Appendix F – Survey Results

PRIM Survey Date – Preliminary Summary and Analysis

In this preliminary report, we summarize the data received so far, carry out a comparative analysis, and indicate some possible trends that can be explored further during the next phase of the project.

Background – 2000 Benchmarking Study

The June 2000 report, *Benchmarking Metal Finishing,* provides a statistical analysis of responses from 132 metal finishing facilities, covering over 30 different metal finishing processes, with information on six key environmental variables. The data set contained a wealth of useful information, but extracting the information in useful form presented a challenge. Most metal finishing shops run a mix of processes, each with its own particular set of environmental impacts. Shops generally know their overall water and power usage rates, and the total amount of sludge they generate, but are not typically able to provide a process-by-process breakdown of those totals. That makes it difficult to compare one shop's performance with another's, or the impacts of one process with that of another, using the raw data from the reported totals alone.

Although the shops could not say what portion of environmental impacts were due to each process, they were asked for information that could provide surrogate measures of the relative contribution of each process to the total. The most robust of these measures turned out to be the dollar amount of sales due to each process, as a percent of total annual sales over the survey year (1998, in the case of the 2000 report).

Since we now had both total impact numbers and a measure of process mix from each shop, we could apply the statistical technique of regression analysis to extract a measure of how much of each impact variable is associated with each specific process. (A number of statistical tests were performed to check for the influence of variables such as the customer mix of the shop, and to distinguish apparent trends from random fluctuations. A detailed description is provided in the 2000 report.)

The result of the analysis was a set of regression coefficients, one for each impact variable and each process. After tests for statistical significance were applied, sets of coefficients were provided for six major processes:

- Zinc plating
- Nickel plating
- Decorative chromium plating
- Electroless nickel plating
- Anodizing
- Hard chromium plating

For each of these processes, coefficients were provided for four major impact variables:

- Water usage
- Sludge generated
- Hazardous waste generated
- Electricity use

(The coefficients for the remaining combinations of processes and impacts were not statistically significant at the relatively lenient 10% significance level.)

The coefficients measure the average amount of each impact variable generated for every dollar of sales from a specific process. For example, the study found that, based on the data from the survey, a metal finishing shop running a zinc plating operation in 1998, performing at the industry average, could expect to discharge 4.9 gallons of wastewater for every dollar of sales from the zinc line. For the many shops whose sales were primarily from some mix of those six processes, we could calculate from their total sales dollars what their expected total wastewater generation rate would be if they were an average shop. By comparing that expected number with the actual number they provided, we could tell them how they compared with their peers. We could also look for other characteristics of the top performing shops that might indicate what methods or equipment might be particularly effective. The findings are listed in the 2000 report.

PRIM Survey Data

The goal of the PRIM (**P**2 **R**esearch and **I**mplementation for **M**ichigan Metal Finishers) project is to eliminate the information barriers that currently impede the metal finishing industry's ability to implement innovative pollution prevention (P2) technologies and techniques. As part of this initiative, the project is assessing the current environmental performance level of the industry, compared to the information gathered in the 2000 study. A survey was distributed to 600 shops (including members of the NASF nationwide, as well as metal finishers located in Michigan). Participants were given the option of mailing back a paper form, or replying on-line.

As of September 30, 2017, complete surveys have been received from 31 metal finishing facilities (14 paper and 17 on-line). The data collected so far are sufficient to permit some meaningful comparisons between shops responding today and shops in the 2000 study survey, although it does not represent a large enough sample to duplicate the statistical analysis carried out for the 2000 study report.

One way to compare data from the current survey with the 2000 results is to make use of the regression coefficients calculated during the earlier study. The method can be applied to shops whose process mix is dominated by the six processes identified in the 2000 study that had statistically significant coefficients. In such cases, we can use the regression coefficients together with the 2017 sales data to estimate what impact we would expect from a shop if it were performing like the average shop in the 2000 data. We can then compare that number with the actual reported impact, and see whether the shop in 2017 is doing better than, worse than, or about the same as, the average shop in the 2000 data set running the same mix of processes. For 14 of the shops responding to the 2017 survey, 60-100% of their sales were generated by some combination of the six processes.

In order to approach an apples-to-apples comparison, we need to consider how quantities calculated with data from 1998 might have changed over time, even if the population being sampled stayed the same. The regression coefficient can be thought of as a ratio, expressed as impact per production unit. We want to use the ratio to determine whether there have been changes in impact over time. Because we're specifically interested in tracking changes in the numerator, impact, over time, we need to keep the denominator constant – a unit of production from the 2017 data needs to correspond to the same amount of product as measured by the 1998 data.

The 2000 study identified sales dollars as the best production unit for our purposes. One contributing factor may be that companies can typically provide much more accurate data, broken down by process, on sales than they can on other measures (such as total square feet plated, or number of employee hours spent). We expect this remains the case, and that sales dollars are still the best metric to use. But while neither the square foot nor the hour has changed noticeably over the past several years, the dollar is never what it used to be. This unavoidably complicates a comparison based on reported dollars.

To convert 1998 dollars to 2017, we can use a standard inflation measure, the Gross Domestic Product implicit price deflator, as provided by the St. Louis Federal Reserve Bank (https://fred.stlouisfed.org/series/GDPDEF/). Comparing indices for the fourth quarters of 1998 and 2017 respectively, we find that according to this measure, we should use a factor of 1.417 to relate a 1998 to a 2017 dollar. Of course, this is an imperfect measure, since price trends in some metal finishing markets might not match that of the economy as a whole. In particularly competitive sectors, where prices aren't keeping up with inflation, a somewhat smaller factor might be appropriate. (Few metal finishers would be expected to command prices in excess of the general economy, so we assume that a case where the appropriate factor would be greater than 1.417 is unlikely to arise.)

We also need a way to account for that portion of a shop's production that is not included among the six processes with usable coefficients. We assume that, whatever other processes a shop might run, their contributions are small or diverse enough that the average impact per unit due to all of the processes that aren't one of the six works out to about the same as the average impact per unit of the processes that are among the six. That means that the estimated impact can simply be scaled up. Thus if, for example, if we calculate a shop's expected impact due to the processes among the six, and if this represents 90% of the shops production, we would estimate the shop's total impact for all processes to be 100%/90% = 1.11 times the impact estimated for the six processes.

With those two provisos, we are ready to calculate expected vs. actual values for fourteen of the shops in the 2017 data set. Table F-1 lists the regression coefficients from the 2000 study (covering data from 1998) for the six processes and for four environmental impact variables:

- Wastewater discharge (total annual, in gallons).
- Sludge generation (total annual, in pounds).
- Hazardous waste sent to landfill (total annual, in pounds).
- Electricity used (total annual, in kilowatt-hours).

In each case, the table also provides the values of the coefficients when they are rescaled from 1998 to 2016 dollars, as explained in the previous section. The rescaled coefficients measure the expected impact due to each dollar of sales in 2016 if companies' environmental performance were the same on average as companies' performance in 1998, and the only difference between the two time periods were the value of the dollar. (Note that the rescaled coefficients are smaller. Since the same quantity of plated product commands more dollars in 2016 than in 1998, the impact from producing that quantity is being spread over more dollars, so the impact per dollar of sales is lower.)

A typical example can be used to show how the coefficients are used, along with the data from the current study, to generate an estimate of the total annual impact that would be expected from each shop's process mix if they were performing at the average level of shops in the 1998 data set. We will work through the expected wastewater generation rate for one representative company from the 2016 data set. The calculations are similar for all of the remaining impact variables and companies.

So for example in the case of facility #16, 95% of sales in 2016 were from processes among the six with coefficients (80% from decorative chrome, 10% from nickel, and 5% from zinc), and 5% from another process not included among the six. Their sales total in 2016 was $2,728,500. To find the facility's "expected" wastewater discharge for 2016, the calculation would proceed as follows:

> 80% chrome sales in 2016 x $2,728,500 total sales = $2,182,800 from chrome.
>
> From Table 1, each 2016 sales dollar would generate 1.603 gallons of wastewater from shops performing at the 1998 average.
>
> $2,182,800 x 1.603 gallons/2016$ = 3,497,948 gallons expected from chrome sales.

Similarly:

> 10% nickel sales x $2,728,500 total sales x 1.405 gal/2016$ = 383,310 gallons expected from nickel.
>
> 5% zinc sales x $2,728,500 total sales x 3.381 gal/2016$ = 461,321 gallons expected from zinc.

So the total expected flow from processes with coefficients is:

> 3,497,948 + 383,310 + 461,321 = 4,342,579 gallons

If, as explained above, we assume that the impact per sales dollar due to the remaining process is reasonably close to the average of the other processes, we can scale up the total flow proportionally:

> 4,342,579 / 0.95 = 4,571,136 gallons

Tables F-2 – F-5 summarize the results of similar calculations for the 14 facilities whose process mix qualifies them for this analysis, applied to wastewater discharge, sludge generation, hazardous waste shipments to landfill, and electricity use.

Table F-1. Regression Coefficients from 2000 Study, Together with CoEfficients Rescaled for 2016 Dollars

	Anodizing, sulf	Cr, decorative	Cr, hard	E'less Ni	Nickel	Zinc	Zinc (barrel)	Zinc (rack)
Average water discharged (gal/1998$)	1.960	2.270	0.200	1.420	1.990	4.790		
Average water discharged (gal/2016$)	1.384	1.603	0.141	1.002	1.405	3.381		
Sludge generation rate (lb/1998$)	-0.015	0.008	0.006	0.005	0.007	→	0.054	0.016
Sludge generation rate (lb/2016$)	-0.011	0.006	0.004	0.003	0.005	→	0.038	0.012
Haz. sludge, land-disposed (lb/1998$)	0.019	0.005	0.002	0.011	0.002	0.025		
Haz. sludge, land-disposed (lb/2016$)	0.013	0.004	0.001	0.008	0.001	0.017		
Electricity use (kWh/1998$)	0.485	0.458	0.536	0.153	0.453	0.514		
Electricity use (kWh/2016$)	0.342	0.323	0.378	0.108	0.320	0.363		

Table F-2. Expected vs. Actual Wastewater Discharged

	WW discharged (gal/yr)		
	expected		actual
Facility code	six processes	all processes	all processes
5	26,783,076	31,509,501	18,161,271
8	38,650,520	42,945,022	21,499,016
10	5,666,156	8,572,097	7,843,215
11	17,544,909	17,902,968	6,505,652
13	176,487	176,487	460,000
14	224,801,270	241,721,795	78,000,000
15	54,164,677	54,164,677	31,836,146
16	4,342,580	4,571,137	1,201,450
17	17,295,761	17,295,761	12,100,000
18	14,733,882	15,509,349	18,411,421
19	6,481,251	10,802,085	-
25	2,090,493	2,986,418	-
26	18,093,484	30,155,807	25,000,000
31	2,419,606	3,722,471	1,300,000

Table F-3. Expected vs. Actual Sludge Generated

	Sludge generated (lb/yr)			
	Expected		actual (wet)	actual (dry*)
	six processes	all processes	all processes	all processes
5	123,570	145,377	723,484	289,394
8	437,340	485,933	1,957,600	783,040
10	38,476	58,209	10,640	4,256
11	198,525	202,576	-	-
13	7,513	7,513	6,800	2,720
14	1,189,694	1,279,241	951,401	761,121
15	278,512	278,512	894,900	357,960
16	21,361	22,485	65,800	26,320
17	-193,500	(193,500)	800,000	320,000
18	60,178	63,346	50,682	20,273
19	30,330	50,551	12,000	4,800
25	6,287	8,981	-	-
26	41,034	68,389	106,631	42,652
31	732	1,127	8,000	6,400

Table F-4. Expected vs. Actual Hazardous Waste Shipped to Landfill

	HazWaste landfilled (lb/yr)		
	Expected		actual
	six processes	all processes	all processes
5	127,442	149,932	-
8	197,691	219,656	40,000
10	28,981	43,845	-
11	89,739	91,571	-
13	1,853	1,853	6,800
14	762,979	820,407	82,798
15	126,464	126,464	-
16	10,816	11,385	-
17	164,133	164,133	-
18	97,413	102,540	50,682
19	41,355	68,924	-
25	11,961	17,088	-
26	100,104	166,839	106,631
31	12,348	18,997	-

Table F-5. Expected vs. Actual Electricity Used

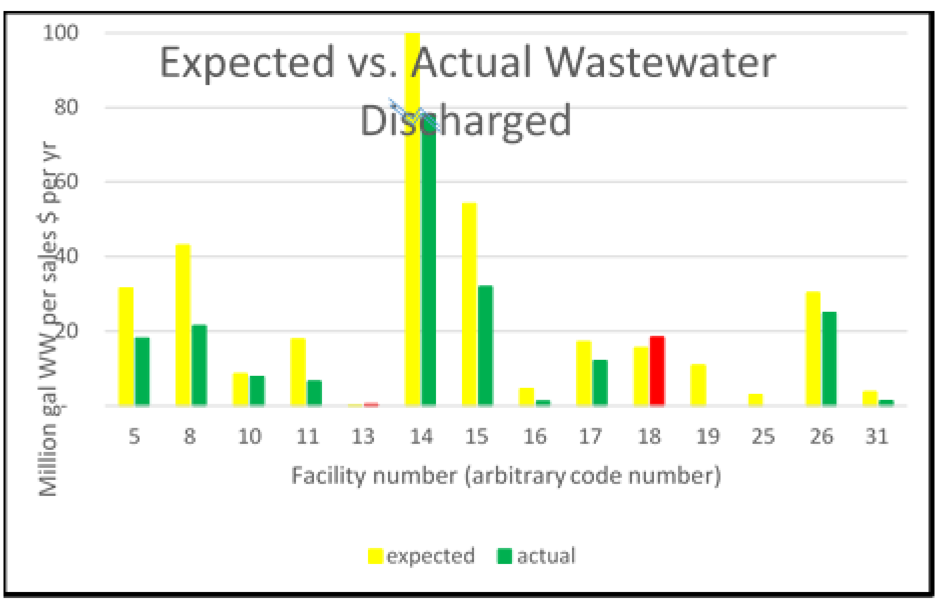
	Electricity used (kWh/yr)		
	Expected		actual
	six processes	all processes	all processes
5	3,137,467	3,691,138	3,800,000
8	4,147,467	4,608,297	6,316,929
10	608,018	919,845	483,680
11	1,882,690	1,921,112	1,935,293
13	472,986	472,986	440,000
14	38,267,119	41,147,440	25,400,000
15	10,928,380	10,928,380	5,053
16	842,512	886,855	841,093
17	4,279,818	4,279,818	7,200,000
18	1,584,457	1,667,849	2,240,160
19	868,445	1,447,408	960,000
25	236,581	337,973	380,000
26	3,183,832	5,306,387	3,575,415
31	270,686	416,440	134,000

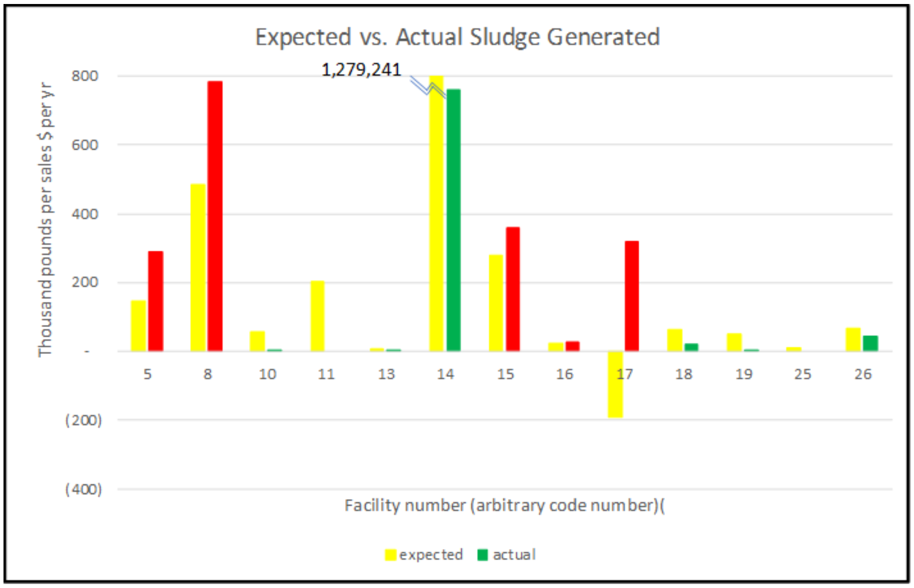
Preliminary Conclusions and Questions:

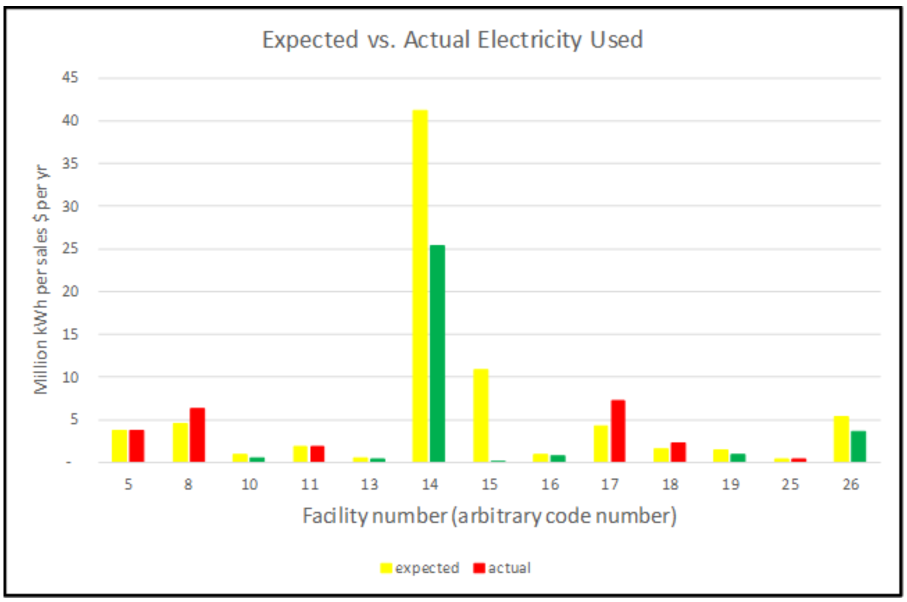
To assist in interpreting the results, the information from the tables is presented in graphic form below. In each case, the expected impact from each facility is depicted as a yellow bar. Immediately to the right of each bar, a second bar shows the actual reported impact from that facility. These bars are colored either green or red, depending on whether the actual impact is better or worse, respectively, than expected.

As is apparent from the graphs, this comparison indicates that almost all of the facilities did significantly better – in some cases dramatically better – in wastewater discharged per sales dollar than would have been expected from the average performance of shops in 1998. The results for sludge generation and for electricity usage are mixed. (Fewer shops were able to provide information on hazardous waste shipments, so this impact variable was not graphed.)

As described above, two of the steps in the calculation, the inflation adjustment and the scale-up for processes without coefficients, introduce some unavoidable uncertainty into the analysis. If, for example, all of the impact variables were showing systematic improvement, the apparent trend could be due to an inappropriate choice of inflation factor. The fact that sludge generation and power usage do not follow the same trend suggests that the inflation factor is not introducing a systematic bias. As far as the scale-up is concerned, inspection of Table F-2 indicates that, in many cases, the actual wastewater generation rate is below what would be expected if the processes without coefficients hadn't even been running (i.e., compared to what the expected impact would have been before it was scaled up). The conclusion that shops represented in the 2016 data set have actually improved their wastewater reduction practices, compared to shops in 1998, seems reasonably robust.







Next Steps

This preliminary analysis suggests several questions that may warrant further investigation during subsequent stages of the project. For example:

- What factors might be associated with the apparent overall improvement in water consumption over the past two decades? Possibilities might include economic factors (such as increasing water and/or sewer rates), or factors associated with regulatory or reporting requirements.

- Why have improvements in water consumptions not been matched by corresponding improvements in electricity use and sludge generation rates? Have electricity rates and sludge disposal costs increased less rapidly than costs associated with water use and wastewater disposal? In the case of sludge generation rates, do metal finishers perceive less regulatory emphasis on minimizing solid waste than on minimizing wastewater disposal?
- Is it possible that improvements in water consumption and discharge rates are associated with factors that mask improvements in the other impact measures? Better sludge removal might be improving the quality of the wastewater, easing the treatment load for the POTW, but at the cost of generating that much more sludge. Better wastewater treatment might also be associated with somewhat higher power consumption.

It may also be worthwhile at this stage of the project to try to understand why the response rate for the 2017 survey fell below that for the 2000 study. Factors might include changes specific to the industry (such as increasing fragmentation as manufacturing moves offshore), as well as a general "survey fatigue" that is not restricted to metal finishing. The fact that the 2000 study was conducted in the context of the Strategic Goals Program (SGP), an EPA initiative that offered regulatory recognition for targeted improvements, might also have given participants in the earlier study additional incentive to cooperate. It may not be possible to recreate under current circumstances the conditions that boosted the response rate two decades ago, but it may be worthwhile to understand the extent to which sector-based voluntary programs like SGP can help promote sector-wide cooperation in pollution prevention efforts.