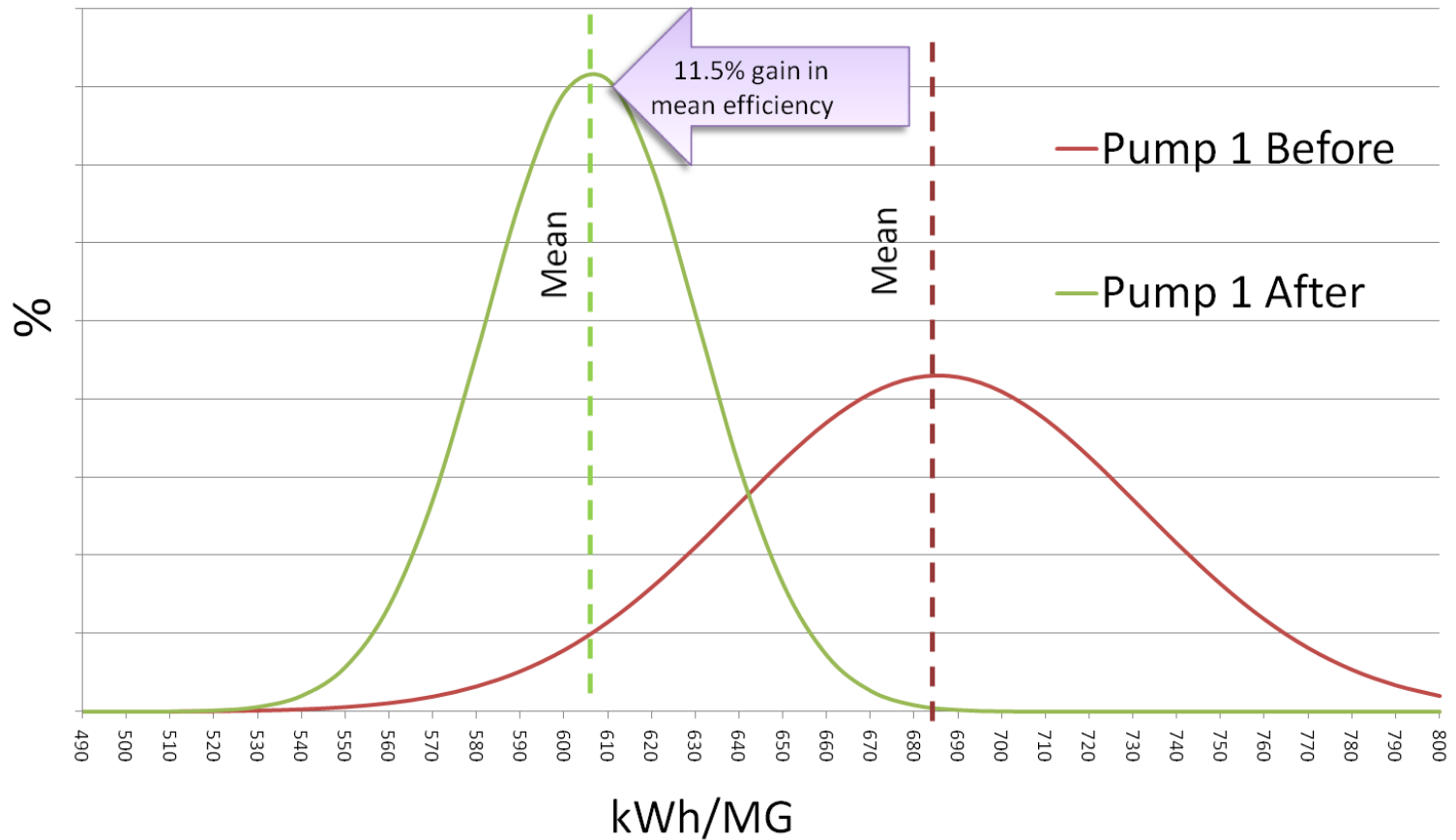
Pump station efficiency improved universally

EBMUD Aquadapt Pump Efficiency Improvements, 2003-2008

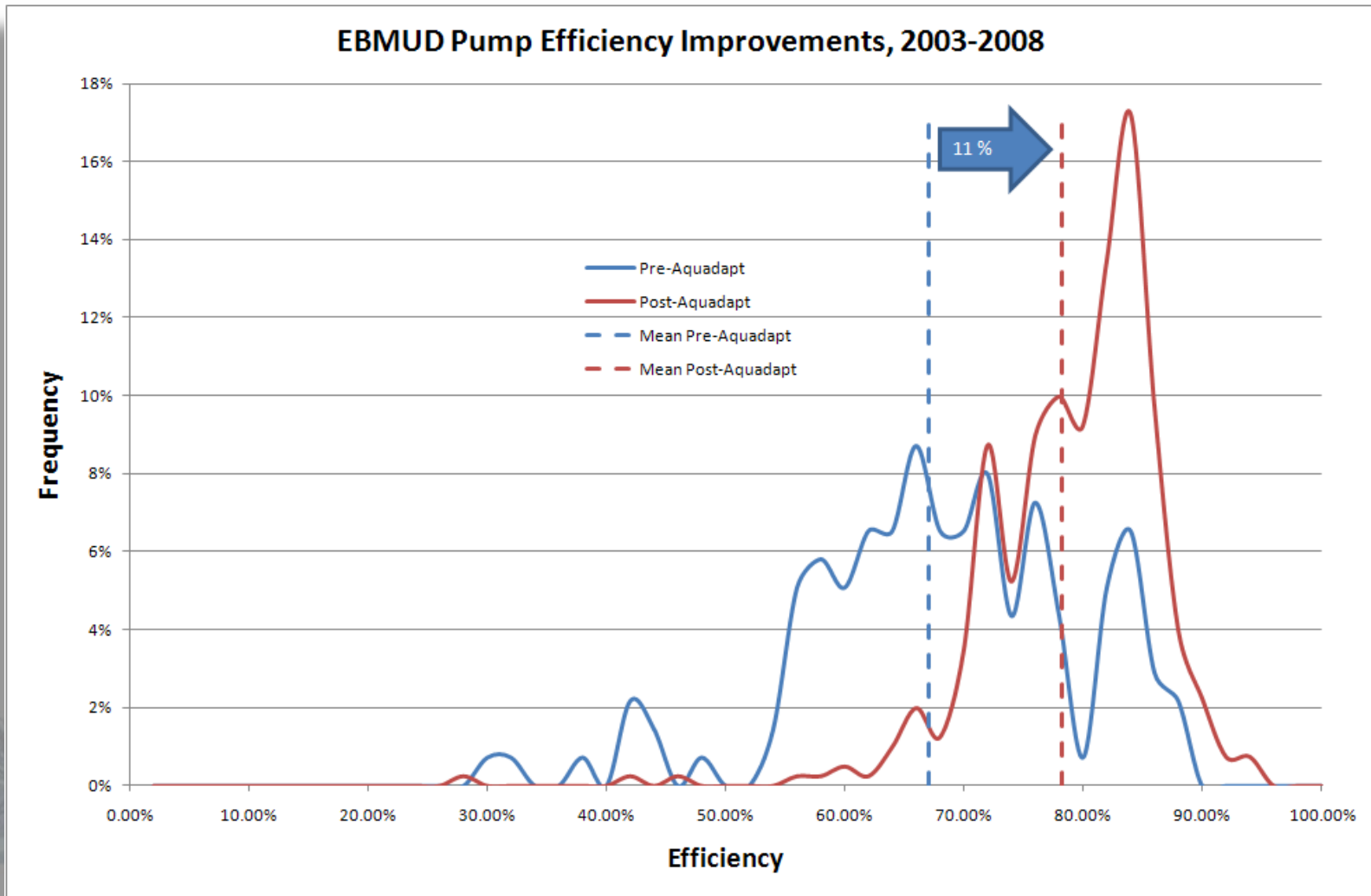


Pumps operate more efficiently

Improvements in mean efficiency and consistency at EMWD



The whole distribution system was more efficient



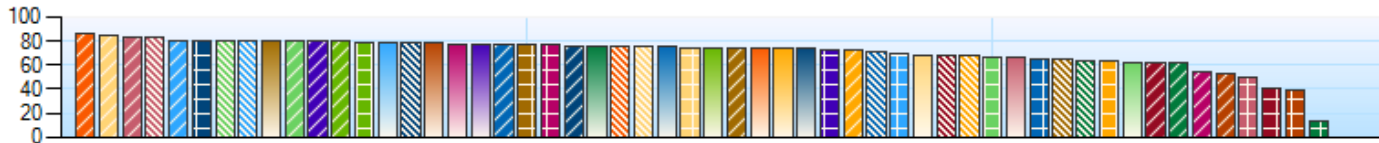
Average Pump Efficiency
 Production Volume
 Pump Energy Usage

< Week > 2008 31: Jul-28 > Starts 28 Jul >

Energy Usage and Savings : Pump Station Summary

Pump Station Comparison

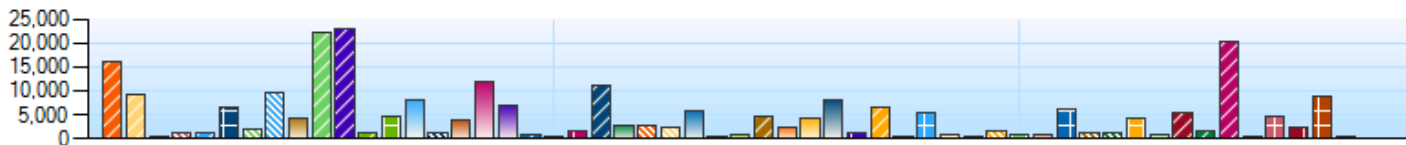
Average Pump Efficiency (%)



Production Volume (MG)



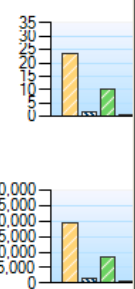
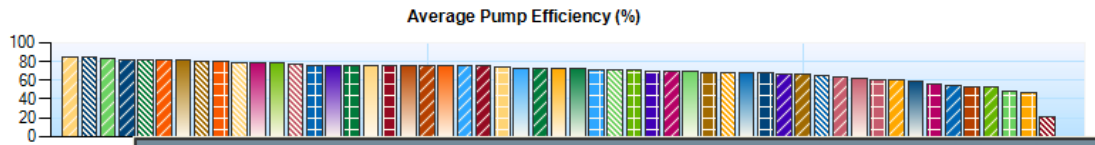
Pump Energy Usage (kWh)



- | | | | | | |
|----------------------|------------------|-------------------|---------------|---------------------|------------|
| Moreno Valley #2 PSG | Antelope2 | Covey PSG | R&C PSG | LasBrisas | LakePerris |
| Hemlock PSG | Ellis | Garboni | QualityFarms | Landmark PSG | |
| Hidden Springs PSG | P&F PSG | QuailValley | Olivas | R&I PSG | |
| Romoland | Murrieta | C&N PSG | Medley PSG | S&I PSG | |
| Antelope1 | P&I PSG | RiderStreet | Bahler | PatRoad | |
| MeadValley1 | Pettit PSG | P&K PSG | Sanwood | EastHolland | |
| Ridgemoor | Pigeon Pass PSG | S&F PSG | MeadValley2 | GoodHope2 | |
| Craig | R&L PSG | North Country PSG | K&S PSG | Cajalco | |
| Elder PSG | Markham&Decker | Nason&Dracaea | Harvill | Vista | |
| Heacock PSG | Brosseau | Ellsworth PSG | JuniperFlats2 | GoodHope1 | |
| AuldRoad | Village Road PSG | Stagecoach | JuniperFlats1 | Moreno Valley 1 PSG | |

Energy Usage and Savings : Pump Station Summary

Pump Station Comparison



S&F PSG

Pump Efficiency

Energy/Volume/Head

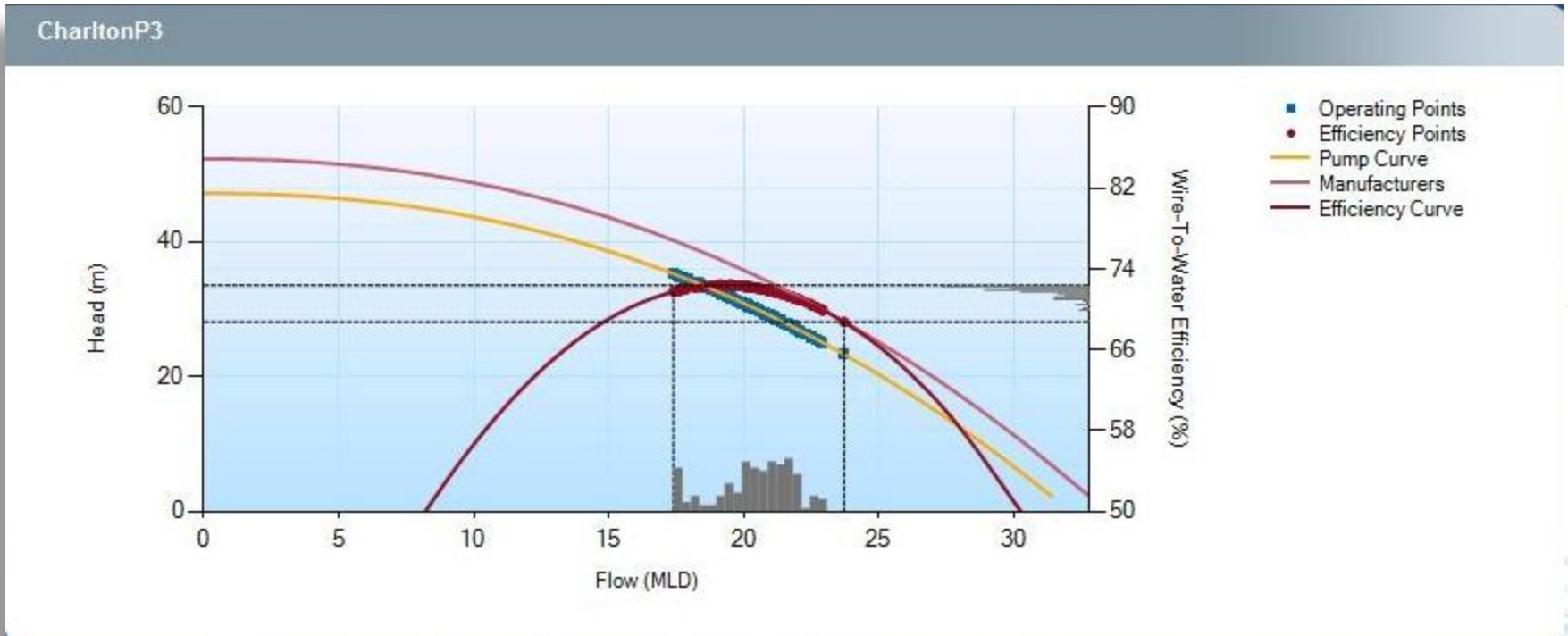
8.8 4.33 kWh/MG/Ft

Statistic	Value	Unit
Avg Efficiency	73	%
Post-Aquadapt	4.33	kWh/MG/Ft
Pre-Aquadapt	5.74	kWh/MG/Ft
Change	25	%

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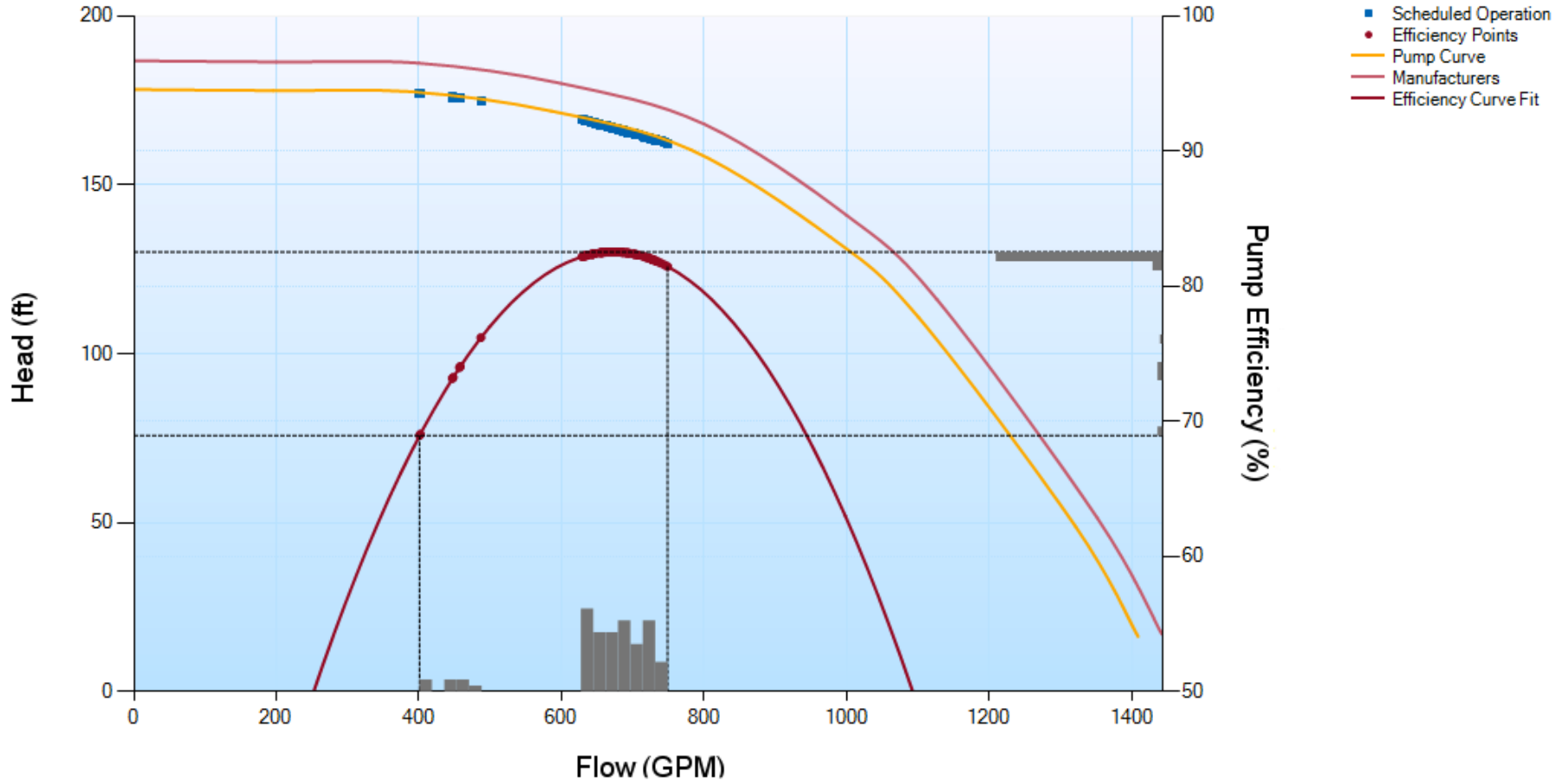
- Moreno
- Ridgem
- Hemlock PSG
- Hidden Springs PSG
- Murrieta
- Antelope1
- Ellsworth PSG
- Romoland
- Ellis
- Craig
- Pigeon Pass PSG
- Markham&Decker
- R&C PSG
- MeadValley1
- North Country PSG
- Harvill
- Pettit PSG
- PatRoad
- P&F PSG
- Antelope2
- P&K PSG
- S&F PSG
- Nason&Dracaea
- Covey PSG
- Vista
- Garboni
- Brosseau
- Bahler
- AuldRoad
- QualityFarms
- C&N PSG
- GoodHope2
- LasBrisas
- Village Road PSG
- JuniperFlats2
- Heacock PSG
- Landmark PSG
- MeadValley2
- Sanwood
- S&I PSG
- Stagecoach
- EastHolland
- RiderStreet
- Cajalco
- JuniperFlats1
- Moreno Valley 1 PSG

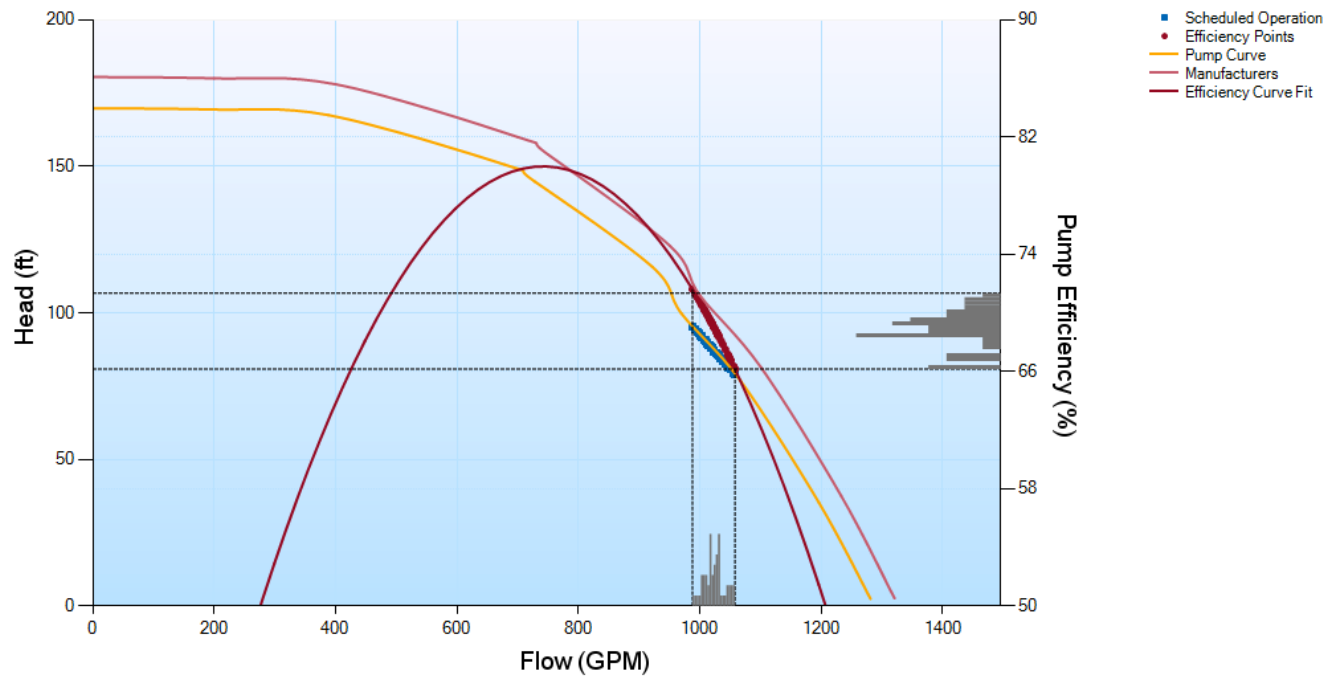
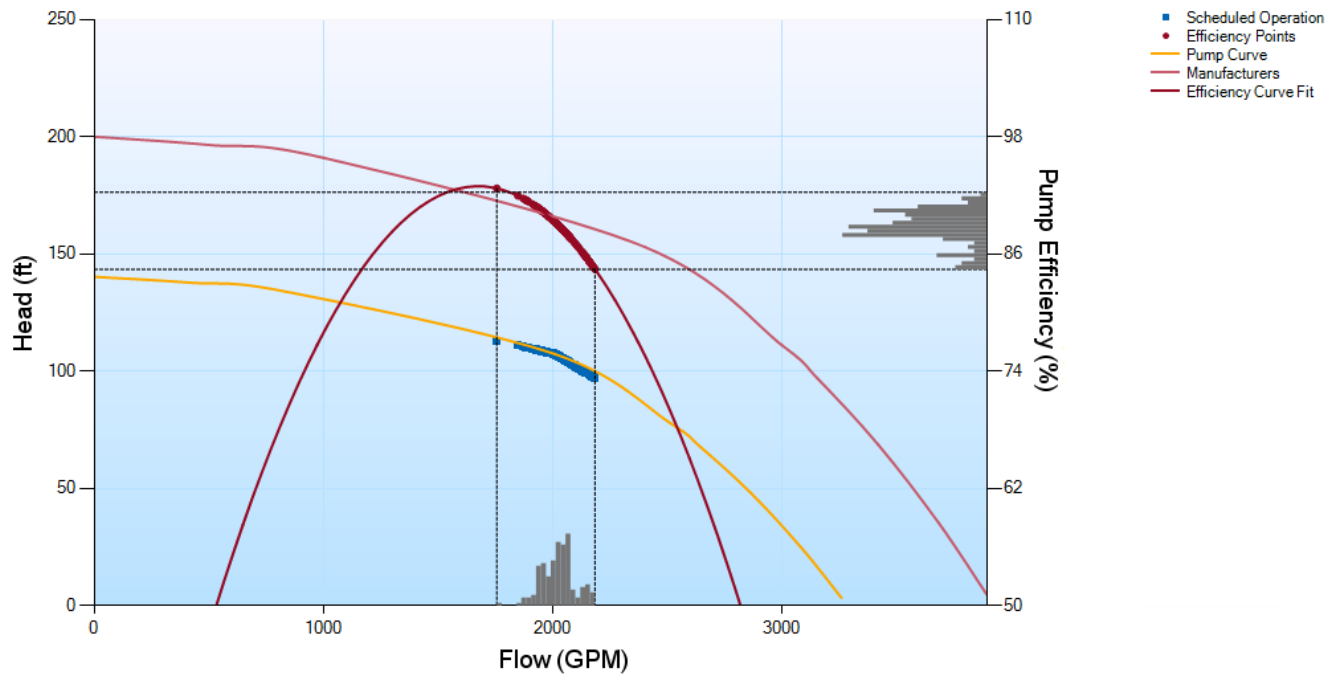
Real-time pump curve data



In this example a pump is running well on its curve and at peak efficiency

Flat pump curves can be a problem





Conclusions

- You have to be able to measure something before you can aim to improve it
- Pumps wear and this wear can have serious implications for performance and efficiency
- 90% of all purchased power by Water and Wastewater Utilities is used by pumps
- With 3% of all US generation power going to Water and Wastewater utilities, getting pumps operating well should be a key goal
- Payback for these types of projects is exceptionally good, 3 months to 2 years typically

So you have no excuse!

Thank You

Questions?