The City of Hamilton

Container Line Performance Audits and Improvement Recommendations

PREPARED BY: Reclay StewardEdge Inc. and Stantec

This page has been intentionally left blank.

Contents

Tables

Figures

Appendices

1. Executive Summary

Introduction

In 2013, the City of Hamilton invested $1.9M to upgrade the front-end of their container line by installing a new glass clean up system, a new drum feeder and a bag breaker. These changes improved sorting efficiencies and the City's ability to market glass, a material which has historically been difficult and expensive to manage. The Continuous Improvement Fund (CIF) funded this project to conduct a performance audit on the container line to measure the effectiveness of the front-end system, and also to identify areas for improvement for the balance of the sorting line. This report was produced by a team led by Reclay StewardEdge Inc. (RSE) and supported by Stantec (the Project Team).

Methodology

The Project Team worked with City staff and their service provider (Canada Fibers Ltd.) to conduct a controlled test to represent normal operations. During the test, the container line was shut down, and all belts and bunkers were emptied prior to the test. Sample materials were collected randomly from the tip floor (1.7 tonnes of container materials) and introduced to the line to be sorted under regular operations.

Key Findings

Following the results of the test, the Project Team summarized the key findings within this report:

- The glass clean-up system is effective at separating glass from the rest of the container stream. Approximately 98% of all glass is captured by the new equipment. Additionally, non-glass materials only represent 8% of the materials found within the glass bunker.
- The bag breaker is effective at ripping open large sealed bags of recyclables with an efficiency rate of 99%; however, the equipment is less effective at ripping smaller bags with an efficiency rate of 55%. Unopened smaller bags can go through multiple loops until they eventually rip open, either at the drum feeder or the bag breaker.
- The film grabber appears to be misconfigured (too high off the belts surface) to effectively capture film. Additionally, issues with the suction at the top of the film grabber and the mechanical "fingers" used to grab film render it ineffective. This places the entire burden of removing plastic film on manual sorters at the second manual station and at other manual QC sort stations further downstream.
- HDPE containers are manually sorted at the first and second manual sort stations which are able to achieve approximately 80% capture. Sorters targeting HDPE containers are also tasked with removing other materials including residue, plastic film, fibre and oversized containers. Due to the amount of film found within the container stream, sorters missed HDPE containers either due to being occupied with removing film and residue, or missed them as they were buried under other materials. If the City were able to achieve a 90% capture rate for HDPE containers, it would generate an additional $53,000 in revenue annually.
- The eddy current currently achieves an efficiency rate[1] of 86% of the aluminum cans that passes through it. Similar to the HDPE issue, aluminum containers are buried under other materials such as PET, mixed plastics, polycoat and residue that hinders its ability to effectively sort aluminum containers. If the City were able to achieve a 98% capture rate (manufacturers spec) for these containers, it would allow the City to generate an additional $130,000 in revenue annually.

---

[1] Efficiency rate is defined as the ability for each piece of equipment to correctly identify and sort the material it is intended to sort

- The City currently has a dual-eject optical sorter programmed to target PET as the first eject, and mixed plastics and polycoat as the second eject. The optical sorter is required to recognize 75% of the material passed through the machine. This overburdens the optical sorter and results in lower efficiency rates for mixed plastics on the second eject.
- The optical sorter has an efficiency rate of 79% for PET containers, 63% for mixed plastics and 88% for cartons. Additionally, the optical sorter incorrectly recognizes 43% of material passed through the machine as mixed plastics and/or polycoat (purity rate of 57%). PET containers make up approximately 13% of the composition within the mixed plastics bunker, while HDPE makes up approximately 11% of the composition.
- A secondary objective of this project was to evaluate the benefit of reprocessing post-optical residue at the City's MRF. At the beginning of this study, the City was baling and transferring post-optical residue to be processed at a secondary facility at a transportation cost incurred by the City. It was identified that high value materials such as PET and aluminum cans made up approximately 25% of this stream. The Project Team identified that City would realize a reduction in their operating costs of $53,000 under its current operation if the materials were to be reprocessed and mined for valuable materials like PET and aluminum cans.

Recommendations

The Project Team has provided the City with three recommendations to address the issues identified in this report:

- **Recommendation #1a: Removing Film from the Curbside Program** – Plastic film posed a significant burden on manual sort staff and equipment to effectively remove these materials. It's recommended that the City consider the overall collection and sorting costs for plastic film and then evaluate if removing plastic film from the curbside program can result in decreased overall costs while achieving higher diversion. A high-level analysis estimates the collection of plastic film through alternative methods could result in cost savings to the City of $145,000 to $315,000 annually. A detailed study would need to be conducted to evaluate the costs required to implement such a program change.
- **Recommendation #1b: Film Clean-Up** – Recognizing that evaluating Recommendation #1a will require time to implement, the Project Team proposed an interim solution of reconfiguring the existing film grabber to return it to the stated manufacturer's specs (30% efficiency rate). Any improvement in the reduction of film required to be sorted manually would yield a net benefit to sorting operations further downstream. A cost estimate was not provided for reconfiguring the equipment as the City is currently in discussion with its service provider.
- **Recommendation #2: Repurpose Existing Optical Sorter and Add Second Optical Sorter** –The Project Team proposed the addition of a second optical sorter to improve sorting efficiencies and increase capture rates for all materials that pass the optical sorter machines. Three equipment suppliers were contacted to provide equipment configurations and costs estimates for adding a second optical sorter. Suggested configurations varied between suppliers including the equipment required (single vs. dual-eject optical sorters), the materials to be targeted by the new and existing optical sorters (different combinations of HDPE, film, fibre, PET, mixed plastics, and cartons), and the placement of the new optical sorter. Suggested configurations were aimed at either reducing burden depths before the eddy current by allowing for manual sorters to be repurposed or removal of large volume materials (PET to be removed by the new optical sorter). Cost to install and commission a second optical sorter and reconfigure the existing optical sorter ranges between $1.2M and $1.5M in investment costs. Estimated payback periods ranged from 3.5 to 10 years based on the expected increase in efficiency rates.
- **Recommendation #3: Install Return Conveyor System to Reprocess Post-Optical Residue** – A third recommendation was made by the Project Team in the event the City was unable to implement recommendations #1 or #2. As there is approximately 25% of high value materials (PET and aluminum containers) within the post-optical residue and the revenue to reprocess these materials in the Hamilton

MRF is greater than the sorting cost; the Project Team proposed three considerations to reprocess these materials in-house:

- Post-optical residue is reintroduced to the front-end via conveyors to minimize manual handling (e.g. bobcats, front end loader); however this poses some logistical challenges and is the most expensive option ($250,000 - $300,000). Estimated payback period would be 6.0 years.
- Residue from normal operations (first pass) would be bunkered until sufficient volumes for a dedicated run are accumulated. These materials would then be reintroduced manually via loaders. This consideration is manually intensive and will likely require the City to negotiate a cost with its service provider.
- Replace the residue outfeed conveyor with a longer (possibly inclined if necessary) conveyor to feed directly to a storage area on the floor. These materials would then be reintroduced to the system manually by loaders. The estimated cost would be $150,000 with a payback of 3.2 years.

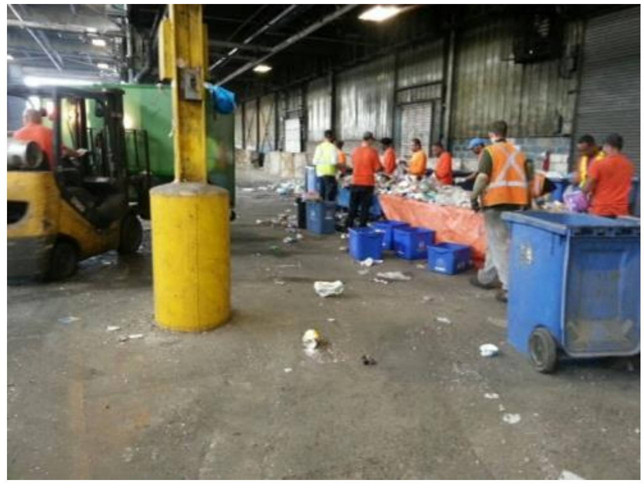
Next Steps

This report is being reviewed by the City of Hamilton and the CIF to determine which of the recommendations can be pursued given individual priorities and budget availability. The Project Team has proposed recommendations can achieve the best results for the City and can be implemented individually.

2. Objectives and Background

2.1. Project Objectives

The City of Hamilton (City) and the Continuous Improvement Fund (CIF) commissioned this study to evaluate the performance of the container line in the City's dual-stream material recycling facility (MRF). Additionally, this project was initially intended to evaluate the performance of the glass clean-up system, and had been modified at the start of the project to also assess the extent to which the balance of the container line can achieve optimal performance. This study evaluated the current efficiency and effectiveness of the container line and provides options to improve the overall effectiveness of the City's sorting operations. In order to provide improvement options, detailed on-site and off-site analyses were undertaken. On-site evaluations included an audit of the container line equipment and material flow, as well as a visual assessment to determine the capture of targeted materials and composition of the residue stream. Off-site analysis involved compilation of the data collected through the audit and a maintenance record review in order to determine the performance baseline of the system. With performance baselines established, cost and improvement options to enhance the efficiency and effectiveness of the container line could be developed.



2.2. Background

The City of Hamilton MRF, owned by the municipality and operated by Canada Fibers Ltd., is a dual stream facility that processes on average 45,000 tonnes of recyclable materials annually. Residents are provided with a blue box bin in which to set out recyclable containers. They can also set out recyclable containers in clear or translucent plastic bags if they do not have enough bins or space in their bins. Film plastics are collected in the program and sorted in the containers stream at the MRF. In 2013, the City of Hamilton invested $1.9M to upgrade the front-end of their container line through the installation of a new drum feeder, glass clean up system (fines screen, ORSE screen, eddy current), and a bag breaker. These changes improved system efficiencies and material revenues by allowing sort staff to efficiently open sealed bags of recyclables, and improve the commodity value for glass, a material which has historically been difficult and expensive to manage.

2.3. Description of Existing System

A drawing of the MRF container line is provided in **Appendix I** and a process flow diagram for the line is provided in **Figure 1**. This section generally discusses material flow and handling of containers through manual and automated means.

Containers collected via the curbside program are received on the tip floor prior to being loaded via a front-end loader to a bunker belt with drum feeder. The drum feeder, with a rated capacity of 12 tonnes per hour (TPH) feeds material to an inclined conveyor to the fines screen. The fines screen segregates glass and other materials 2.4 inches or less in size from the balance of the container stream. Materials that fall through the screen are fed through an ORSE (organic separator) screen which cleans the glass by removing light-weight materials such as paper and plastic. The light-weight materials are then fed to an eddy current separator equipped with a magnetized belt that separates aluminum and steel can lids. Aluminum cans drop through an inlet hopper to an air supply injector system (not shown in above diagram), which transfers aluminum cans directly to the aluminum bunker. Steel lids are captured by the magnet and released at the bottom of the belt into a small cage. The remaining light weight material, mostly plastics, is a residue stream that is disposed.

The balance of the container stream that is not transferred to the glass processing system is fed to an elevated sorting platform where two quality control (QC) sorters remove large oversized plastics and residue (large items not in the program) and HDPE bottles. In addition, these sorters remove bagged recyclables and place them on a conveyor belt to the bag opener. The bag opener is designed to rip open bagged recyclables fed via conveyor back to the bunker belt/drum feeder for reintroduction to the container line.

Remaining material feeds horizontally into a mechanical film grabber. Film captured by the film grabber is intended to be snagged and lifted from the belt by the grabber to a vacuum hood, which is supposed to air convey it to a storage bunker.

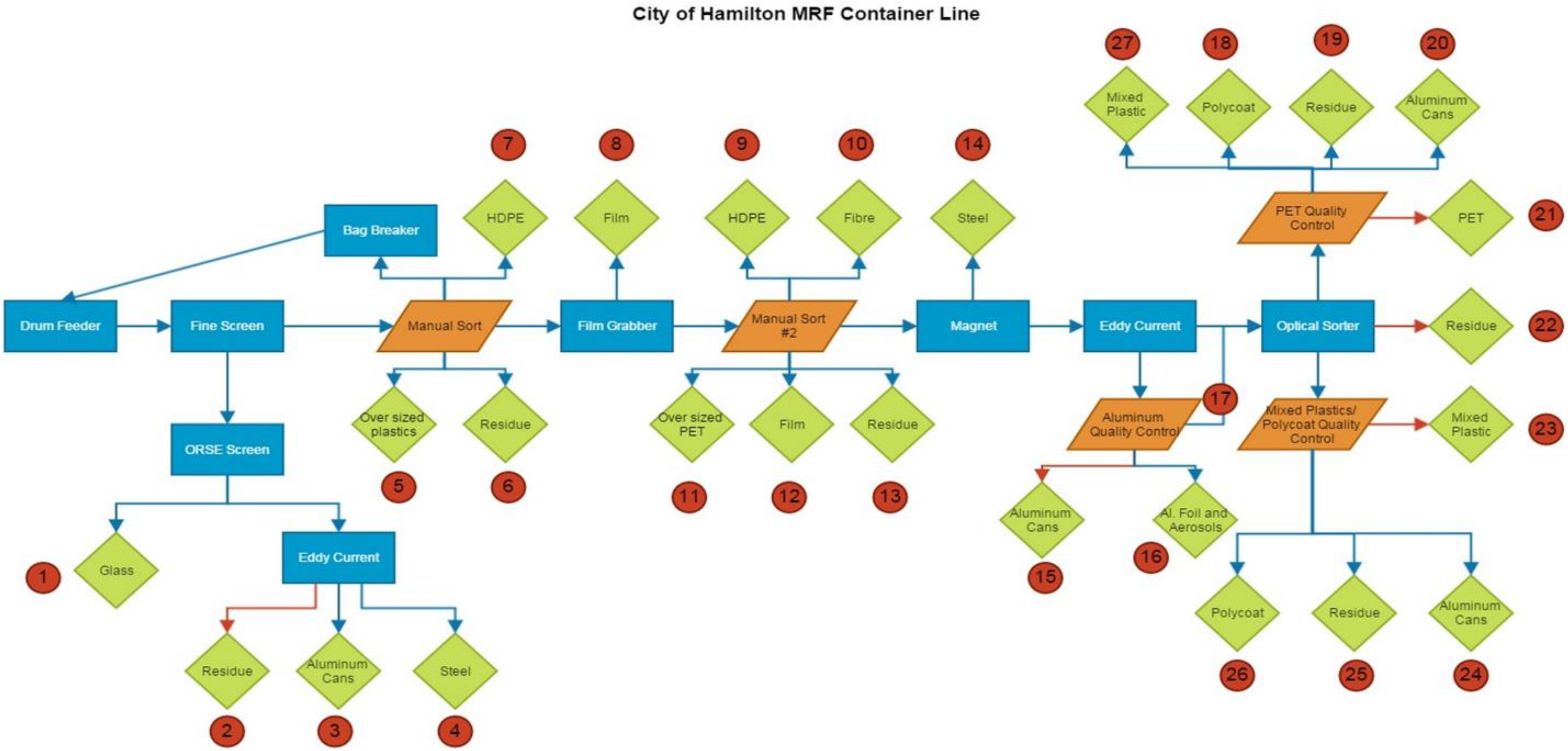
Remaining materials are fed onto a second manual sorting conveyor belt where seven (7) to eight (8) sorters positively sort HDPE, oversized PET (15 litre water bottles), mixed paper, and residue. Film is also sorted at this station and fed into vacuum hoods located above the conveyor. The film in the bunker is removed as necessary via a skid-steer and periodically baled as necessary.

Ferrous cans are then removed by an overhead magnet while non-ferrous materials continue downstream. Next, aluminum cans and aluminum foil are separated by an eddy current. There is an aluminum QA/QC sort after the eddy current to separate aluminum beverage cans from aluminum food cans, foil and aerosols.

The remaining material then passes through a two valve TiTech Polysort Optical Sorting System. The optical sorter separates PET onto one line and separates mixed plastics and polycoat on to another line. The remaining materials are considered residue and go directly into the post-optical residue bunker. One QC sorter is stationed on the PET ejection line and two QC sorters on the mixed plastic/polycoat ejection lines. The QC staff person on the PET line actively removes non-PET contaminants (mixed plastic, polycoat, residue and aluminum cans) from the PET stream and places them into individual bunkers or storage bags from the line. Similarly, the QC staff person on the mixed plastic/polycoat lines positively sorts polycoat into a bunker, and removes remaining contaminants (residue and aluminum) and places them into storage bags. Live-bottom storage bunkers below store these materials until they are ready to be baled.

Figure 1: Process Flow Diagram of the Container Line

In the process flow diagram above:



- Blue arrows indicate flow of materials
- Red arrows indicate negative sorts of materials
- Blue rectangles indicate sorting equipment
- Orange indicates a manual sorting station or manual quality control station
- Green indicates commodity/material bunkers
- Numbers indicate the project data collection points

2.4. Limitations of Results

The following limitations should be considered when interpreting the results of this review:

- **Accuracy of Data:** No investigation was conducted as to the completeness or accuracy of statements made or data obtained. Information on the City of Hamilton MRF Container line was limited to data available from publically available sources (e.g., annual reports, studies, websites, etc.) as well as information willingly disclosed by City of Hamilton representatives.
- **Unaudited Information:** The data provided in this report has not been audited or otherwise verified. There have not been any independent audit activities performed or verification of the information contained in any of the materials or statements provided by the City of Hamilton under consideration.

3. Methodology

At the beginning of this study, the Project Team conducted a tour of the City of Hamilton MRF to observe normal sorting operations and document the flow of materials. During this tour, the Project Team also identified data collection points throughout the sorting operations which were used to conduct the analysis outlined below **Figure 1**. Following the completion of the MRF tour, the Project Team worked with the MRF staff to conduct a controlled test to represent normal sorting operations. As part of the controlled test, all bunkers were emptied and conveyor belts cleared to allow the team to conduct the audits without contending with previously sorted material **Figure 2**. Additionally, tarpaulins were placed in locations where fines are present (e.g. glass bunker) and quality control return chutes were bagged to ensure material flow and sorting efficiency could be accurately tracked.

Figure 2: Material Flow Procedure and Sampling Approach

Also, with the assistance of MRF staff, the project team obtained samples from the container line tip floor totaling 1,744 kg, or enough material for approximate ten minutes of run time at normal processing rates. This material was set aside from the rest of the container line tip floor and would be introduced at the beginning of the test. Manual sorters were instructed to follow regular sorting procedures during the test. Auditors were also positioned at key locations to observe the flow during the tests at the bag breaker, eddy current after the ORSE screen and film grabber as materials handled at these points could not be separated from materials sorted at different points. At the conclusion of the test, all equipment was stopped and bunkers emptied and brought to a staging area to be sorted. Materials at each data point were sorted into the categories identified in **Table 1**.

Table 1: List of material categories sorted during bunker audits

Commodity	Material Category
Paper Packaging	Gable top cartons
	Aseptic cartons
	Paper cups
	Ice cream containers
	Composite cans
	Other laminated packaging
Plastics	#1 PET bottles, jugs and jars
	#1 PET thermoforms
	#2 HDPE bottles, jugs and jars
	#3 PVC bottles and jars
	LDPE/HDPE film
	#4, #5, #6, and #7 rigid plastic packaging
	#6 Expanded polystyrene
	Plastic laminates
	Large HDPE & PP pails and lids
	Other plastics - non-packaging/durable goods
Metals	Aluminum food and beverage cans
	Aluminum foil, trays and aerosols
	Steel and other metals food and beverage cans
	Steel aerosols containers
Glass	Glass < 3/8" in size
	Glass > 3/8" in size
Other	Other recyclables (fibres)
	Other non-recyclables

Manufacturers' performance specifications and maintenance records were gathered to be used as part of the equipment assessment. Manuals were provided by the equipment supplier (Van Dyk Baler). The combination of the material flow mapping, the results from the audits, and the equipment expected efficiency rating have provided the basis for the following analysis.

4. Observations and Results

4.1. Tip Floor Composition

For the purposes of this study, the tip floor composition was determined after conducting the material flow study. The cumulative weight of each material collected during the material flow study represents the total weight of the material introduced into the system (taken from the tip floor). The results of the tip floor composition are shown in **Table 2**.

Table 2: Processed material composition (weight based) results and cumulative average

Commodity	Material Category	Composition (%)
Paper Packaging	Gable top cartons	2.0%
	Aseptic cartons	0.5%
	Paper cups	0.6%
	Ice cream containers	0.1%
	Composite cans	0.2%
	Other laminated packaging	0.1%
Plastics	#1 PET bottles, jugs and jars	14.8%
	#1 PET thermoforms	5.2%
	#2 HDPE bottles, jugs and jars	7.0%
	#3 PVC bottles and jars	0.0%
	LDPE/HDPE film	7.8%
	#4, #5, #6, and #7 rigid plastic packaging	9.0%
	#6 Expanded polystyrene	1.3%
	Plastic laminates	1.3%
	Large HDPE & PP pails and lids	0.9%
	Other plastics - non-packaging/durable goods	1.0%
Metals	Aluminum food and beverage cans	4.4%
	Aluminum foil, trays and aerosols	0.6%
	Steel and other metals food and beverage cans	8.9%
	Steel aerosols containers	0.5%
Glass	Glass < 3/8" in size	6.9%
	Glass > 3/8" in size	14.9%
Other	Other recyclables (fibres)	3.4%
	Other non-recyclables	8.4%
TOTAL		**100%**

This composition was compared to previous audits[2] conducted by the City of Hamilton and appeared to be consistent with these audits.

4.2. Efficiency and Purity Rates

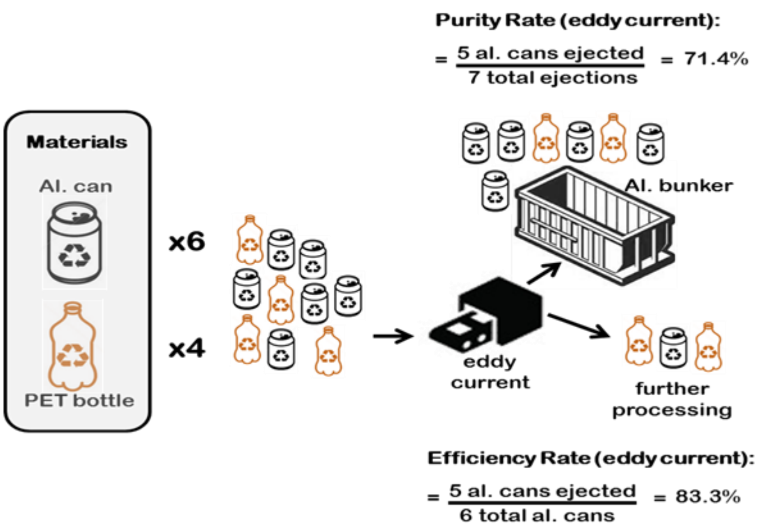
For each piece of equipment, the project team identified the expected efficiency rate based on manufacturer's

[2] The City of Hamilton has contracted with Golder Associates to conduct several inbound audits throughout the year. The City provided audit results from Oct. 2013, Dec. 2013, Mar. 2014, Apr. 2014, May 2014 and Aug. 2014.

specification and evaluated it against the actual efficiency rate. The efficiency rate is defined as the ability for each piece of equipment to correctly identify and sort the material it is intended to sort. For example, the eddy current is intended to target non-ferrous materials (typically aluminum). Therefore, the efficiency rate of the eddy current is calculated by dividing the total aluminum found in the aluminum bunker by the sum of all aluminum containers found within the bunker and all subsequent bunkers downstream. It is important to note, the efficiency rate is not calculated by dividing the total target materials captured by the total introduced to the system as there are some material losses prior to reaching the appropriate sorting station. Following the steel example, material lost before even reaching the magnet is not considered in the efficiency calculation as the magnet never had the opportunity to sort that material.

In addition to calculating equipment efficiency rates, **Table 3** also provides a summary on purity rates. Purity rates are defined as the amount of targeted materials sorted/ejected divided by the total amount of materials sorted/ejected by the equipment. For example, the purity rate for the eddy current is the total number of aluminum containers ejected by the eddy current divided by the total number of containers (including non-aluminum materials) ejected by the eddy current. **Figure 3** illustrates how the efficiency and purity rates are calculated.

Figure 3: Illustration of Efficiency and Purity Rate Calculation



The importance of purity rates is shown in the bunker compositions. Equipment with sufficiently high purity rates to meet market specifications do not need further QA/QC before being conveyed to a bunker in preparation for baling and sale; materials whose purity as produced by the equipment that does not meet market specifications requires additional quality control prior to being sent to market.

Table 3: Expected and actual efficiency and purity rates of sorting equipment

Equipment	Description/Purpose	Expected Efficiency (%)	Actual Efficiency (%)	Actual Purity (%)
Fine Screen	Separates glass from inbound material before it reaches main sort line	N/A[3]	98%	85%
ORSE Screen	Separates glass from all other light-weight materials	98%		
Glass			100%	92%
Other non-glass materials			56%	100%
Eddy Current (Aluminum Station 3)	Removes non-ferrous, aluminum containers from the glass/fines	98%	71%	100%
Bag Breaker	Rips bags of sealed recyclables to be reintroduced into the sort line	95% of all bags		
Large bags			99%	N/A
Small bags			55%	N/A
Film Grabber	Removes plastic film from main sort line	30%	0%	0%
Magnet (steel)	Removes ferrous metals from main sort line	98%		
Food and beverage cans			98%	83%
Aerosols containers			100%	
Eddy Current (Aluminum Station 15/16)	Removes non-ferrous, aluminum containers from the sort line	98%		
Food and beverage cans			86%	88%
Foil, trays and aerosols			68%	
Optical Sorter	Dual-eject optical sorter; first eject on PET containers; second eject on mixed plastics & polycoat	90-98%		
#1 PET bottles, jugs and jars			77%	91%
#1 PET thermoforms			84%	
Gable top cartons			89%	57%
Aseptic cartons			85%	
Ice cream containers			79%	
#3 PVC bottles and jars			39%	
#4, #5, #6, and #7 rigid plastic packaging			63%	

The project team also measured the efficiency of the manual sort stations and manual quality control stations throughout the container line. **Table 4** illustrates the efficiency of each station to capture or remove targeted materials.

[3] Expected efficiency rate was not provided.

Table 4: Efficiency rates of manual sorters to capture targeted materials

Sort Station/Target Material	Description	Efficiency Rate
Manual Sort #1	Positive manual sorts on targeted materials	
Oversized plastics (5)		N/A[4]
Residue (6)		1.4%
HDPE (7 & 9)		81.3%
Manual Sort #2	Positive manual sorts on targeted materials	
Fibre (10)		16.9%
Oversized PET (11)		100%
Film (12)		55.8%
Residue (13)		33.7%
Manual Sort Aluminum Quality Control		
Aluminum foil, trays and aerosols (16)	Positive manual sort on "B" grade aluminum	97.7%
Anything but aluminum (17)	Positive manual sort on non-aluminum materials	55.2%
Manual Sort Optical Sorter PET Quality Control	Positive manual sorts on targeted materials	
Polycoat (18)		
Gable top cartons		55.0%
Aseptic cartons		31.1%
Ice cream containers		66.5%
Residue (19)		24.8%
Aluminum cans (20)		41.9%
Mixed Plastics (27)		17.7%
Manual Sort Optical Sorter Mixed Plastics/Polycoat Quality Control	Positive manual sorts on targeted materials	
Aluminum cans (24)		21.8%
Residue (25)		35.9%
Polycoat (26)		
Gable top cartons		91.9%
Aseptic cartons		61.9%
Ice cream containers		56.0%

While all detailed results of the MRF flow analysis are provided in the tables above, several observations of critical note were made regarding existing equipment and material flow through the MRF in **Table 5**.

[4] Oversized Plastics that were non-packaging materials were grouped with all other non-packaging materials. Therefore, an efficiency rate could not be effectively calculated.

Table 5: Equipment observations during tests

Equipment/ Sort Area	Observations
Bag Breaker	- Effective at ripping larger bags[5] but ineffective at opening smaller bags. Smaller bags do not always make contact with the two sets of ripping fingers and only 55% these smaller bags are opened. - Unopened bags appear to go in a continuous circular loop and can end up repeatedly picked from the sorting line by staff until they are ripped open by the bag breaker or the drum feeder (due to repeated passes).
Film Grabber	- Appears to be misconfigured (too high off the belt's surface) to effectively capture film. In effect, the film grabber "hovers" over the belts, spinning in dead space. - Suction hood at the apex of the film grabber mechanism designed to remove and transport film to the appropriate bunker is ineffective. Of the limited amount of film captured by the grabber during observations, all of it was dropped back onto the line. - One of the four sets of sorting "fingers" on the grabber – designed to drop by gravity at the bottom of the drum to capture film - appears to be stuck in place.
Manual Sorting (main sorting stations)	- Conveyor belt following the film grabber stops for seemingly random intervals of time. Material from the pre-sort area is still sent to this belt and stoppage creates a pile of material. Although it was indicated this isn't a typical event, the burden depth is adversely affected until backlog is cleared.
Optical Sorter	- QC sorters after optical sorter appears to be overwhelmed with the amount of residue and film being ejected on the PET and mixed plastics/polycoat lines. A high incidence of film is sent, erroneously, towards the mixed plastic/polycoat bunker.
Optical Residue	- Only 30% residue and a significant amount of PET and mixed plastics, some aluminum.
Mixed Plastics	- Significant amounts of HDPE and PET are found within the mixed plastic bunker.
Film Flow Through MRF	- While film capture is generally good and ending up in the film bunker there are still significant amounts of film in the residue bunkers, 27% (from stations 6 and 13) and 6% (optical sorter residue) of their composition by weight. There are also high incidents of film in mixed plastics, most commodity bunkers have some film in minor amounts.

4.2.1. Evaluation of the Glass Clean Up System

The Project Team also evaluated the effectiveness of the newly installed glass clean-up system as it was installed to improve the marketability of Hamilton's mixed broken glass. The glass clean-up system is the first piece of sorting equipment following the drum feeder, and consists of a fine screen, ORSE Screen and an eddy current. As shown in **Table 3**, the fine screen is able to remove 98% of the glass entering the container line. Of the 98% of glass captured by the fine screen, the ORSE is able to capture 100% of the glass and direct it to the glass bunker. However, the ORSE screen also incorrectly sends approximately 8% of non-glass materials (ORSE Screen has a 92% purity rate) to the glass bunker. The 8% of non-glass materials consists largely of mixed plastics (primarily bottle caps) and residual materials. The combination of the fine screen and ORSE Screen appear to be effective at capturing the vast majority of glass entering the stream and minimizing the residue within the mixed broken glass bunker.

---

[5] For the purposes of this study, any bags larger than grocery bags were classified as large bags.

4.3. Mass Balance

To better understand the flow of materials within the MRF, **Table 6** summarizes how each material is handled throughout the container line. Specifically, it identifies the total amount of materials introduced into the system, the amount lost before reaching the intended sorting station/equipment, the amount captured by the sorting station/equipment, and the amount missed by the sorting station/equipment.

Table 6: Mass Balance of Container Materials

Material	Equipment / Sort Station	Total Weight (kg)	Lost Before Sort Equipment / Station (%)	Captured (%)	Missed (%)
Glass	Fine Screen	377	0%	98%	2%
	ORSE Screen		2%	98%	0%
HDPE	Manual Sort	121	0%	81%	19%
Film	Film grabber	136	1%	0%	99%
	Manual Sort		1%	55%	44%
Steel	Magnet				
Food and beverage cans		154	7%	92%	2%
Aerosol containers		8	1%	99%	0%
Aluminum	Eddy Current				
Food and beverage cans		76	3%	83%	13%
Foil, trays and aerosols		11	7%	63%	30%
PET	Optical Sorter				
#1 PET bottles, jugs and jars		255	6%	72%	21%
#1 PET thermoforms		90	7%	78%	15%
Cartons/Polycoat	Optical Sorter				
Gable top cartons		35	2%	87%	11%
Aseptic cartons		8	5%	81%	14%
Ice cream containers		2	12%	69%	19%
Mixed Plastics	Optical Sorter				
#3 PVC bottles and jars		0.4	13%	34%	53%
#4, #5, #6, and #7 rigid plastic packaging		156	20%	50%	29%

The percent captured is based on the following formula:

[1 – “Lost Before Sort Equipment / Station (%)”] * [“Equipment / Manual Sort Efficiency (%)”]

The sum of “Lost Before Sort Equipment / Station (%)”, “Captured (%)” and “Missed (%)” represents the complete mass balance for each material.

4.4. Material Capture Rates

The following table outlines the capture rates for various materials. Focus is drawn on the commodity grades marketed by the MRF as well as residue bunkers; a detailed table outlining capture rates is provided in **Appendix II.** The capture rates presented for materials are based on where the material *will* end up after the sorting process. This is a combination of the materials correctly sorted by each sorting station or sorting equipment, plus any additional QC sorts to recover missed materials. For example, the capture rate for mixed plastics indicates 43.1% of the available materials in the facility ended up in the mixed plastics bunker. This is a combination of the materials correctly captured by the optical sorter (Mixed Plastic #22) and the missed materials recovered at the PET Quality Control station (Mixed Plastic #26). The remaining 56.9% was distributed in other bunkers or ended up in the residue stream. With regards to material ending up in other bunkers (and not residue), although it is theoretically sold to an end market it may be considered contamination/out throws depending on the commodity and the contract details.

Table 7: Material capture rates

Material Type	Capture Rate (%)
Glass	97.9%
HDPE	81.2%
Film	55.1%
Steel	93.9%
Aluminum food and beverage cans	84.3%
Aluminum foil, trays and aerosols	62.6%
PET	73.1%
Mixed Plastics	43.1%
Cartons	73.6%
Residue	64.0%

The lowest capture rate belongs to mixed plastics at just over 43%. Much of the remaining 57% was found in the optical residue stream (27%) and this result is corroborated by the low sorting efficiency rate of the optical sorter on mixed plastics (approximately 63%).

4.5. Bunker Composition

The following table highlights the composition of all targeted commodity bunkers. Each commodity is baled and sold to an end market with the exception of glass, which is sold loose. Residue is disposed at the City owned landfill.

Table 8: Bunker composition results

	Bunkers										
Commodity	**Glass**	**HDPE**	**Film**	**Steel**	**Al. Prime**	**Al. B-Grade**	**PET**	**Mixed Plastics**	**Cartons**	**Residue (Pre-OS)**	**Residue (Post-OS)**
Glass	**92.0%**	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.3%	3.0%
HDPE	0.0%	**88.5%**	0.2%	0.0%	0.1%	0.0%	0.1%	11.4%	0.0%	0.2%	2.2%
Film	0.0%	0.1%	**85.3%**	0.3%	0.1%	0.0%	1.3%	6.4%	0.1%	27.3%	5.8%
Steel	0.4%	0.0%	2.1%	**83.4%**	0.2%	0.0%	0.4%	0.1%	0.1%	3.4%	0.4%
Al. Food and Bev. Cans	0.0%	0.1%	0.0%	0.3%	**97.0%**	**81.7%**[6]	0.3%	0.9%	0.1%	1.3%	2.6%
Al. Foil and Aerosol	0.0%	0.0%	0.5%	0.0%	0.2%		0.0%	0.0%	0.0%	0.3%	1.2%
PET	0.0%	1.4%	4.7%	1.5%	0.2%	0.4%	**93.9%**	12.5%	0.1%	5.8%	21.1%
Mixed Plastics	3.6%	9.8%	1.2%	0.7%	0.4%	0.0%	1.7%	**51.7%**	1.2%	7.7%	18.9%
Cartons	0.0%	0.0%	0.4%	0.1%	0.1%	0.0%	0.1%	3.6%	**93.2%**	0.3%	2.2%
Residue	4.0%	0.0%	4.6%	13.1%	0.9%	17.9%	1.6%	11.5%	4.0%	**44.4%**	30.0%
Other Recyclables	0.0%	0.0%	1.1%	0.4%	0.9%	0.0%	0.4%	1.9%	0.6%	9.1%	**12.6%**
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

- Aluminum prime, PET, HDPE, film, polycoat, steel and glass bunkers have the lowest amount of contamination.
- Several pots and pans were found in the aluminum B-grade bunker (classified as residue) which decreased the % composition of B-grade aluminum overall.
- The mixed plastics bunker had the lowest purity rate compared to other commodities.
  - The most problematic commodity bunker, mixed plastics had the highest composition of film of all bunkers (excluding film itself).
  - It also contained a relatively high percentage (>10%) of PET and HDPE containers.
  - The bunker also had one of the highest rates of contamination from residue.
- Residual from the optical sorter (post-optical residue) has a fairly high percentage of PET containers and mixed plastics, and a relatively high percentage of aluminum containers.

[6] The City of Hamilton markets two grades of aluminum: Aluminum Prime grade which consists primarily of beverage cans; and an Aluminum B-grade which consists of aluminum food cans, foil and aerosols.

4.6. Existing Equipment Maintenance Assessment

Based on a review of Preventative Maintenance Inspection (PMI) records for a six (6) month period in 2014, it appears that equipment is routinely inspected and that routine preventative maintenance is occurring when issues are identified (e.g. parts are wearing and need replacement). The PMI records addressed major equipment, all conveyors as well as repair/parts replacement records for the following pieces of equipment; the optical sorter, eddy current and the film grabber. Records included but not limited to the replacement of rollers, repairing blocked air valves, and repairing of holes in air pipes.

As identified in **Table 5**, the film grabber is no longer configured to effectively remove plastic film from the container line. Based on discussions with City staff and the equipment supplier, the effectiveness of the film grabber was impacted when the City undertook an upgrade to its front-end in 2013. This was principally due to the current sorting belt, before the film grabber, being shortened and placed horizontally rather than at an incline to the grabber.

5. Areas for Improvement

5.1. Handling of Plastic Film

The effective management of plastic film has posed a challenge to both single-stream and multi-stream MRFs due to its tendency to wrap around other materials and equipment. The City of Hamilton faces similar challenges as based on the audit data collected. The composition of the incoming plastic film ranges from 6-8% by weight which translates to approximately 1,100 tonnes annually or approximately 39,000m^3. In 2007, the City installed a film grabber to mechanically remove plastic film and to improve sorting operations further downstream of the equipment. However, after the front-end upgrade in 2013, the film grabber is effectively operating at a zero (0) efficiency rate and places the full burden of film sorting onto the manual sorters.

Based on the combination of informal interviews with MRF staff, operational observations and data collection during the facility tests the Project Team identified plastic film and flexible packaging as a major concern to sorting operations. The high incidence of these materials in the sorting system impedes the ability of manual and mechanical sort stations to complete their duties as efficiently as possible. Currently, four (4) sorters at the second manual sort station are tasked with pulling film into vacuum hoods. These sorters are only able to capture 55% of the plastic film while the rest progresses further downstream. Additional sorters at the second manual sort station (after the 4 sorters) and QC stations downstream remove film as residue.

In total, plastic film is removed manually by a total of eight (8) sorters at various stages of the sorting process. In addition, the movement of significant volumes of film over the manual sort stations also translates to higher burden depths and burying of commodities relying on manual sorting, the most valuable being HDPE. The removal of plastic film from the curbside program would alleviate issues related to burden depths and also allow for existing sorters to be repurposed to effectively sort other materials.

5.1.1. Financial Impact of Managing Film

As identified above, the City utilizes a combination of mechanical equipment (currently ineffective) and manual sorters to remove plastic film. Four (4) sorters at the second manual station split their duties between pulling film, fibre, and HDPE. Since, the removal of film is largely a manual task, it is challenging for the Project Team to quantify the financial impact of handling plastic film in the program without a detailed activity based costing study. As this is outside the scope of this project, the Project Team has provided some observational comments regarding managing plastic film.

If plastic film were to be removed from the curbside program and transitioned to an alternate method of collection, potential savings could be realized through reduced labour and maintenance costs. In addition, the exclusion of film from the curbside program would allow existing sorters to be repurposed to target other materials such as HDPE, yielding higher capture rates for more valuable materials and greater revenue; or the removal of residual materials to reduce burden depths improve sorting efficiencies further downstream. A high level summary is provided in Section 7.1 for the collection of film through alternate collection methods.

5.2. Missed Capture of HDPE Containers

Currently, the City manually sorts HDPE containers at the first and second manual stations. After these two points, any HDPE remaining on the line either ends up in mixed plastics or Post-Optical Residue. The sorters at these two manual sort stations are also tasked with removing other materials such as residue, fibre, film and oversized containers. The Project Team identified that a significant amount (~20%) of HDPE containers were being missed by the sorters. It was observed that plastic film was directly impacting the sorters ability to capture HDPE containers. The large amounts of plastic film entering the system created challenges for the sorters removing plastic film to also target HDPE containers, residue and other materials. Additionally, the large volumes of plastic film and other materials tended to “bury” the HDPE containers further impairing the sorters ability to capture these materials.

5.2.1. Financial Impact of Missing HDPE Containers

Table 9 provides a summary of the financial impact of the missed capture for HDPE containers.

Table 9: Lost Revenue from Missed HDPE Containers

Material	Amount Available (tonnes)	Current Efficiency Rate (%)	Expected Efficiency Rate (%)	Missed materials (tonnes)	Lost Revenue ($)
HDPE	993	81%	90%	87	$53,164

For the purposes of this analysis, we have assumed an expected efficiency rate of 90% based on the expected efficiency rate of the existing optical sorter.

5.3. Missed Capture of Aluminum Containers

The third issue identified by the Project Team was the amount of aluminum containers missed by the eddy current. The eddy current is currently placed after the glass clean up system, manual sort station and steel magnet, but before the optical sorter. Only 10% of the materials passing through the eddy current is aluminum containers; the vast majority of the materials are plastic containers (>60%). The higher burden depths and volume of materials pose a challenge for the eddy current to effectively remove aluminum cans. Most facilities have an eddy current at the end of the container line which increases the effectiveness of the eddy as burden depths are lower and this increases the ability of the eddy current to repel high value aluminum away from other materials.

5.3.1. Financial Impact of Missed Aluminum Containers

The removal of higher volume materials (plastics) before the eddy current could potentially see an increase in the capture of aluminum containers. Currently, the eddy is operating at an 86% for aluminum food and beverage cans and 68% for aluminum foil and aerosols. Based on manufacturer’s specs, the eddy currents should be able to achieve a 98% efficiency rate. **Table 10** summarizes the financial impact for achieving the current efficiency rates compared to the manufactures’ specs.

Table 10: Lost Revenue for Missed Aluminum Containers

Material	Amount Available (tonnes)	Current Efficiency Rates (%)	Expected Capture Rate (%)	Missed materials (tonnes)	Lost Revenue ($)
Aluminum Prime	626	86%	98%	75	$131,167
Aluminum B-Grade	87	68%	98%	26	$29,531
TOTAL	**713**			**101**	**$160,698**

Note: The analysis is intended to isolate the efficiency of the equipment alone and doesn't take into consideration materials lost before the eddy current as identified in Section 4.3.

5.4. Optical Sorter Configuration

The Project Team also identified lower than expected efficiency rates for the materials targeted by the optical sorter. Currently, the City has a dual eject optical sorter targeting PET, mixed plastics and polycoat. After following up with the equipment supplier, as well as obtaining comments from industry experts, two reasons were provided to explain the reduced efficiency for the equipment:

1. **Optical sorter is over-worked:** Optical sorters in general are able to achieve a higher efficiency rate when programmed to target 60% or less of the materials that passes through it. The current configuration of the dual-eject optical sorter (first eject on PET; second on mixed plastics/polycoat) requires it to sort ~75% of the material that passes through. An overworked optical sorter can result in one of two issues: 1) the air compressor doesn't have the capability to effectively eject materials into the appropriate bunker, or; 2) as materials are continuously being ejected, there is a greater likelihood of materials deflecting in mid-air and landing in the wrong bunker.
2. **Efficiency rates are lower for materials targeted by the second eject:** Dual-eject optical sorters are not recommended for most MRFs as the efficiency rates drop dramatically for materials ejected by the second valve (in Hamilton's case, mixed plastics and polycoat). Manufacturers indicate the efficiency rates on the second eject can be about 1/3 less than those materials on the first eject. This issue is further compounded as the optical sorter is overworked as identified above.

5.4.1. Financial Impact of Missed PET, Mixed Plastics and Polycoat

Table 11 summarizes the financial impacts of the optical sorter's inability to achieve the expected manufacturer's efficiency rates. The analysis below assumes all of the available materials pass through the optical.

Table 11: Lost Revenue for Missed PET, Mixed Plastics and Polycoat

Material	Amount Available (tonnes)	Current Efficiency Rates (%)	Expected Capture Rate (%)	Missed materials (tonnes)	Lost Revenue ($)
PET	2,842	79%[7]	90%	317	$127,811
Mixed Plastics	1,406	63%[8]	90%	379	$20,613
Cartons	376	88%[9]	90%	9	$935
TOTAL	**4,624**			**705**	**$149,359**

[7] Weighted efficiency rate for PET Bottles and PET Thermoforms.
[8] Weighted efficiency rates for #3 PVC containers and #4, #5, #6, and #7 rigid plastic packaging.
[9] Weighted efficiency rates for gable top cartons, aseptic cartons, and ice cream containers.

6. Financial Analysis

6.1. Financial Impacts of Missed Materials

In addition to a flow model, the project team also developed a financial model to highlight the missed revenue opportunity of improperly sorted or missed materials **Table 12**. The following analysis used historical inbound/outbound tonnage data and average commodity pricing (Sept 2013 to Aug 2014).

Using the tip floor composition and the average commodity prices provided by the City, it was estimated the City could obtain an additional $700,000 annually if all of the materials entering the facility were correctly sorted to their appropriate grades. Although, it is not realistic to expect a 100% capture for all materials, it is evident that high value materials such as PET, HDPE, and Aluminum Prime could achieve higher capture rates.

Table 12: Inbound/Outbound revenue generation and potential estimates

Materials	Available (tonnes)	Capture Rates (%)	Amount Captured (tonnes)	Expected Revenue ($)	Actual Revenue ($)	Net Benefit (Loss) ($)
Glass	3,099.7	97.9%	3,033.7	-$85,396	-$83,579	$1,817
HDPE	992.5	81.2%	806.3	$606,551	$492,733	-$113,819
Film	1,115.6	55.1%	615.1	$0	$0	$0
Steel	1,371.8	93.9%	1,287.8	$423,337	$397,414	-$25,924
Aluminum Prime	626.3	84.3%	527.8	$1,095,678	$923,375	-$172,302
Aluminum B-Grade	86.7	62.6%	54.3	$98,489	$61,683	-$36,807
PET	2,842.2	73.1%	2,077.6	$1,124,653	$822,126	-$302,527
Mixed Plastics	1,406.1	43.1%	606.4	$76,519	$33,002	-$43,517
Cartons	375.6	73.6%	276.6	$40,478	$29,806	-$10,671
TOTAL	**11,916.6**	**77.9%**	**9,285.8**	**$3,380,309**	**$2,676,558**	**-$703,751**

The three highest commodity materials (aluminum, PET and HDPE) are currently being missed and ending up in either mixed plastics or post-optical residue. A total of 9% of the inbound aluminum prime and 15% of the inbound PET ends up in post-optical residue; only 4% of the inbound HDPE is found within post-optical residue. Additionally, 5% of the inbound PET and 13% of the HDPE is found within mixed plastics.

6.2. Value of Optical Sorter Residue

One of the secondary objectives of the project was to determine the value of post optical sorting residue to provide insight into the loss of revenue due to the above noted equipment/sorting inefficiencies. Depending on the loss of revenue, the project team also evaluated whether the optical sorter residue could be reprocessed in house. At the beginning of this study, the City was bailing and transferring post-optical residue to a secondary facility for further reprocessing at a cost to the City. The City has since stopped shipping post-optical residue to be further processed. However, during the time period of Sept 2013 to Aug 2014, the City of Hamilton shipped 1,302 tonnes of optical residue for further reprocessing. Using this figure, **Table 13** shows reasonable revenue[10] that can be achieved by reprocessing post-optical residue.

[10] Reasonable revenue is calculated based on current capture rates of materials. It does not take into consideration the revenue for materials that end up in the wrong commodities (for example, PET found in mixed plastics).

Table 13: Composition and reasonable revenue for reprocessing post-optical residue

Commodity	Total Tonnes	Composition (%)	Max. Revenue[11] ($/tonne)	Capture Rates (%)	Total Reasonable Tonnes	Reasonable Revenue ($)
Glass	39	3.0%	-$869	98%	39	-$850
HDPE	29	2.2%	$16,426	81%	23	$13,344
Film	75	5.8%	$2,265	55%	42	$1,249
Steel	5	0.4%	$1,672	94%	5	$1,570
Aluminum food and beverage cans	34	2.6%	$62,549	84%	29	$52,713
Aluminum foil, trays and aerosols	16	1.2%	$14,814	63%	10	$9,278
PET	274	21.1%	$88,660	73%	201	$64,811
Mixed Plastics	246	18.9%	$11,545	43%	106	$4,979
Cartons	28	2.2%	$2,366	74%	21	$1,742
Residue[12]	391	30.0%	$0	64%	250	$0
Other Recyclables[13]	164	12.6%	N/A	17%	N/A	N/A
TOTAL	**1,302**	**100.0%**	**$199,428**		**725**	**$148,835**
$ per tonne			**$153**			

Note: The Total Reasonable Tonnes does not take into consideration materials ending up in the wrong bunkers. Therefore, the Total Reasonable Tonnes does not add up to the Total Tonnes.

As shown in **Table 13** actual residue only accounts for 30% of the post-optical residue. A significant percentage of the composition is made up of recyclable materials that can achieve high commodity prices (notably PET and aluminum). If the City were to reprocess the post-optical residue in-house, it could achieve a profit of approximately $53,000 as opposed to paying for it to be reprocessed off-site at a cost to the City. **Table 14** summarizes the cost-benefit analysis for reprocessing post-optical residue in-house.

11 Max revenue is based on 100% of all materials within the post-optical residue.
12 The City does not pay disposal costs for residue.
13 Other recyclables include fibre products such as newspaper, cardboard, etc. which is captured and returned to the fibre line. The Project Team didn't determine the reasonable revenue that could be achieved by the capture of these materials.

Table 14: Cost-benefit analysis for reprocessing post-optical residue

Reasonable Costs for Reprocessing	
Total tonnes	1,302
Total tonnes less residue[14]	1,052
Sorting cost ($/tonne)	*$91*[15]
Total sorting cost ($)	$96,000
Reasonable revenue ($)	$149,000
Result of reprocessing in-house (cost) ($)	**$53,000**

The City is faced with one of three options:

1. Landfill post-optical residue – This option would results in lower costs compared to reprocessing at a secondary facility as they are able to landfill materials for free; however, it would also reduce the City's overall diversion rate.
2. Continue shipping post-optical residue to be reprocessed – This would assist the City to achieve its diversion goals; however, this would be the greatest cost option as there is a net benefit of $53,000 to reprocess these materials in house.
3. Reprocess post-optical residue in-house – This option would not only allow the City to increase its diversion rate but is also the lowest cost option as it provides a net benefit to the City. This is the recommended option and further details to reprocess these materials in-house are provided in Section 7.4

Implementing the recommendations of this report is expected to increase the capture rates of certain materials and therefore would diminish the benefit of reprocessing post-optical residue in-house. Upon implementing the recommendations within this report, it is suggested that the City conduct additional audits to determine the composition of the post-optical residue to determine if it is still beneficial to reprocess it in-house.

7. Recommended Improvements and Implementation Plan

7.1. Recommendation #1a: Removing Film from the Curbside Program

The Project Team recommends that the City of Hamilton strongly consider the collection of plastic film through alternative methods (depot collection, return to retail, etc.). This recommendation is based on qualitative data collected during this study, visual observations, and industry reports on the subject as identified in Section 5.1.

In addition, collecting film through alternative methods instead of curbside collection, not only reduces the sorting cost to manage film within a MRF, but also increases the commodity value for sorted film. **Table 15** provides a high level summary of removing plastic film from the program.

[14] The City does not pay a sorting cost on residue materials. The Total Sorting Cost is determined on the total tonnes (1,302 tonnes) less the tonnes of residue (250 tonnes) multiplied by the Sorting Cost rate.
[15] 2012 WDO Datacall (latest publically available data). This figure includes the cost to dispose residual materials.

Table 15: Comparison of the different methods to handle (collect and process) plastic film

Total Film Collected (tonnes)	1,116	
	($/tonne)[16]	**($)**
Status Quo: Curbside Collection and Processing Cost	$357	$398,000
Alternative Option #1: Film collected via depots/return centres and baled on site		
Return Centre Collection Cost (on-site baling)	$225	$251,000
Net Cost (benefit) for Collecting through Return Centre (on-site baling)		($147,000)
Alternative Option #2: Film collected via depots/return centres without baling, and back hauled		
Return Centre Collection Cost (loose with back haul)	$75	$84,000
Net Cost (benefit) for Collecting through Return Centre (loose with back haul)		($315,000)

The Project Team recognizes the significant promotional and educational effort required to undertake this program change. Additionally, the implementation of this change may also affect neighbouring municipalities interested in being part of a regional program with the City of Hamilton.

It is recommended that the City conduct a detailed cost benefit for removing plastic film from the curbside program and collect it via depots or return centres. This study should be designed using local conditions in Hamilton and should also consider the cost to promote a change in behaviour. Promoting a change would require significant effort from both the City and its residents. While the detailed cost estimate was not part of the scope of work outlined as part of this study, other savings can be expected in the form of reduced maintenance costs, reduced sorting costs and improved revenue for other commodities as contamination rates are expected to be lower.

7.2. Recommendation #1b: Film Clean-Up

Recognizing that the above recommendation will take time to implement, the Project Team recommends the reconfiguration of the existing film grabber to return it to operational level prior to the front-end upgrade. During the course of this study, the City has indicated it has entered into discussions with its service provider to reconfigure the existing film grabber. As these are on-going discussions between the City and its service provider, the Project Team has **not** provided an estimate on the cost to reconfigure the system.

7.3. Recommendation #2: Repurpose Existing Optical Sorter and Add Second Optical Sorter

In this recommendation, a second optical sorter should be considered which should alleviate some of the manual sorting burdens at the front-end of the system, and enable sorters to be repurposed to remove additional film and residue. The Project Team contacted four equipment suppliers and requested a price estimate to install a second optical sorter to improve current capture rates. Each of the equipment suppliers were tasked with developing the ideal configuration and to propose equipment that would maximize current capture rates. The

[16] Analysis of Flexible Film Packaging Plastic Packaging Diversion Systems, 2013. http://www.plastics.ca/_files/file.php?fileid=itemyTWHUVJURT&filename=file_Final_Flexible_Film_Report.pdf

Project Team received responses from three out of the four equipment suppliers who provided high level estimates for equipment, delivery, installation, and contingency. It should be noted this process was not designed to be a formal tender process and therefore the costs provided are only high-level estimates. Based on the responses provided, it appeared there was consensus among the three suppliers to install a second single-eject instead of dual-eject optical sorter, ahead of the existing optical sorter; however, the material to be targeted with the new optical varied between the three options. The range of options varied between suppliers and are listed below:

- New single-eject optical to target HDPE.
- New single-eject optical to target HDPE, fibre, and film. Manual sorters to remove HDPE containers
- New single-eject optical to target PET; Existing dual-eject optical to be reprogrammed to target HDPE and mixed plastics/polycoat.

The proposed solutions should reduce manual sorting requirements at the front end for HDPE which will positively impact the payback period for this equipment. The challenge is that a substantial realignment of equipment at the back end of the line will be necessary to support a new installation. As the baler is located between columns (#43 and 44 as shown in Appendix I) in order to avoid movement, it may be more feasible to shift equipment between columns 42 and 43 to the south.

7.3.1. Payback Analysis to Implement Recommendation #2

Three out of the four equipment suppliers responded with price estimates for different configurations supplemented schematics on implementing their recommendations. The cost to implement the suppliers' recommendations ranged from $1.2M to $1.5M, which included costs for the optical sorter, additional conveyors, delivery, installation, and contingency. We believe the range to be a conservative estimate and will likely be further refined following an official tender through the City of Hamilton.

The first two recommendations look to increase the MRF's ability to effectively remove plastic film at the front end of the system and to optically sort HDPE to increase capture rates. By reconfiguring the existing film grabber, it is expected to reduce the burden of sorting on all sort stations (manual and mechanical) found downstream of the system. In theory, this would enable sorters at the second manual sort station to be repurposed to increase the capture of valuable material(s) (such as HDPE) and further remove residue that may inhibit the sorting efficiency of the eddy current and optical sorters. As these benefits cannot be accurately quantified, the following payback scenarios are presented to illustrate a range of payback periods based on the price estimates provided by the equipment suppliers. The figures have been arbitrarily selected from a minimum of a 5% increase in capture rates for all materials downstream to a maximum of achieving the stated manufacturers' efficiency rate.

Table 16: Scenario 1 - The reconfiguration allows the MRF to increase capture rates by 5% overall.

Material	Amount Available (tonnes)	Current Capture Rates (%)	Estimated Increase in Capture (%)	Additional Captured (tonnes)	Additional Revenue ($)
Glass	3,099.7	97.9%	N/A	N/A	$0
HDPE	992.5	81.2%	86%	49.6	$30,328
Film	1,115.6	55.1%	N/A	N/A	$0
Steel	1,371.8	93.9%	98%	56.6	$17,457
Aluminum Prime	626.3	84.3%	89%	31.3	$54,784
Aluminum B-Grade	86.7	62.6%	68%	4.3	$4,924
PET	2,842.2	73.1%	78%	142.1	$56,233
Mixed Plastics	1,406.1	43.1%	48%	70.3	$3,826

Material	Amount Available (tonnes)	Current Capture Rates (%)	Estimated Increase in Capture (%)	Additional Captured (tonnes)	Additional Revenue ($)
Cartons	375.6	73.6%	79%	18.8	$2,024
TOTAL	**11,916.6**		**81%**	**373.0**	**$169,576**

Table 17: Payback analysis if second optical increase capture of all containers by 5%

Capital Costs	**$1,500,000**
O&M costs ($/yr)	$20,000
Equipment Lifespan (yrs)[17]	10
Annual savings (est.)	$169,576
Capital Cost Payback period (yrs)	8.8
Capital Cost and O&M Payback Period (yrs)	10.0

Table 18: Scenario 2 - The reconfiguration allows the MRF to increase capture rates by 10% overall.

Material	Amount Available (tonnes)	Current Capture Rates (%)	Estimated Increase in Capture (%)	Additional Captured (tonnes)	Additional Revenue ($)
Glass	3,099.7	97.9%	N/A	N/A	$0
HDPE	992.5	81.2%	90%	87.0	$53,164
Film	1,115.6	55.1%	N/A	N/A	$0
Steel	1,371.8	93.9%	98%	56.6	$17,457
Aluminum Prime	626.3	84.3%	94%	62.6	$109,568
Aluminum B-Grade	86.7	62.6%	73%	8.7	$9,849
PET	2,842.2	73.1%	83%	284.2	$112,465
Mixed Plastics	1,406.1	43.1%	53%	140.6	$7,652
Cartons	375.6	73.6%	84%	37.6	$4,048
TOTAL	**11,916.6**		**84%**	**677.3**	**$314,203**

[17] Amortization period based on WDO data (10 years for major equipment).

Table 19: Payback analysis if second optical increase capture of all containers by 10%

Capital Costs	$1,500,000
O&M costs ($/yr)	$20,000
Equipment Lifespan (yrs)[18]	10
Annual savings (est.)	$314,203
Capital Cost Payback period (yrs)	4.8
Capital Cost and O&M Payback Period (yrs)	5.4

Table 20: Scenario 3 - The reconfiguration allows the MRF to increase capture rates to meet the manufacturers expected efficiency rates.

Material	Amount Available (tonnes)	Current Capture Rates (%)	Estimated Increase in Capture (%)	Additional Captured (tonnes)	Additional Revenue ($)
Glass	3,099.7	97.9%	N/A	N/A	$0
HDPE	992.5	81.2%	90%	87.0	$53,164
Film	1,115.6	55.1%	N/A	N/A	$0
Steel	1,371.8	93.9%	98%	56.6	$17,457
Aluminum Prime	626.3	84.3%	98%	86.0	$150,389
Aluminum B-Grade	86.7	62.6%	98%	30.7	$34,837
PET	2,842.2	73.1%	90%	480.3	$190,062
Mixed Plastics	1,406.1	43.1%	90%	659.0	$35,865
Cartons	375.6	73.6%	90%	61.5	$6,624
TOTAL	**11,916.6**		**90%**	**1,461.0**	**$488,397**

Table 21: Payback analysis if second optical increases capture of all containers to rated efficiency rates.

Capital Costs	$1,500,000
O&M costs ($/yr)	$20,000
Equipment Lifespan (yrs)[19]	10
Annual savings (est.)	$488,397
Capital Cost Payback period (yrs)	3.1
Capital Cost and O&M Payback Period (yrs)	3.5

[18] Amortization period based on WDO data (10 years for major equipment).
[19] Amortization period based on WDO data (10 years for major equipment).

7.4. Recommendation #3: Install Return Conveyor for Post-Optical Residue

In the event that the cost to implement Recommendation #2 is prohibitive, it is recommended that the City consider reprocessing post-optical residue on-site. As identified in Section 6.2, the reprocessing of post-optical residue could provide the City with an additional $53,000 in profit.

Consideration #1: The first consideration by the team was to feed the post-optical residue via conveyor directly back to the front end of the system to minimize manual handling (e.g. bobcats, front end loader); however this poses some logistical challenges and is the most expensive option ($250,000 - $300,000).

Firstly, reintroducing these materials back into the system during regular operations can create issues with burden depths if not carefully monitored by the loader operator in concert with loading from the tip floor. Otherwise this would further exacerbate the challenges posed on the current sorting equipment to effectively capture materials. Secondly, post-optical residue that have been reprocessed should be kept separate from materials that have not been reprocessed. If these materials were to be mixed back in, it would potentially create a continuous loop where the same materials are handled multiple times which reduces the net benefit of reprocessing. To address these issues, these materials would ideally be stored and only introduced into the system in isolation of tip floor materials.

Consideration #2: The most straight-forward approach to implement this would be to re-process the existing residue stream on a weekly or bi-weekly basis from the start of the processing line. Residue from normal operations (first pass) would be bunkered until sufficient volumes for a dedicated run are accumulated. This approach will permit staff resources to be focused on areas of greatest potential return from re-processing and also allow a clear cost/benefit review of the true effectiveness of this second run through the complete sorting line. Any residue remaining after the second processing run would be shipped off site for disposal.

To implement this option the City would reconfigure the existing bunkers for residue to enable manual movement by bobcat to a storage bunker/area, likely somewhere near the tip floor. Residue from the optical sorter is in the order of 1,300 TPY which represents approximately 5 TPD (252 operating days per year). This material would then be moved via loader and reintroduced to the front end of the line. Given material volume and storage limitations this would likely occur weekly (e.g. with 25 tonnes for processing). If this material is stockpiled and not bunkered the costs are restricted to the operating costs associated with bobcat/loader movement and some reconfiguration of bunker floors for which costs would need to be determined.

Consideration #3: If bobcat movement is deemed too onerous, the residue outfeed conveyor, already elevated in the plant, may be able to be replaced with a longer (possibly inclined if necessary) conveyor to feed directly to a storage area on the floor. Given this material has a typical bulk density in the order of 25 kg/m^3 the most cost effective way to manage storage is likely to pile it (like tipping floor materials) as opposed to bunker construction. This material would require about 200 m^3 of storage capacity (to store up to 5 tonnes) which for a simple standard concrete block structure would cost in the range of $4,500 - $5,000 (approximately 8 x 9 by 3 meters).

An associated conveyance system would require de-installation of the existing conveyor, fabrication, shipping and installation of a new conveyor, footing etc. with contingency would be somewhere in the order of $150,000.

It should be noted that a drawback with this configuration is that the bunker or pile would need to be moved/loaded at the front end of the container line prior to starting up the lines as return residue would be fed back into the bunker/pile for disposal.

7.4.1. Payback Analysis to Implement Recommendation #3

As shown in Section 6.2, the reprocessing of post-optical residue would generate a profit of $53,000 to the City of Hamilton. The following payback analysis illustrates the return on investment under different considerations for reintroducing the post-optical residue to the sort line.

Consideration #1: Conveyor system designed to feed post-optical residue directly back to the front end of the system to minimize manual handling (e.g. bobcats, front end loader).

Table 22: Payback calculation for Consideration #1

Capital Costs	**$300,000**
Maintenance and Replacement costs ($/lifespan)	$20,000
Equipment Lifespan (yrs)[20]	10
TOTAL COST	$320,000
Annual savings (est.)	$53,000
Capital Cost Payback Period (yrs)	5.7
Capital Cost and Maintenance & Replacement Cost Payback Period (yrs)	6.0

Consideration #2: Manual removal and transportation of post-optical residue from the current bunkers to a staging/storage area. This consideration doesn't include any capital cost and is strictly an operational cost. Therefore, a payback analysis has not been provided for this consideration.

Consideration #3: Replacing current residue outfeed conveyor with a conveyor to feed directly to the storage area. This includes the cost to build a concrete storage area for the post-optical residue materials.

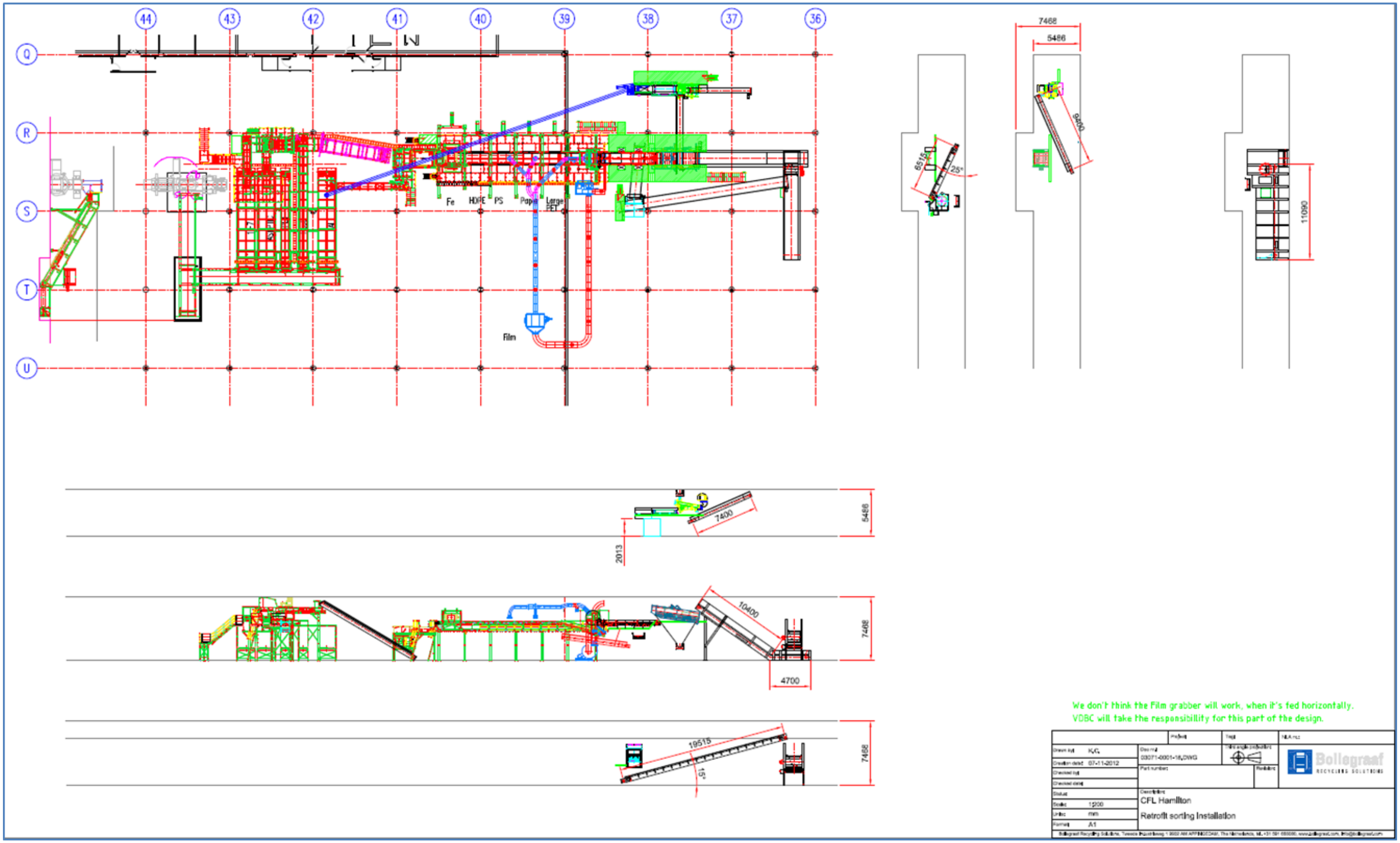
Table 23: Payback calculation for Consideration #3

Capital Costs	**$150,000**
Maintenance and Replacement costs ($/lifespan)	$20,000
Equipment Lifespan (yrs)[21]	10
TOTAL COST	$170,000
Annual savings (est.)	$53,000
Capital Cost Payback Period (yrs)	2.8
Capital Cost and Maintenance & Replacement Cost Payback Period (yrs)	3.2

[20] Amortization period based on WDO data (10 years for major equipment).
[21] Amortization period based on WDO data (10 years for major equipment).

Appendices

Appendix I – MRF Container Line Drawing



Stantec Reclay StewardEdge

Appendix II – Detailed Material Capture Rates

Shaded boxes below indicate the desired bunker in which the associated commodity should be sorted. Reading horizontally the flow of each commodity, and therefore the capture rate, can be assessed. For the two aluminum categories, the sum of aluminum (A) & (B) are used to calculate overall capture rate (e.g. aluminum food and beverage cans capture rate: 78.1% + 6.2% = 84.3%). It is important to note the high rates of targeted commodities ending up in the residue bunkers, especially the post-OS residue bunker.

	Bunkers												
Commodity	**Glass**	**HDPE**	**Film**	**Steel**	**Aluminum Prime**	**Aluminum B-Grade**	**PET**	**Mixed Plastics**	**Cartons**	**Residue (pre-OS)**	**Residue (post-OS)**	**Other**	**Total***
Glass	**97.9%**	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	2.0%	0.0%	**100%**
HDPE	0.0%	**81.2%**	0.2%	0.0%	0.0%	0.0%	0.3%	13.4%	0.0%	0.2%	4.5%	0.0%	**100%**
Film	0.0%	0.1%	**55.1%**	0.4%	0.0%	0.0%	2.6%	6.7%	0.0%	24.1%	10.6%	0.3%	**100%**
Steel	1.1%	0.0%	1.1%	**93.9%**	0.1%	0.0%	0.6%	0.1%	0.0%	2.4%	0.6%	0.1%	**100%**
Al. food and beverage cans	0.1%	0.1%	0.0%	0.8%	**78.1%**	6.2%	1.2%	1.7%	0.1%	2.4%	8.5%	0.8%	**100%**
Al. foil, trays and aerosols	0.0%	0.0%	3.9%	0.5%	0.9%	**61.7%**	0.5%	0.0%	0.0%	2.8%	29.2%	0.5%	**100%**
PET	0.0%	0.5%	1.2%	0.8%	0.0%	0.0%	**73.1%**	5.2%	0.0%	2.4%	15.1%	1.7%	**100%**
Mixed Plastics	8.3%	6.3%	0.6%	0.8%	0.1%	0.0%	2.7%	**43.1%**	0.3%	9.8%	27.3%	0.6%	**100%**
Cartons	0.0%	0.0%	0.7%	0.5%	0.1%	0.0%	0.4%	11.3%	**73.6%**	0.7%	11.7%	0.9%	**100%**
Residue	7.3%	0.0%	1.8%	11.1%	0.2%	1.1%	2.0%	7.4%	0.7%	30.3%	33.8%	4.2%	**100%**
Other Recyclables	0.0%	0.0%	1.6%	1.3%	0.9%	0.0%	2.0%	4.5%	0.3%	19.9%	52.8%	16.7%	**100%**

Note: May not sum to 100.0% due to rounding.

www.reclaystewardedge.com