

A thick dark blue vertical bar runs down the left side of the page. A blue arrow-shaped banner points to the right from this bar, containing the date. In the bottom left corner, several thin, curved lines in dark blue and light grey sweep upwards and to the right.

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# HURRICANE PUMP ANALYSIS, PART 1

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# EXECUTIVE SUMMARY

We were asked by the Steering Committee of the Center for Risk Management to conduct a survival analysis on the pump stations on the gulf coast area during hurricane Katrina. In the course of this analysis, we discovered that survival times and rates varied significantly between different causes of failure (flooding, mechanical failure, surges due to levy failure, and jamming with debris). Due to these differences, we recommend against grouping failures by the source of failure (water-caused vs. mechanically caused), as doing so would mask important insights to be made based on failure type. We also recommend that further analysis be done on the failure types to better understand why exactly the pumps failed and what can be done in the future to mitigate the risk of failure.

# ANALYSIS

## Summary Statistics

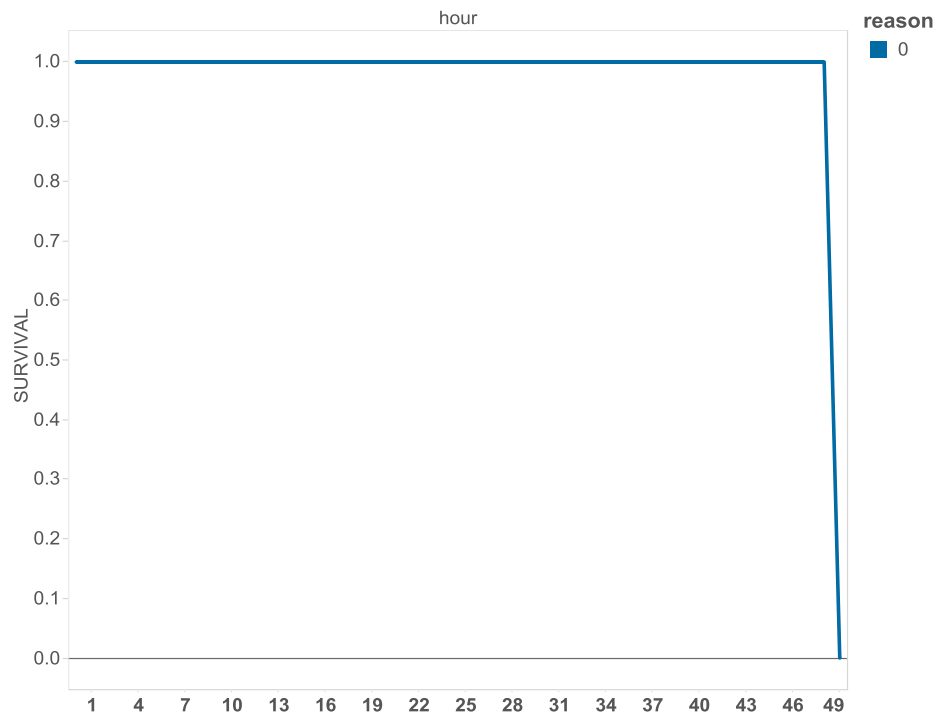
We were asked by the Steering Committee to provide summary statistics as part of our final report. These statistics are listed in the following table:

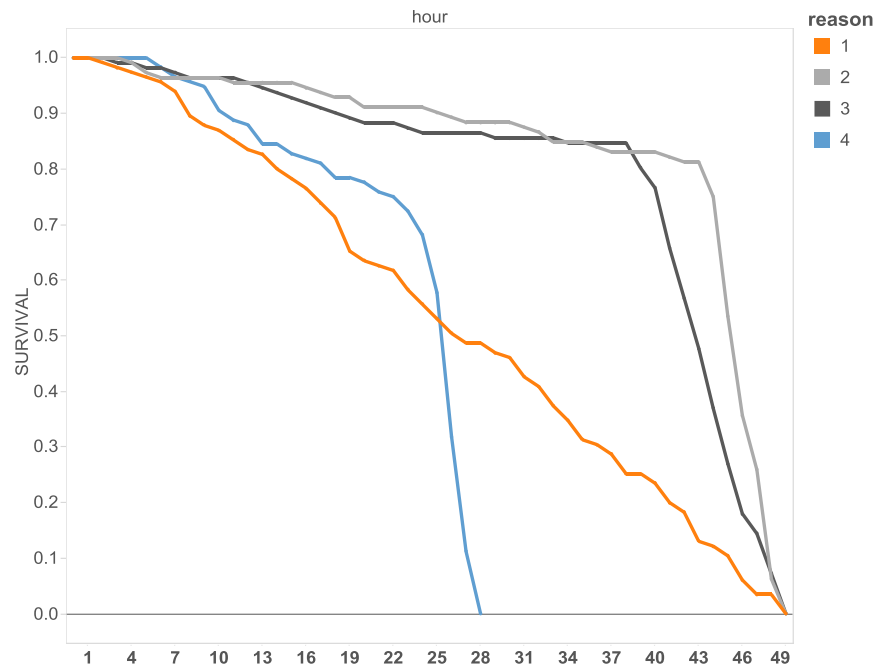
Reason for Failure	Percent of Pumps in Category	Average Survival Time (Hours)
<b>0: (Did not fail)</b>	41.0	N/A (48)
<b>1: (Flood)</b>	14.9	26.4
<b>2: (Motor)</b>	14.6	41.0
<b>3: (Surge)</b>	14.2	38.8
<b>4: (Jammed)</b>	15.1	21.9

According to our analysis, there is a statistically significant difference between the average survival times for each type of pump failure, except for types 2 and 3 (Motor and Surge).

## Survival Curve Analysis

We also calculated a survival analysis graphs for all pumps that survived the hurricane (displayed first) and all pumps that did not (displayed second).





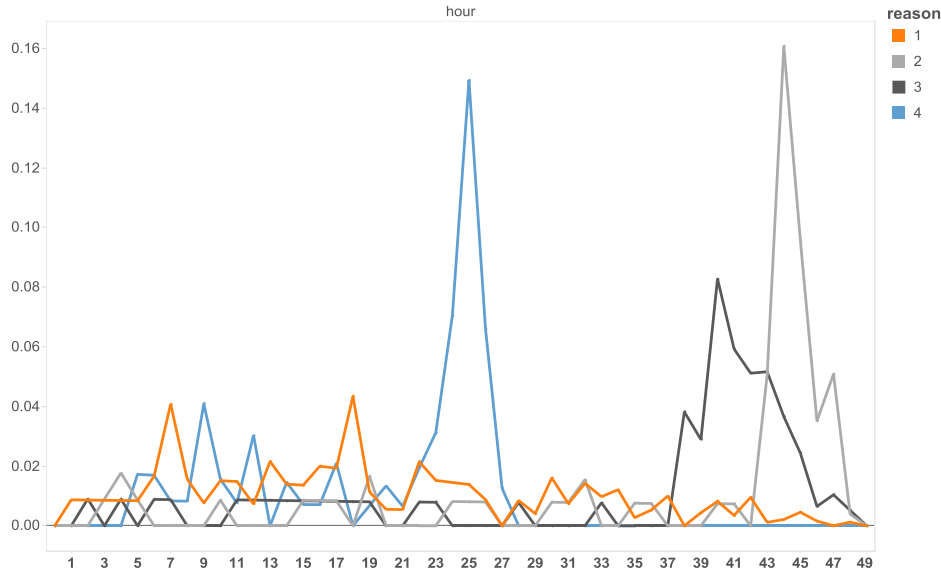
The uniform distribution in the graph displaying the survival curve of pumps that survived is what could be expected—since each of these pumps survived the hurricane, the survival curve should not deviate from a horizontal line at a probability of 1. However, there are some interesting insights given by the second graph. Three aspects are most notable: first, the difference in curve shape between the pumps that failed due to flood (1) compared to the others is intriguing. While every other type of failure experienced some sort of steep drop-offs in survival rates at some specific point in time, the rate of failure due to flood seems relatively uniform over the time period. Second it may be worthwhile to investigate why the survival rates of pumps that failed due to jamming (4) appear to drop off much earlier than those that failed due to motor or surge problems (2 or 3). Third, this graph also begs the question why exactly the relationship between motor and surge failure (2 and 3) is so highly correlated.

Like the comparisons between the average survival times among failure types, testing also revealed a statistically significant difference between each survival curve except for 2 and 3.

The outcomes of these graphs and tests indicate that combining failure types based on the source of the failure (water vs. mechanical) would inhibit our insight from this data. Doing so would combine groups with significantly different survival curves (groups 1 and 3 or 2 and 4) and thereby mask the true relationship between failure type and average survival time.

## Hazard Probability Graphs

We also compiled the hazard probability graphs associated with each failure type, depicted below.



While the position of major changes in survival rates in time match up with those depicted in the survival rate graph, the hazard probability graph gives further insight to when exactly the spikes in each failure type took place. It also fosters more questions. For example, examine the hazard probability curve of reason 4. Why would there be such a sudden spike of jamming failures in the first place? What would cause trash or landslide materials to accumulate so suddenly, and why did the spike in failure rates due to jamming take place so much earlier relative to the other types of failure? Speaking of the other types of failure, what exactly took place at 37 hours to instigate the spike in motor and surge related failures? Furthermore, we had initially speculated that the relationship between motor and surge failures was correlated because as a surge of water assailed the pumps, the motors were overwhelmed and subsequently failed. However, this graph shows that the spike in motor failures actually preceded the increase in surge failures. Why would this be the case, and what do we really know about the relationship between motor and surge related failures?

## CONCLUSION

Through comparison of mean survival times and survival analysis techniques, we were able to establish the connection between survival rates and failure types over the duration of the hurricane. With further analysis, we may be able to exploit that insight to reduce the risk of pump failure in the future.