

Lifecycle management of stormwater facilities

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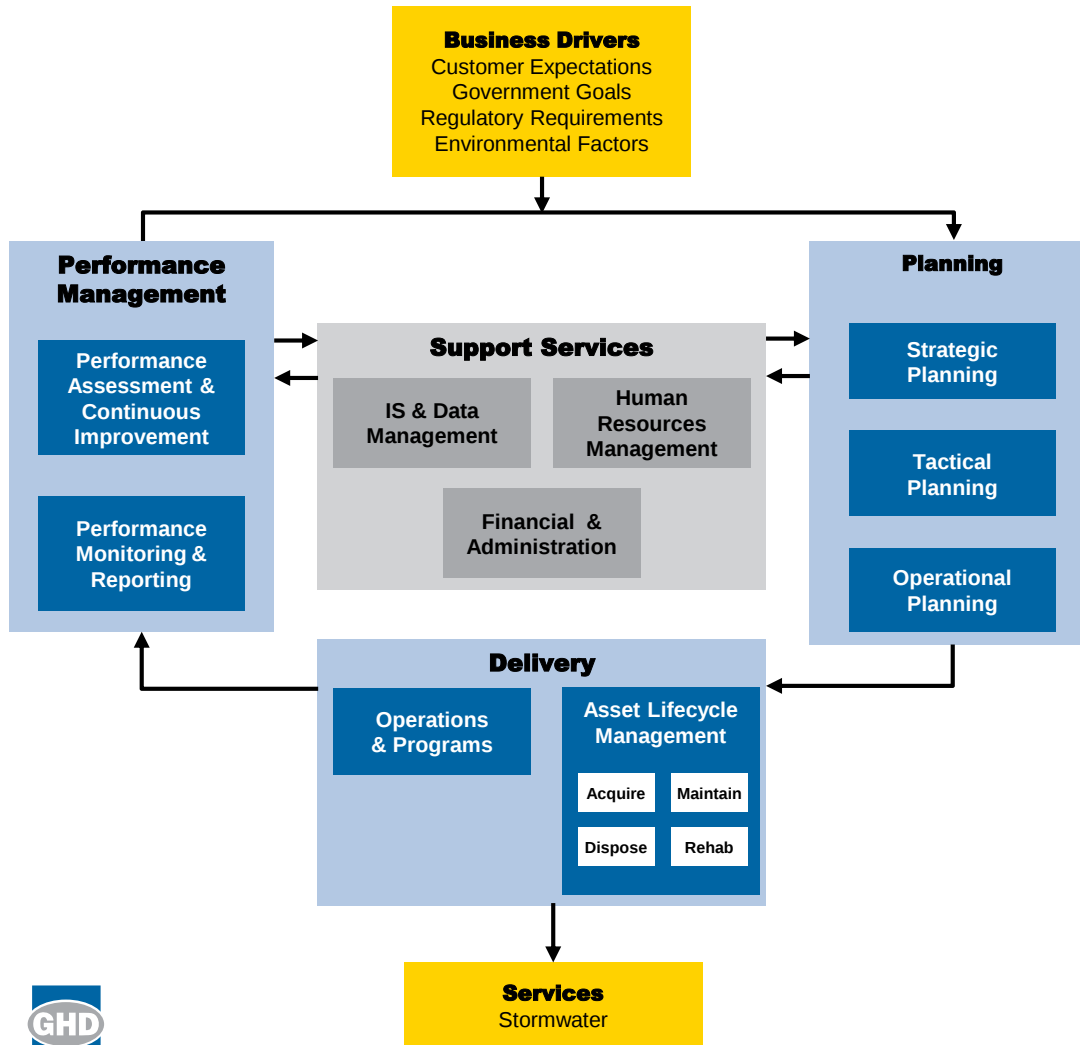


Agenda

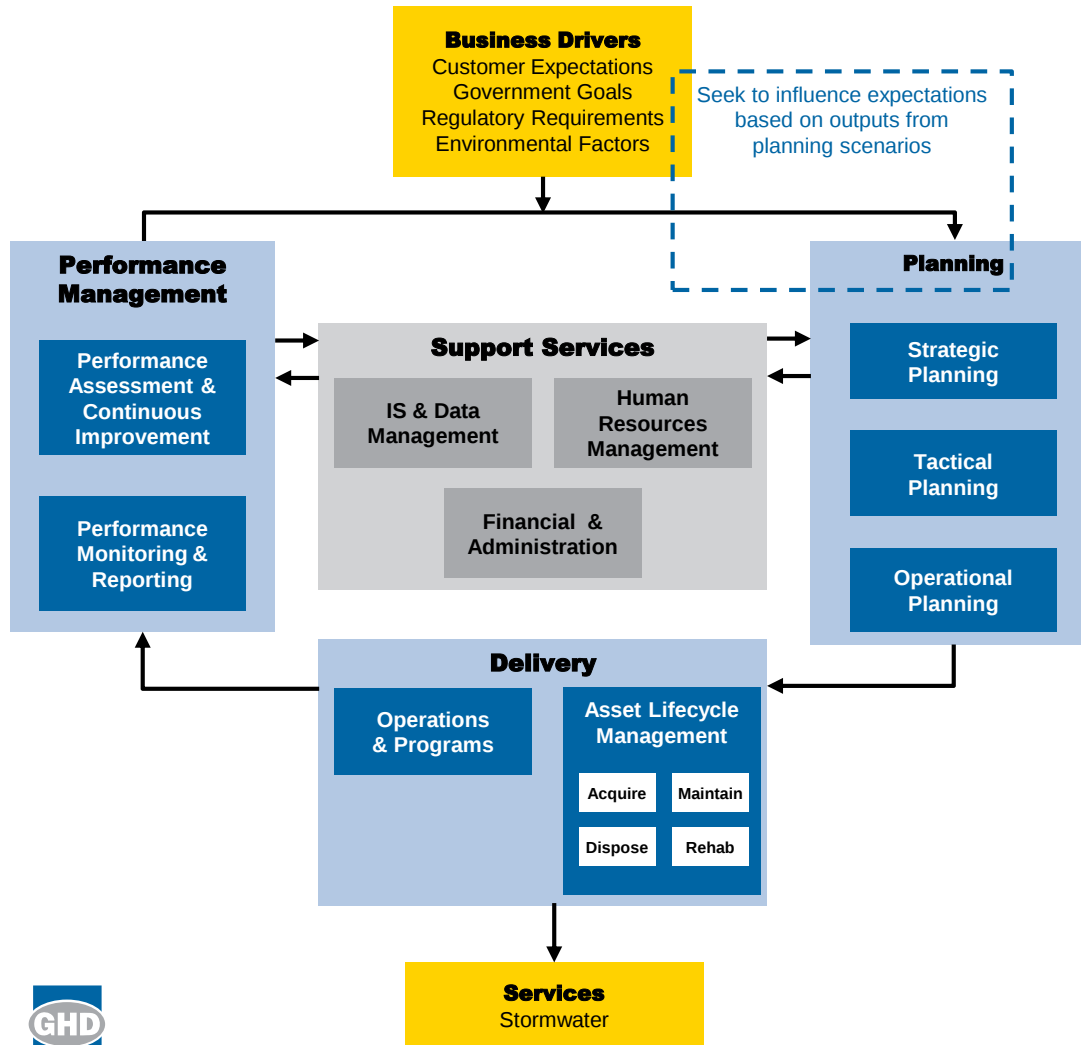
- Introductions
- Asset Management Principles
- SWMF Asset Management Case Study – City of Barrie
- CMMS as a Asset Management Tool
- Green vs. Gray Infrastructure Management
- Discussion

Asset management principles

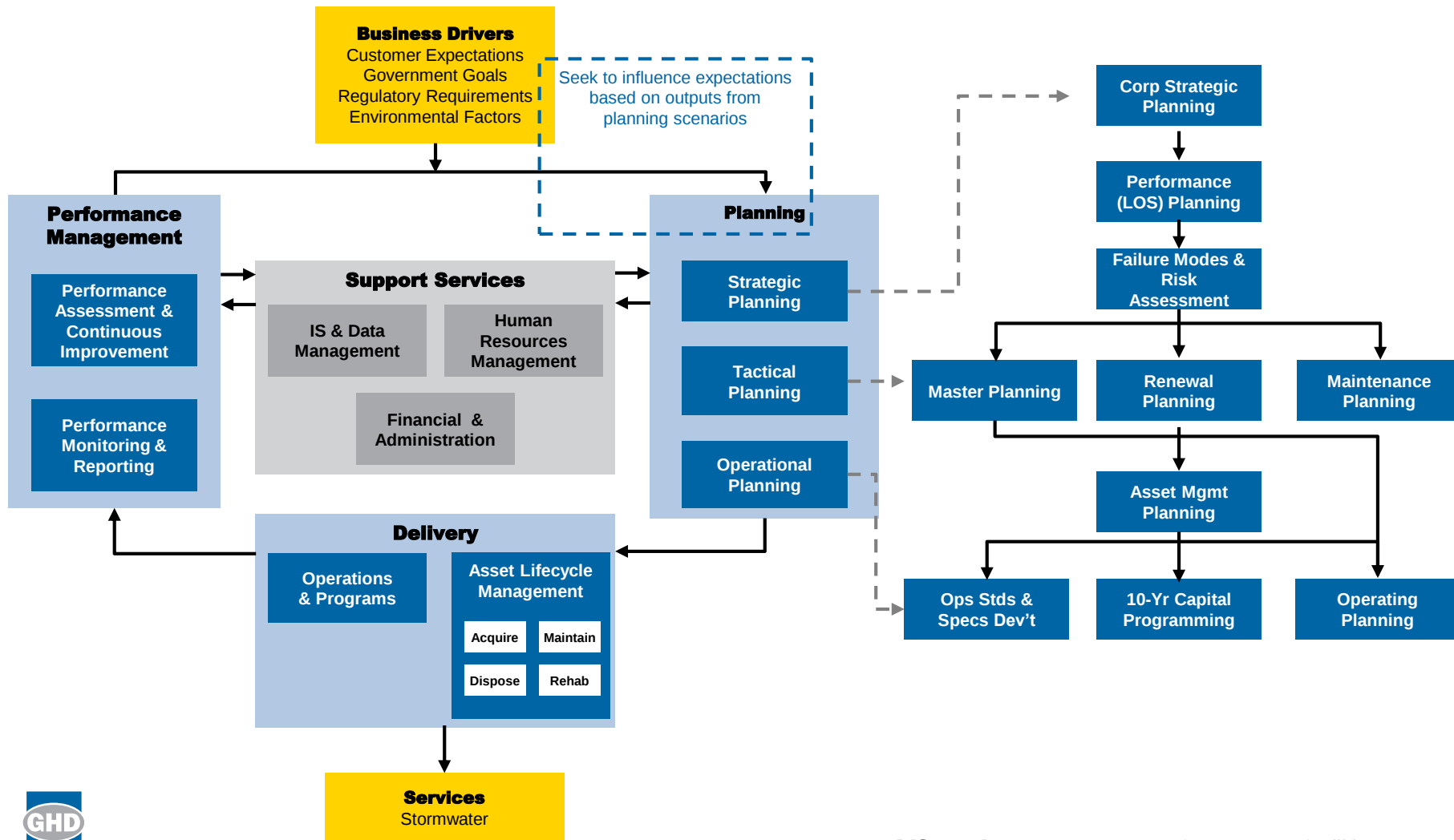
Asset management framework



Asset management framework



Asset management framework



Asset management planning

1. What is the current state of my assets?

Create
asset
registry

Assign
condition
ratings

Determine
remaining life
& decay rates

Determine O&M
& replacement
costs

2. What is my required level of service?

Set Levels of
Service (LOS)

3. Which assets are critical?

Determine
Business Risk
Exposure (BRE)

4. What are my best O&M and Capital investment strategies?

Optimize
O&M
investment

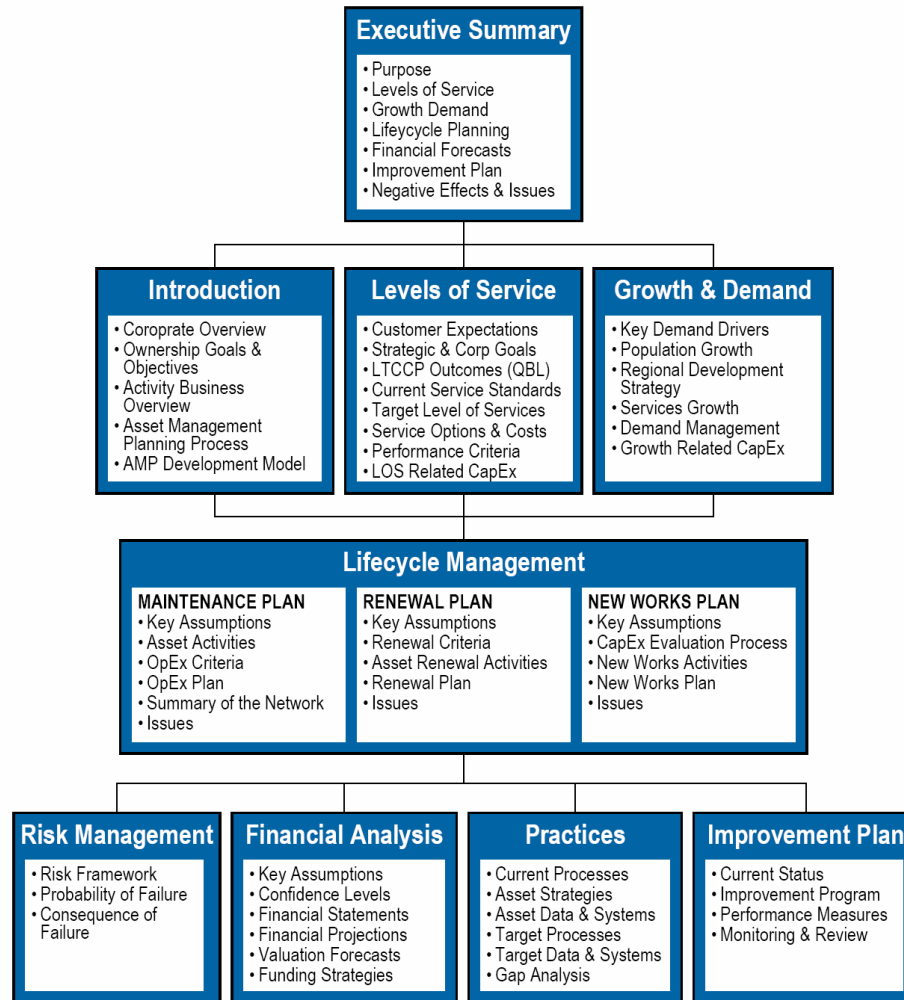
Optimize
capital
investment

5. What is my best long-term funding strategy?

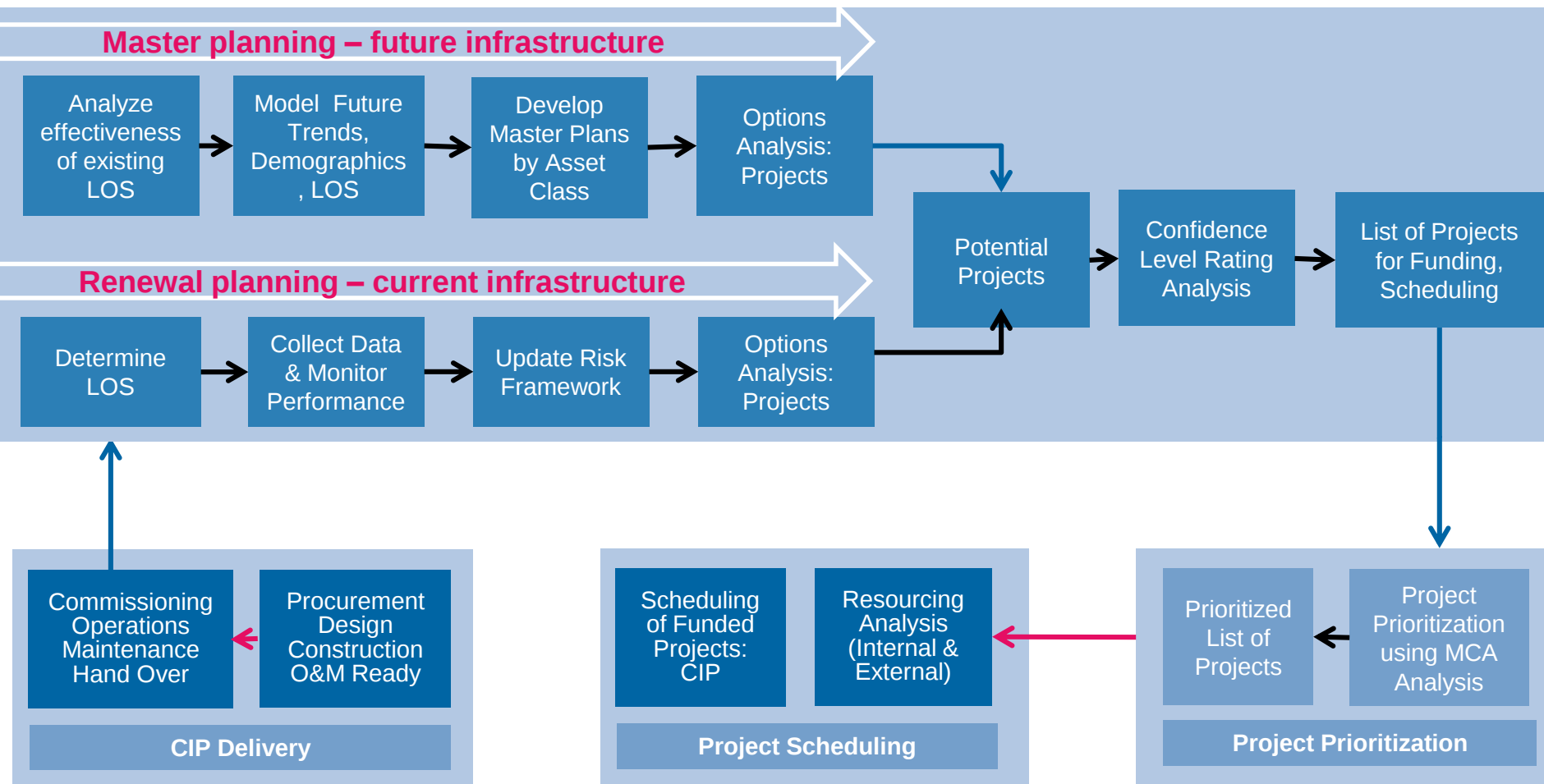
Determine
funding
strategy

Build AM
plan

Asset management plans

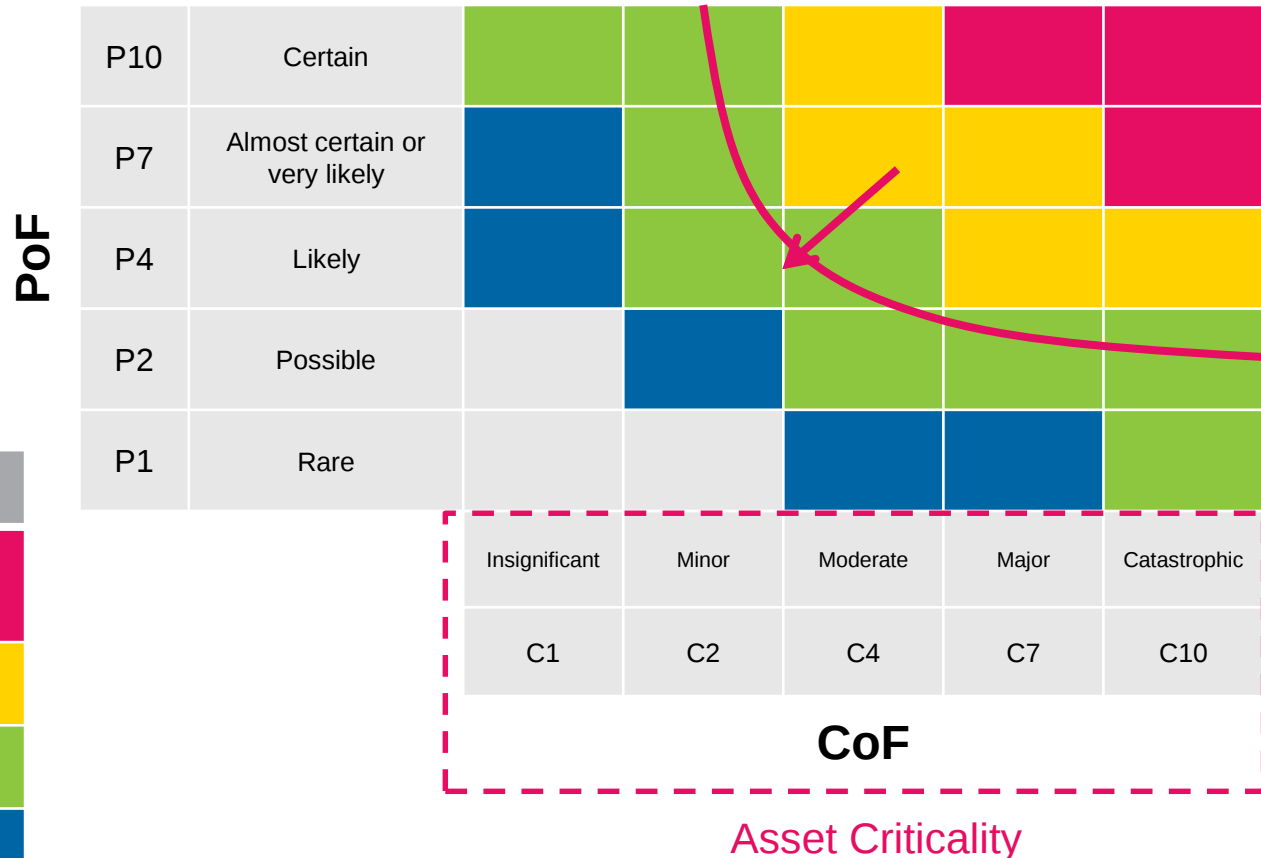


Master, renewal & replacement planning



Risk mapping and decision making

Risk = PoF x CoF	
Catastrophic	Immediate action to prevent impact to LOS, safety, and environment
Extreme	Gearing up for immediate action
High	Monitoring regime, response plan in place
Moderate	Management responsibility specified
Low	Manage using routine procedures



SWMF case study: City of Barrie



Case Study: City of Barrie

- City of 140,000 people in central Ontario, Canada
- Located 90 minutes north of Toronto
- City lies on the western shore of Lake Simcoe



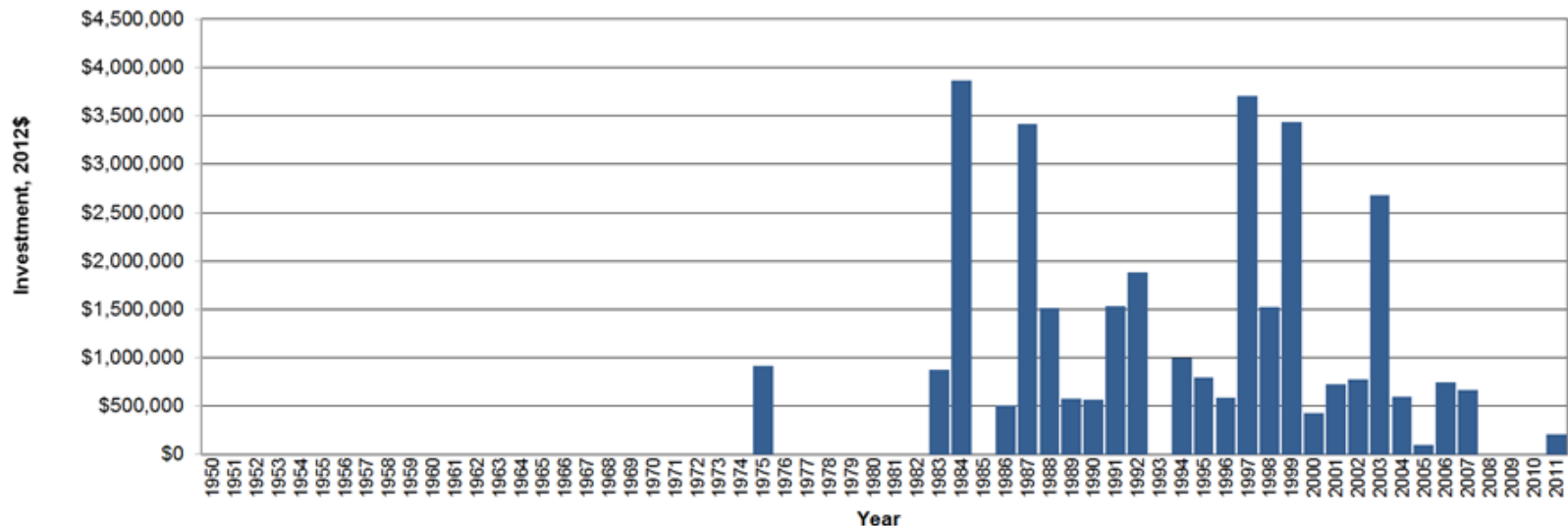
Lake Simcoe

- Lake Simcoe is the fourth largest lake in Ontario
- Popular for boating, fishing, and beaches
- Lake-related tourism plays a major part of the City of Barrie's economy
- Lake has significant environmental stress due to eutrophication
- Watershed revitalization plans underway



Stormwater management assets

- The City of Barrie owns and operates 93 SWMFs
- Valued at approximately \$33 million (replacement cost value)
- Installed in a 35 year period from 1975 to 2011



Types of stormwater assets and components

- 93 City-owned stormwater management facilities (ponds) at locations distributed across 12 watersheds
- Smallest volume pond: 128 m³ (33,800 gal)
- Largest volume pond: 118,420 m³ (31 Mgal)
- Most are for 100-year storm design criteria
- Each location can have any combination of the following stormwater asset components:
 - Pre-treatment: 4
 - Inlet conveyance: 73
 - Inlet structure: 73
 - Sediment forebay: 37
 - Storage pool: 93 (all)
 - Outlet structure: 24
 - Outlet conveyance: 69
 - Maintenance access: 93 (all)
 - Security: 47
 - Landscaping: 93 (all)

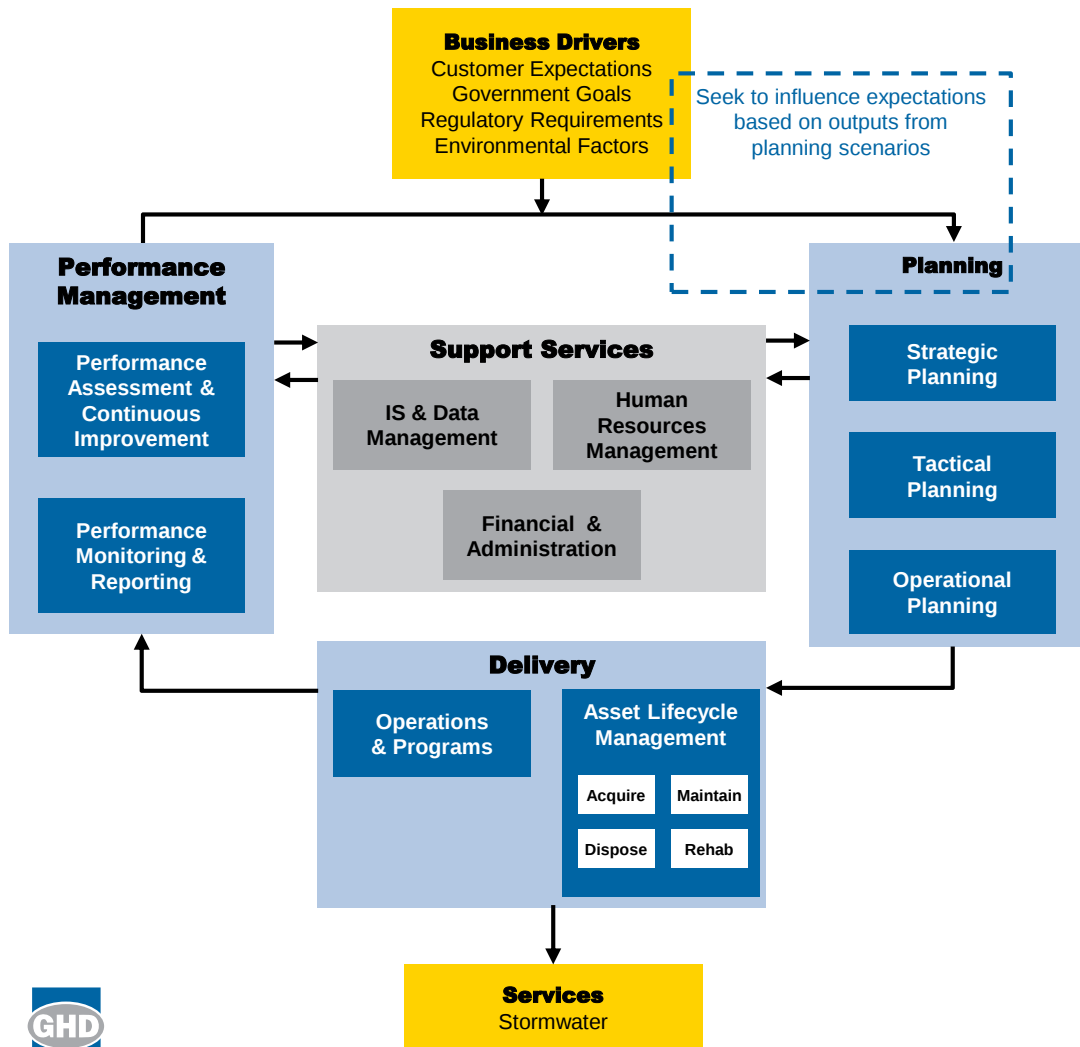


Drivers for a SWMF asset management plan

- City realized they were not adequately budgeting for SWMF renewals and replacement
- A proactive Asset Management approach was encouraged by the Ministry of the Environment
- **Need to meet required levels of service specified by MOE regulatory requirements and the additional requirements of the 2008 Lake Simcoe Protection Act**



Asset management framework



City of Barrie business drivers:

- Population growth from the 1980's to the 2000's
- O&M staff could not keep up with maintenance or condition monitoring
- Inadequate budgeting for maintenance or replacement
- City strategic goals
- Legislative requirements

Project objectives

1. Identify critical SWMFs and develop mitigation strategies to manage the risk of failure across the portfolio of SWMFs
2. Develop lifecycle management strategies on those assets that are most important to the delivery of stormwater management services for the City
3. Develop an updated asset management plan for the SWMFs

MIND THE GAP

Implementation steps

- 
1. Develop the Asset Hierarchy/Attributes
 2. Develop Levels of Service
 3. Define SWMF Functions
 4. Define SWMF Failure Modes
 5. Develop Overall Business Risk Exposure Framework
 6. Develop Asset Management Plan (AMP)

Develop asset hierarchy

Level 1	Level 2	Level 3
Storm Water Management Facility	Pretreatment	Low Impact Developments (LIDs), Oil/Grit Separator
	Inlet Conveyance	Overland Flow Route, Piping, Maintenance Hole, Flow Splitter, Weir, Orifice Plate, Grate
	Inlet Structure	Grate, Screen, Energy Dissipater
	Sediment Fore-bay	Available Volume, Riprap
	Storage Pool	Available Volume, Vegetation, Floating Island, Berm, Bed / Liner, Riprap, Benching, Fountain
	Outlet Structure	Orifice Plate, Pipe, Hickenbottom, Reverse Slope Pipe, Maintenance Drain Pipe (Fish Screen, Valve)
	Outlet Conveyance	Headwall, Flow Splitter, Emergency Spillway, Receiving Watercourse
	Maintenance Access	Road, Material Drying / Laydown Area
	Security	Fence, Sign, Gate, Lock
	Landscaping	Vegetation

SWMF levels of service

Customer Value	Customer Expectation
Available	Provision of stormwater drainage outlet of sufficient capacity for all customers Clear and accessible information is available when needed
Cost Effective	Stormwater management usage costs are affordable and managed at the lowest possible costs Compliance requirements result in affordable usage costs
Reliable	Facilities function as and when required and is well communicated Facility maintenance and repairs are completed promptly
Responsive	Opportunities for stakeholder involvement in decision making are provided People understand their rights and responsibilities, are informed, consulted and heard Customers are treated fairly and consistently, within acceptable timeframes, demonstrating respect, empathy and integrity
Safe	Facility providers take safety seriously and have safety measures in place Customers and City staff feel safe when using and working in facilities
Suitable	Facilities are suitable for the functions for which they are required, including provision of water quantity control, water quality treatment, and a safe, accessible and aesthetically attractive facility
Sustainable	Long term plans are prepared and facilities are being maintained and managed to provide the required functions for future generations Facilities operate in a way that minimizes damage to the environment

Asset functions

Pond Type	Function
Dry Pond	Designed to control water quantity only (typically older ponds)
Wet Pond	Designed to provide both water quality treatment (i.e., settling of suspended solids and removal of phosphorous) and water quantity control: Water quality treatment is provided by a sediment fore-bay to capture larger particles at the inlet of the pond and settling of sediment in a permanent pool of water within the pond Water quantity control is provided by a storage pool that provides reserve capacity to capture storm event water and discharge it over time as allowed by the outlet controls Tend to be more aesthetically pleasing (more natural) than dry ponds, but tend to attract animals
Wetland	Similar to Wet Pond (i.e., can be designed to provide both water quantity control and water quality treatment) but has a larger footprint and is shallower, with wetland vegetation plantings that encourage growth of natural habitat for water quality treatment.

Asset failure modes

Failure Mode	Description	SWMF example
Utilization	The demand exceeds the capacity of the existing asset or network of assets (or vice versa in some cases)	Capacity is diminished due to the build-up of sediment Designed capacity is no longer adequate due to increased development and changes to the natural environment
Physical Mortality	The structural condition of the asset is such that it has reached the end of its effective life	Maximum potential life has been exceeded
Financial Efficiency	The cost of the asset exceeds the economic return necessary to justify retention of the asset	Costs associated with maintaining the asset exceed the cost of creating/install a replacement asset
Level of Service	The asset no longer performs reliably or does not meet higher regulatory requirements	Asset performance has diminished – i.e., inlet or outlet blockages Service delivery commitments made by the City are not being achieved Customer expectation are not being met Technical and legislated requirements are not being satisfied

Condition rating scale

Rating		Description
5	Very Good	Asset is physically sound and is performing its function as originally intended. Required maintenance costs are well within standards & norms. Typically, asset is new or recently rehabilitated.
4	Good	Asset is physically sound and is performing its function as originally intended. Required maintenance costs are within acceptable standards and norms but are increasing. Typically, asset has been used for some time but is within mid-stage of its expected life.
3	Fair	Asset is showing signs of deterioration and is performing at a lower level than originally intended. Some components of the asset are becoming physically deficient. Required maintenance costs exceed acceptable standards and norms and are increasing. Typically, asset has been used for a long time and is within the later stage of its expected life.
2	Poor	Asset is showing significant signs of deterioration and is performing to a much lower level than originally intended. A major portion of the asset is physically deficient. Required maintenance costs significantly exceed acceptable standards and norms. Typically, asset is approaching the end of its expected life.
1	Failed	Asset is physically unsound and/or not performing as originally intended. Asset has higher probability of failure or failure is imminent. Maintenance costs are unacceptable and rehabilitation is not cost effective. Replacement / major refurbishment is required.

Cost effective condition inspection

1. Poll knowledgeable staff to identify which SWMFs they felt were immediate high priority needs
2. Train **students** to visit each SWMF and complete a condition assessment checklist based on what they could see and access
3. Based on the student visits, identify specific SWMFs for knowledgeable city staff to visit to conduct a more thorough condition assessment

The City of
BARRIE

E02

Pond Inspection Form

Q:\Community Services\Opr - Roads & Parks - Technical Services\Environmental\ E02 - Storm Sewers\Pond Management Files\Inspection

Priority and Condition Rating Keys

Priority

- 1) **CRITICAL HIGH**: Compromise to safety, impact from service and function loss, needs immediate attention.
- 2) **HIGH**: Time sensitive, service/function loss if ignored, minimum standard of maintenance is required.
- 3) **MEDIUM**: Follow standard procedures to allow for uninterrupted service.
- 4) **MEDIUM LOW**: Preventative measures are to be taken to prevent progression of problem.
- 5) **LOW**: Not required, off season work.

Condition

- A) Acceptable condition. (LOW)
- B) Some evidence of deterioration. (MEDIUM LOW)
- C) Obvious damage and deterioration will need attention. (MEDIUM)
- D) Severe damage, looming failure. (HIGH)
- F) Complete failure. (CRITICAL HIGH)

Date (DD/MM/YY): May 15/13	Pond ID: 0Y04
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Key remarks from completed inspection:

Blocked outlet + presence of beaver

1 | Page

Condition inspection



Sediment	
Current sediment height (cm): N/A	Removal of sediment required: Yes: ☐ No: ☒
Condition A) LOW B) MEDIUM LOW C) MEDIUM D) HIGH E) CRITICAL HIGH	Priority 1) CRITICAL HIGH 2) HIGH 3) MEDIUM 4) MEDIUM LOW 5) LOW
Indicate if and/or where sediment has accumulated: 	
Sediment Forebay	
Sediment forebay: Yes: ☒ No: ☐	Functioning to capacity: Yes: ☐ No: ☒
Damage to sediment forebay: Yes: ☐ No: ☒	
Condition A) LOW B) MEDIUM LOW C) MEDIUM D) HIGH E) CRITICAL HIGH	Priority 1) CRITICAL HIGH 2) HIGH 3) MEDIUM 4) MEDIUM LOW 5) LOW
Additional Comments: 	

Business risk exposure – PoF & redundancy

	Title	Probability	Description
P1	Very Rare	<0.25	Event could occur very infrequently or only in exceptional circumstances, but is not expected
P2	Occasional or Possible	>0.25 & <0.5	Event should occur at some time
P3	Moderate or Likely	0>0.5 & <0.75	Event will probably occur regularly or in most circumstances
P4	Almost Certain or Very Likely	>0.75	Event is expected to occur very frequently or in most circumstances

Level of Redundancy	Reduction Factor
No backup	1.0
20% backup	0.8
50% backup	0.5
75% backup	0.2
100% backup	0.1
200% backup	0.02

Based on age or condition

Business risk exposure - CoF

Level	Title	Economic	Social	Environmental	Service Delivery
C1	Insignificant	Loss of replaceable asset <\$1M	No injuries No media interest	Non-lasting damage	No or few disruptions (<10%)
C2	Minor	Damages, losses or fines < \$1M	Minor injuries Local media coverage	Short-term, repairable damage	Minor (isolated) disruption in non-critical service
C3	Moderate	Damages, losses or fines \$1M to \$10M	Serious injuries, multiple minor injuries Some provincial/national media coverage	Long-term damage, with repairable consequences	Major disruption in non-critical service Minor (isolated) disruption in critical service
C4	Major	Damages, losses or fines > \$10M	Loss of life, serious injuries Extensive provincial/national media coverage	Long-term damage, with lasting consequences	Some critical services unavailable

Business risk exposure - CoF

Facility-level CoF based
on the location and
construction of the SWMF
within the larger system

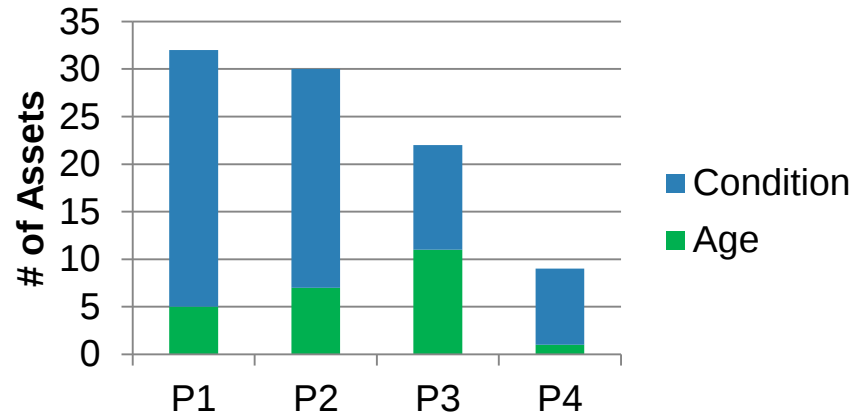
X

Asset-level CoF based
on the importance of that
asset to the service level
of that SWMF

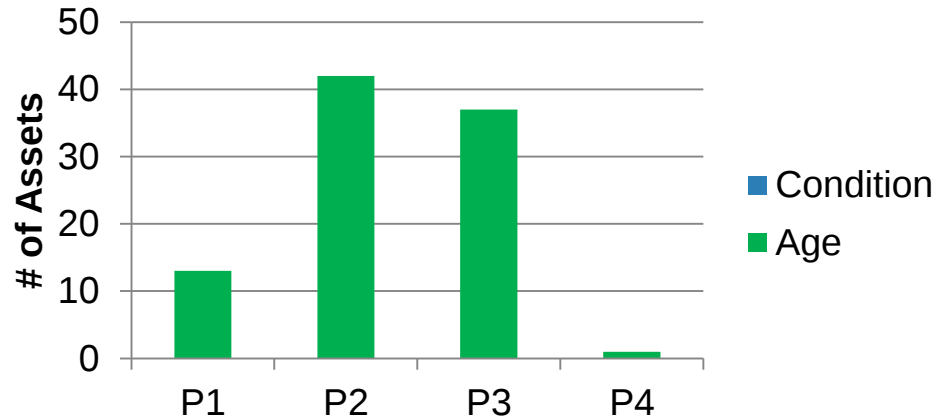
A CoF is calculated for each component of the SWMF

Example PoF results based on age or condition assessment (P1=Unlikely to Fail; P4=Likely to Fail)

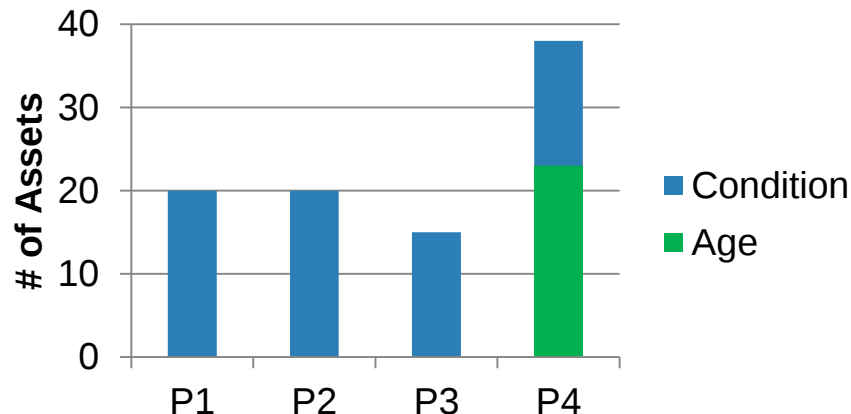
Inlet Conveyance



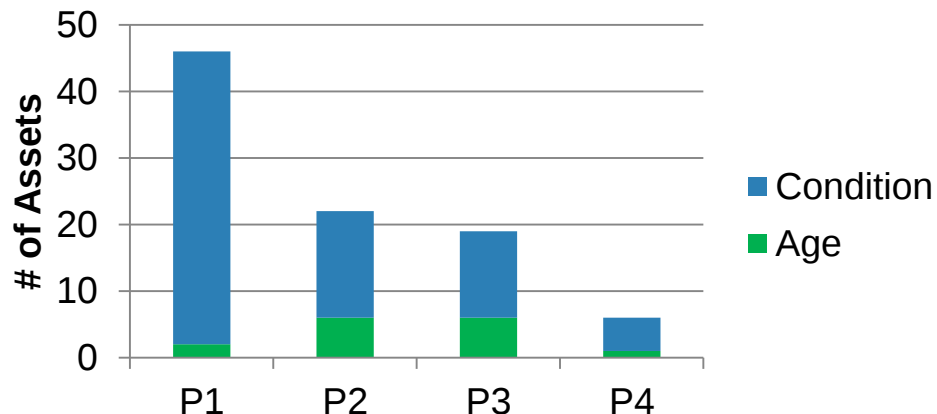
Inlet Structure



Sediment Forebay



Outlet Structure



Example business risk exposure calculation

SWMF ID BR20

Installed in 1992

Has all SWMF components except pre-treatment

POF:

Facility probability of failure based on condition inspection or age

- Inlet conveyance: **P1**
- Inlet structure: **P2**
- Sediment forebay: **P1**
- Storage pool: **P1**
- Outlet structure: **P1**
- Outlet conveyance: **P1**
- Maintenance access: **P2**
- Security: **P2**
- Landscaping: **P1**



Example business risk exposure calculation (cont.)

COF:

Facility consequence of failure = **C3** based on

SWMF subject to Lake Simcoe Protection Act (No)

Proximity to a wellhead protection area (No)

Whether a wet pond is necessary for water quality (Yes)

Whether the SWMF is part of a cold weather fishery (No)

Whether the SWMF is situated within an existing watercourse (No)

Asset consequence of failure based on function

- Inlet conveyance: **C2**
- Inlet structure: **C3**
- Sediment forebay: **C3**
- Storage pool: **C3**
- Outlet structure: **C4**
- Outlet conveyance: **C4**
- Maintenance access: **C1**
- Security: **C1**
- Landscaping: **C1**

Facility-level CoF
based on the location
and construction of the
SWMF within the
larger system

X

Asset-level CoF
based on the
importance of that
asset to the service
level of that SWMF

Business risk exposure: example SWMF ID BR20

PoF	P4				
	P3				
	P2	2		1	
	P1	1	1	2	2
		C1	C2	C3	C4
		CoF			

Business risk exposure: all SWMFs

PoF	P4	0%	0%	4%	12%
	P3	2%	1%	4%	9%
	P2	3%	1%	7%	26%
	P1	2%	8%	11%	10%
		C1	C2	C3	C4
		CoF			

Business risk exposure: all SWMFs

PoF	P4	\$82,699	\$59,047	\$1,283,729	\$4,084,174
	P3	\$556,407	\$315,045	\$1,373,608	\$2,938,892
	P2	\$953,309	\$182,652	\$2,334,734	\$8,470,803
	P1	\$576,184	\$2,762,783	\$3,775,090	\$3,251,175
		C1	C2	C3	C4
		CoF			

Business risk exposure: inlet structures

PoF	P4	\$0	\$0	\$0	\$0
	P3	\$0	\$0	\$127,750	\$305,858
	P2	\$0	\$0	\$234,999	\$407,711
	P1	\$0	\$0	\$24,547	\$138,790
		C1	C2	C3	C4

CoF

25% of SWMF Inlet Structure assets are an extreme business risk to the City.

Business risk exposure: all SWMFs

Percent of individual asset categories in the extreme risk category

- Pretreatment: 0%
- Inlet conveyance: 0%
- **Inlet structure: 25%**
- **Sediment forebay: 27%**
- **Storage pool: 34%**
- Outlet structure: 12%
- Outlet conveyance: 6%
- Maintenance access: 0%
- Security: 0%
- Landscaping: 0%

Lifecycle management plans

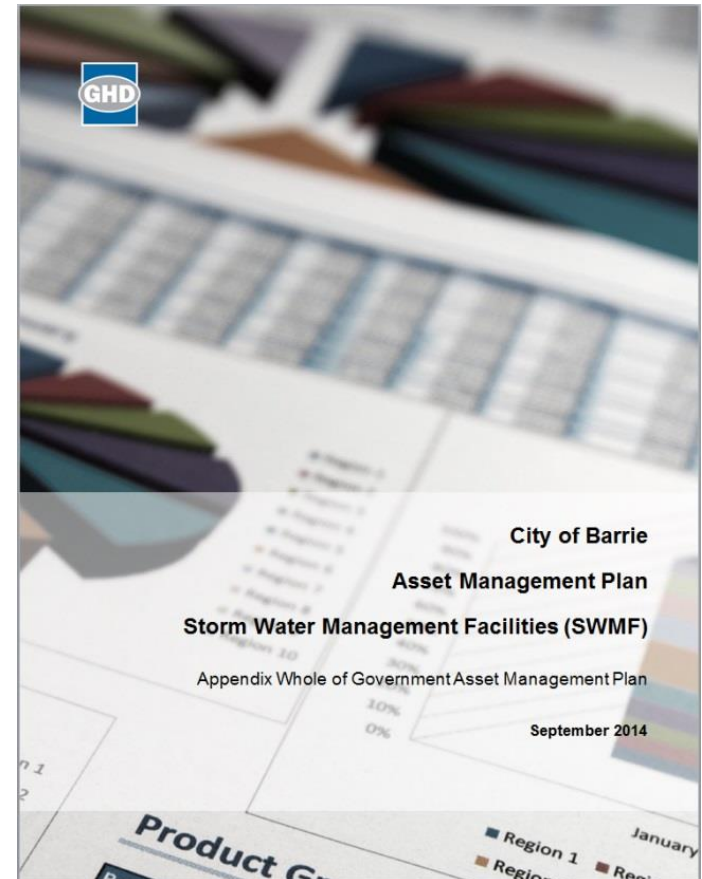
- Inventory and Inspection Plan
- Inspection and Maintenance Plan
- Renewal and Enhancement Plan
- Financial projections



Asset management plan

The overall AMP for the City's storm water management facilities provide the following value:

1. Identification of proactive maintenance and capital renewal investments to reduce the lifecycle cost of managing the SWMFs
2. Understanding and prioritization of needed work and associated costs to enable programming and budgeting for SWMFs
3. Allows for more **comprehensive discussion with City Council** regarding required levels of investment to support necessary service levels.



Maximum Potential Life (MPLs)

SWMF	MPL
Pretreatment	40
Inlet Conveyance	40
Inlet Structure	40
Sediment Forebay	10
Storage Pool	20
Outlet Structure	40
Outlet Conveyance	40
Maintenance Access	40
Security	20
Landscaping	50

Example failure management strategy

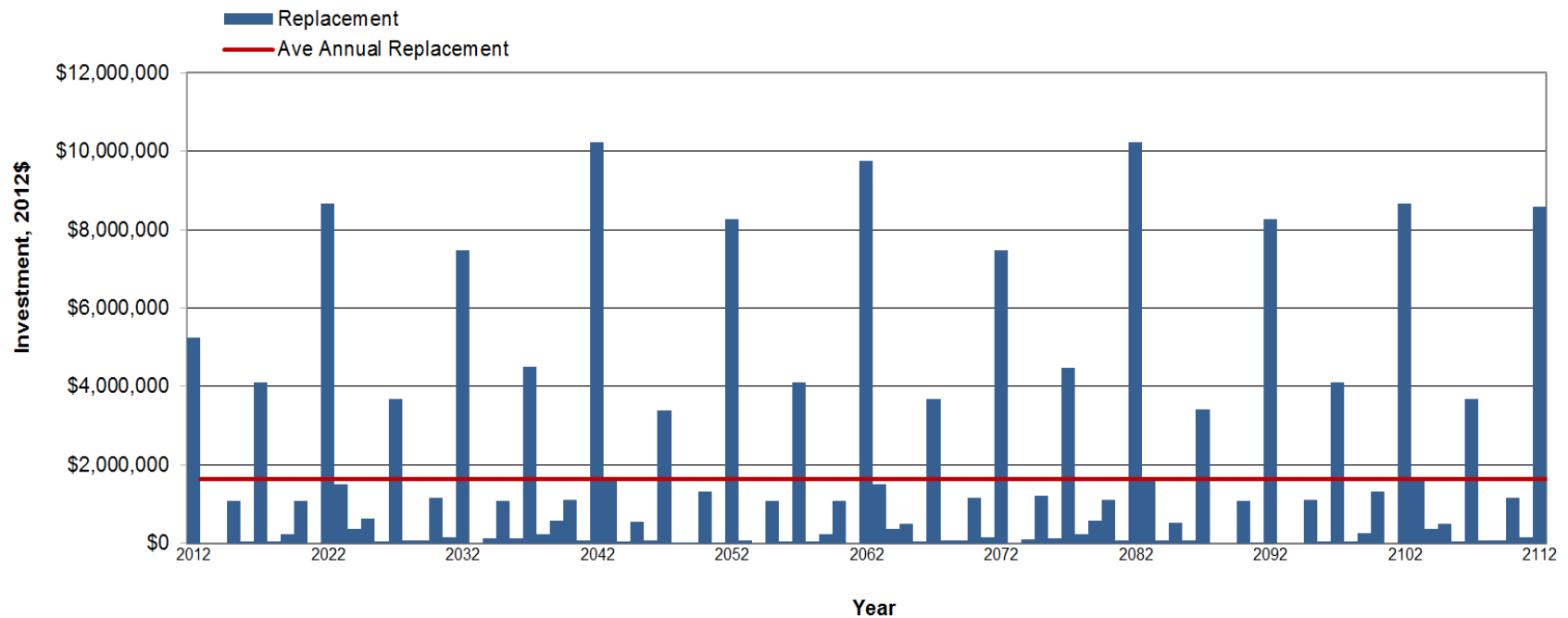
Sediment Forebay

- Inspect annually for damage including excessive sediment accumulation, obstructions, functionality
- Inspect for damage, obstructions, functionality after storm events
- Plan and carry out maintenance to harvest vegetation and clear obstructions, as required
- Plan and conduct bathymetric survey, as required
- Identify, analyze, and program sediment removal, other repairs and/or functional changes, as required

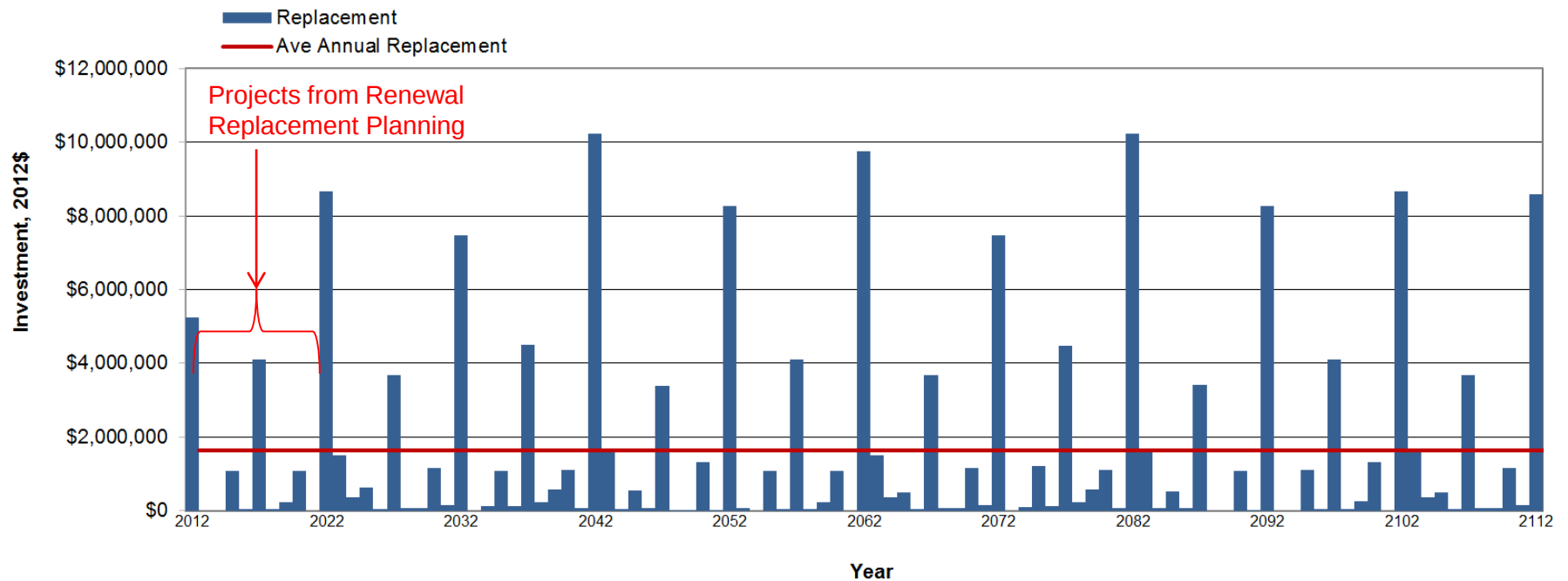
Example renewal and enhancement plan

SWMF	Results & Comments	Recommended Actions	Priority
LV20	- Based on visual inspection data, the Sediment Forebay is Condition = 1, Failed - Risk Exposure = 3.00 (Extreme) - Wet Cell, Offline SWMF - Inspection, bathymetric survey and vegetation analysis completed by GHD in 2012. Results include: - Pond Volume is 4,484 M3 - Sediment Volume is 970 m3 - Volume for 5% decrease in SS removal efficiency is 1,200 m3 - Clean out not yet required - Inspection comments are: Good circulation in permanent pool, stagnant water in sediment forebay; excess sediment accumulation in forebay; full visual inspection of inlet made difficult by excess vegetation; non-standard lock used at one of the gates, could not be opened with 104 or 103 key; "No Trespassing" sign suggested - Most recent inspection comments: Overgrown vegetation in forebay; sediment accumulation observed through overgrown vegetation; beaver dam visible in main cell; minor erosion downstream of outlet headwall; no vehicle or construction access (overgrown vegetation/no access road) - Additional comments: There is no clarification of its end state upon assumption from development; there is environmental sensitivity in the area; the discharge from the pond is loaded with sediment; there is a high sand load from development that occurred; significant sediment and decaying vegetation collected in forebay	- Further assess the SWMF & identify options - Protect the natural environment during any renewal operations - Remove overgrown vegetation from the pond - Drain the pond and conduct a detailed sediment survey and visual inspection to reduce sources of error and uncertainty associated a pond full of water - Collect sediment samples and submit to a laboratory for analysis prior to sediment removal - Clean out the accumulated sediment (estimated to be 970 m3 – not yet critical) - Analyze Options & Optimize Solution - Develop analysis input parameters such as costs and benefits (e.g., risk reduction), and timing - Determine the optimal solution by conducting cost / benefit analysis - Define & Program the Project - Define Project Scope of Work, Schedule and Budget - Program project, obtain funding and implement - Complete a detailed pond bottom survey after the sediment removal	1 (\$175k for Renewal)

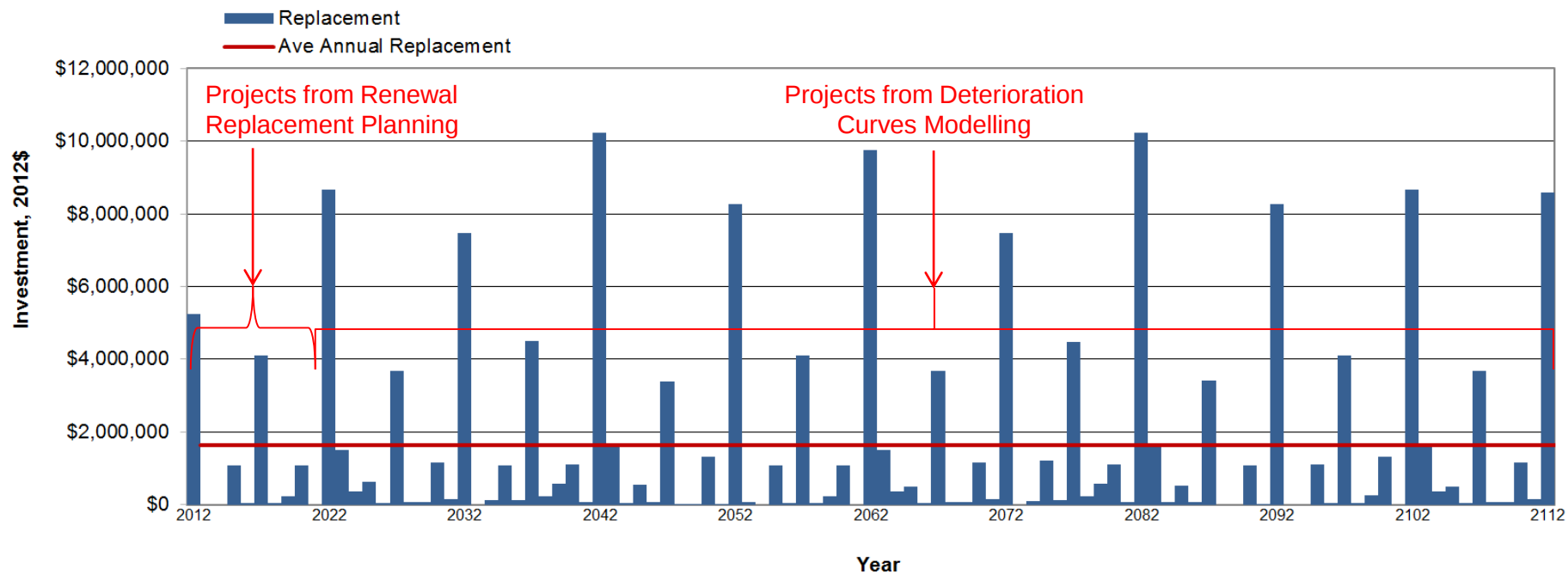
Financial projection for SWMF renewal



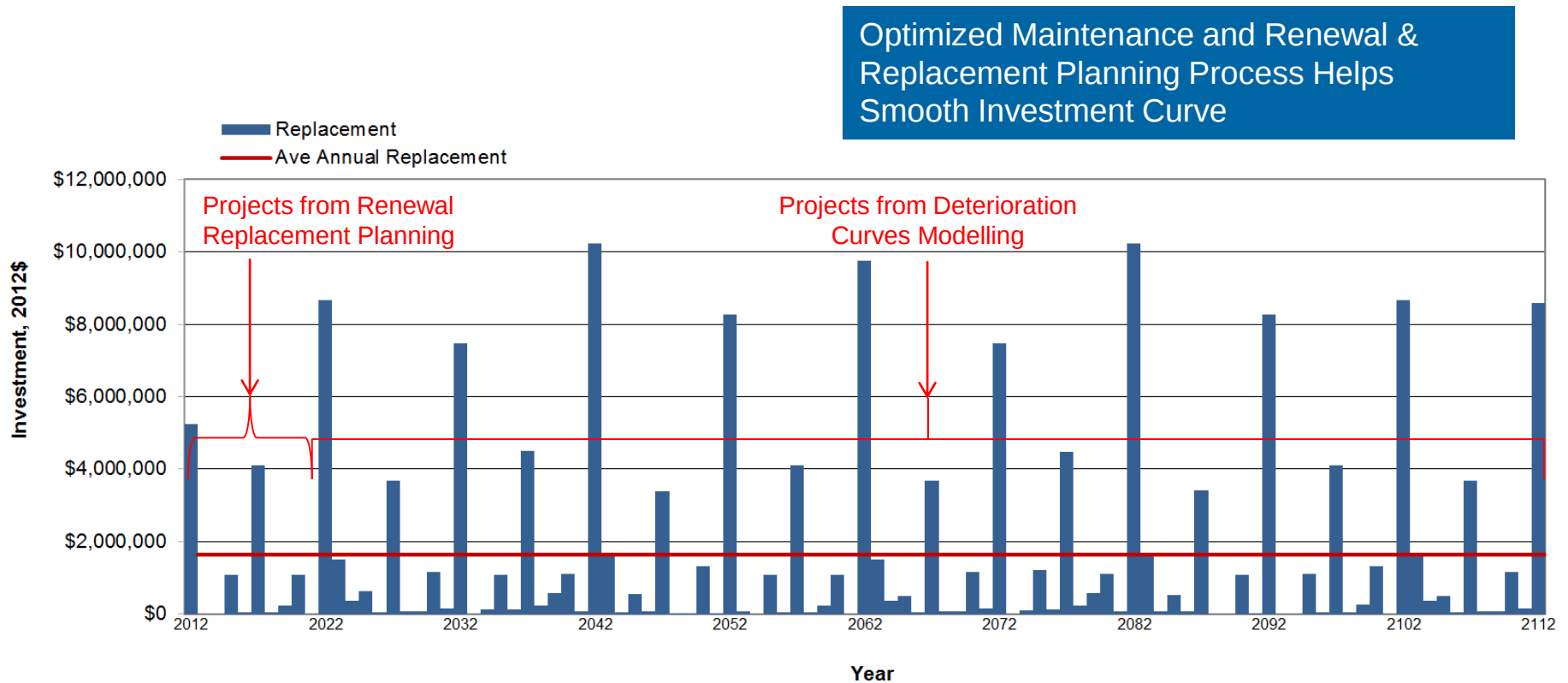
Financial projection for SWMF renewal



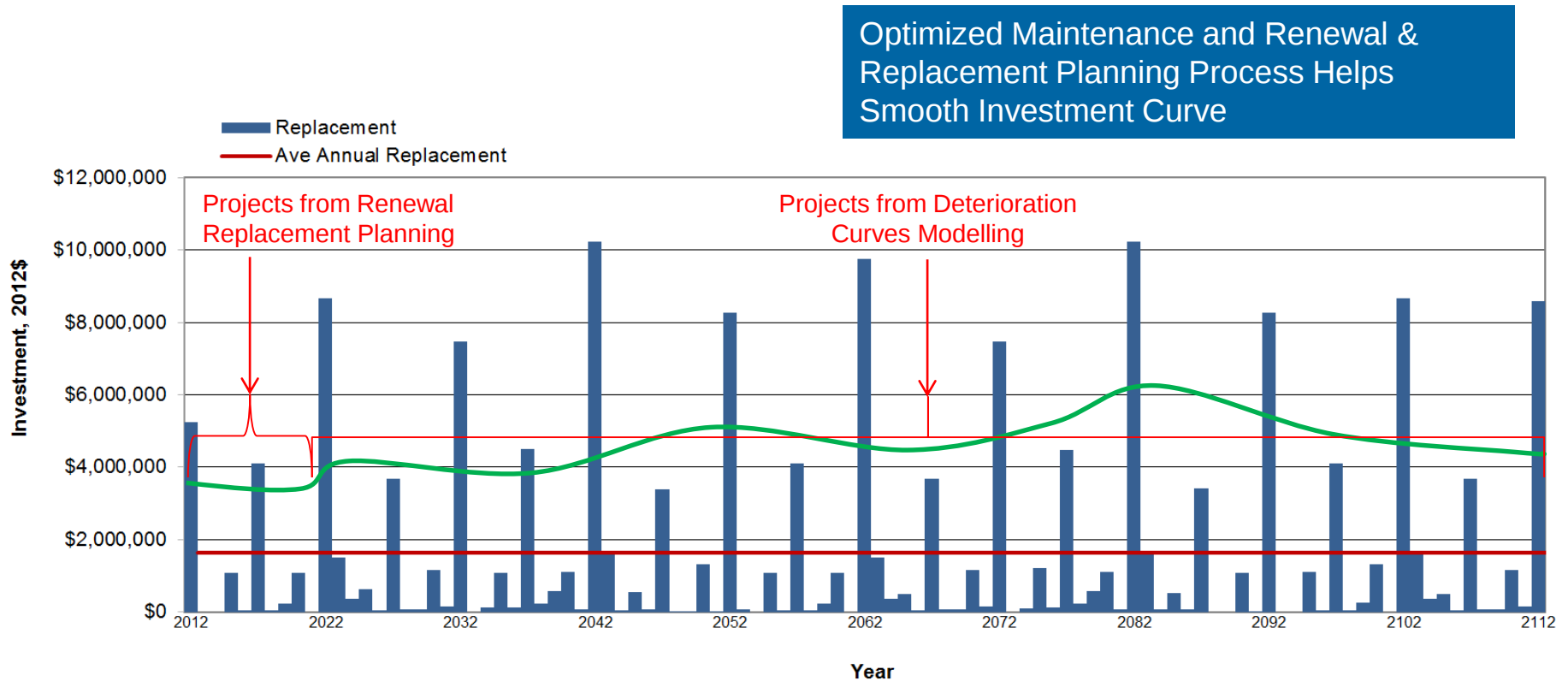
Financial projection for SWMF renewal



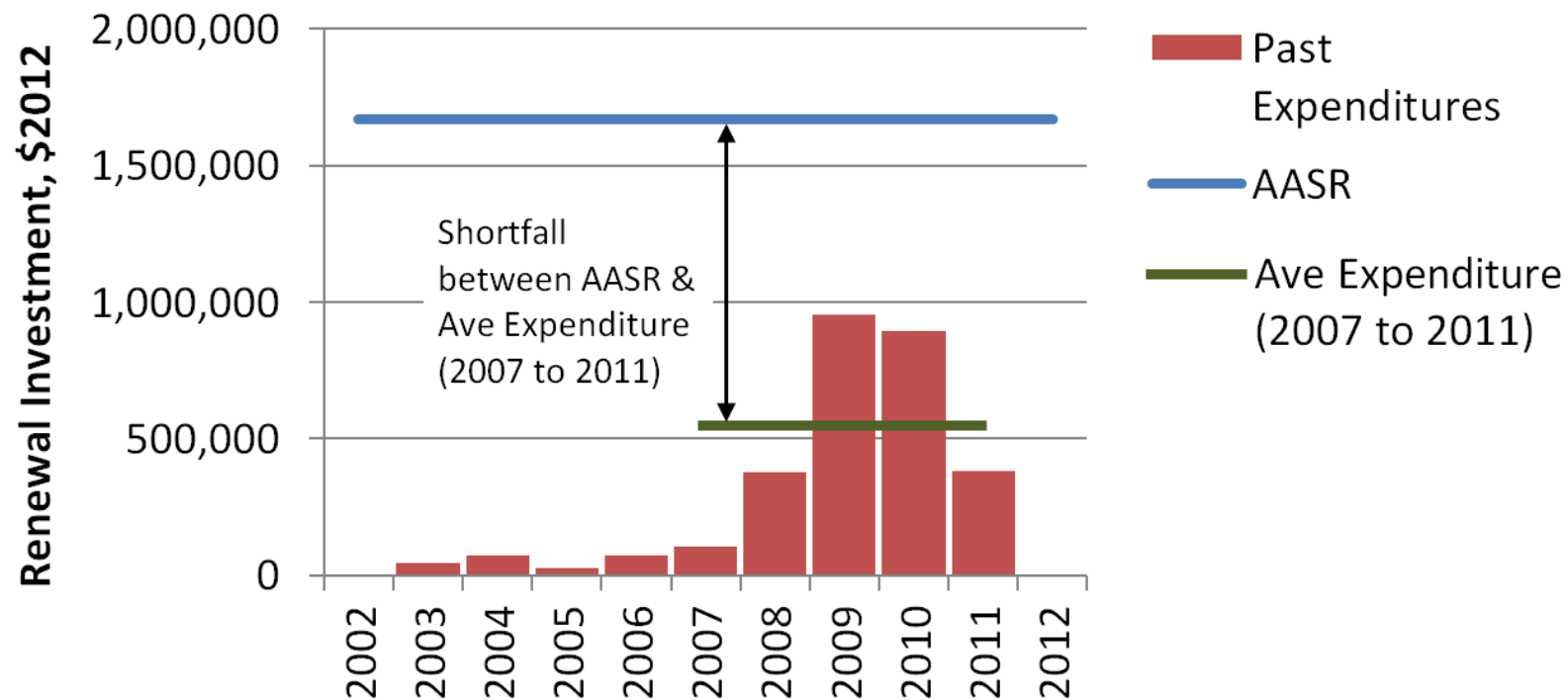
Financial projection for SWMF renewal



Financial projection for SWMF renewal



SWMF renewal investment, \$2012



Next steps for the city's SWMF AM program

1. Undertake the lifecycle plans
2. Plan and implement the Capital Program and Operating budget for the City's SWMF
3. Plan the funding of asset reinvestment needs through the annual Long Range Financial Plan



Additional future considerations

1. Incorporate impact of future regulatory changes
2. Incorporate impact of future environmental changes such as sea level rise
3. O&M investment cost/benefit calculation to quantify value of capital project deferral
4. Expansion to other stormwater assets such as bioretention basins, swales, rain gardens, pervious surfaces, etc.



CMMS as an Asset Management tool



CMMS for stormwater asset management

Example Cityworks CMMS dashboard

The screenshot displays the Cityworks CMMS dashboard with the following components:

- Top Navigation Bar:** Includes tabs for Inbox, Service Request, Work Order, Inspections, Asset Search, and Designer. A search bar is located on the right.
- Left Panel:**
 - Select Template:** A dropdown menu for 'Entity Group' (Storm Sewer) and 'Category'. Below are radio buttons for 'Feature', 'Object', and 'Other'. A list of templates is shown, with 'Main Cleaning (PM)' selected.
 - General:** Fields for Address, Status, Priority (3), Requested By, Supervisor, Submit To, Projected Start, Stage, Expense Type, Location, Comments, and Instructions.
 - Selected Assets:** A table with columns: Entity Type, Entity Uid, Legacy Id, Location, Feature Type, and Feature Name. The table contains one row: STORMMAINS, STM0019058, STORMMAINS, STM.
- Map View:** A central map area showing a street layout with a pink line representing a storm sewer. A 'Legend' window is open on the right, listing various assets such as Sanitary Sewer, Storm Sewer, Storm Manholes, Storm Lift Stations, Storm Inlets, Storm Flared End Sections, Storm Structures, Storm Valves, Storm Fittings, Preliminary Storm Manholes, Preliminary Storm Lift Stations, Preliminary Storm Inlets, Preliminary Storm Flared End Sections, Preliminary Storm Structures, Preliminary Storm Valves, Preliminary Storm Fittings, Preliminary Storm Mains, Preliminary Storm Force Mains, Storm Mains, Storm Force Mains, and Abandoned Storm Mains. A 'Results' window is open at the bottom right, showing 'Selected-Storm Mains (1)' with a table containing one row: Asset_ID (STM0019058), LINEID (11732), and OBJECTID (19058).

CMMS for stormwater

- Enables management of the asset inventory
- Organizes asset data into a usable data hierarchy
- Enables entry and tracking of work orders, condition information and costs tied directly to individual assets
- GIS based for data visualization and spatial analysis
- Supports development of renewal and replacement plans and O&M schedule management
- Helps the organization to schedule planned and preventive maintenance activities and to forecast when corrective maintenance, repair and replacement will need to be done.
- Supports identification of areas where increased O&M strategies can help defer capital investment in a way that does not significantly increase risk.



Green vs. gray infrastructure management



Green vs. gray infrastructure

Most municipalities are experienced at managing gray infrastructure

- Pipes, pumps, treatment facilities, roads, bridges, etc.

Management of green infrastructure like SWMFs is a relatively new service area for municipal governments

- Challenges include:
 - Ownership and site access
 - Inter-agency coordination (i.e. Utilities, Parks and Rec, Highways, etc.)
 - Maintenance requirements
 - Inspection and monitoring
 - Controlling damage: drought, trash and debris, pests, vandalism
 - Capital and O&M expense budgeting

Unique asset management aspects of SWMFs

Managing green infrastructure like SWMFs is very different than maintaining a pump or pipe

Example: Pipe maintenance

- Inspection
- Corrosion control
- Flushing, cleaning, root control, etc.
- All work done by utility crews, only ones with access to asset

Example: SWMF maintenance

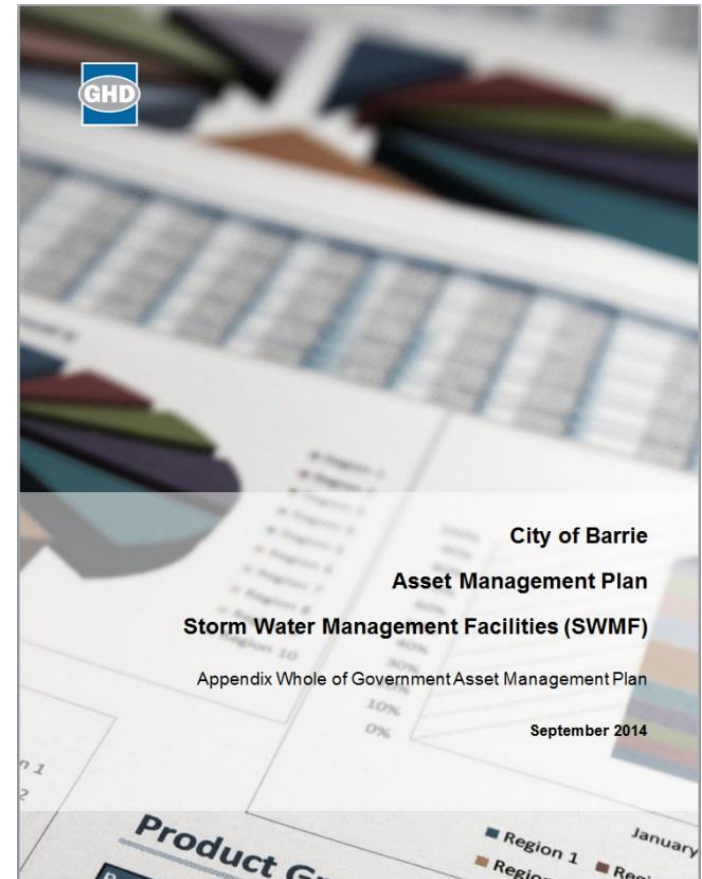
- Inspection
- Weeding, mowing, raking, mulching
- Trash removal and inlet/outlet cleaning
- Watering
- Rodent and insect control
- Sediment removal
- Many people/groups have access to the site and may share maintenance responsibilities

Lack of maintenance for either type can result in decreased performance and ultimately, failure



SWMF management needs

- Asset management plan
- Defined maintenance responsibilities – public vs. private
- Monitoring and inspection program
- Maintenance database with flexibility to accommodate a wide range of asset types
- Regulatory compliance program **to support required permit reporting** (e.g., MS4 requirements)
- Input into annual CIP and O&M budgets
- Funding sources





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