

June 09, 2023

Project Number: P2226

David Schaeffer Engineering Limited  
120 Iber Road, Unit 103  
Stittsville, ON  
K2S 1E9

**Attention: Adam Fobert, P.Eng.**

**Subject: The Drummond (The Ridge Phase 3/4):  
Low Impact Development (LID) Design**

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## Introduction

As a part of the detailed design of the Drummond (The Ridge Phase 3/4) subdivision, located in Barrhaven within the City of Ottawa, J.F. Sabourin and Associates Inc. (JFSA) were commissioned to complete an in-depth analysis of the proposed Low Impact Development (LID) measures within the site to assess/ensure that the site's infiltration targets will be met under post-development condition. The detailed study area consists of **19.06 ha**, which includes **17.33 ha** of residential lands and **1.73 ha** of park. Note that lands external to the site, such as the Ridge Phase 1 & 2 have not been considered in this LID analysis, refer to JFSAs July 29, 2020, memo titled The Ridge (Brazeau) Low Impact Development (LID) Design for full LID/water budget details of that site. A detailed PCSWMM hydrologic/hydraulic model was developed to replicate the proposed development's water budget using historical rainfall data. The following memo outlines the proposed development's water budget and the aquifer recharge benefits that the proposed LIDs will provide.

## Site Infiltration Targets

As a part of the Master Servicing Study Barrhaven South Urban Expansion Area report completed by J.L. Richards in May 2018, it was determined that pre-development aquifer recharge within the study area accounted for **40%** of the overall sites water budget. The City and RVCA determined that pre-development aquifer recharge levels should be maintained under post-development conditions and that the infiltration should be provided across the development and not simply concentrated in one or two locations. The City and RVCA determined that the preferred infiltration servicing strategy for this area would be Etobicoke Exfiltration Systems (EES) and that these systems should be limited only to local roads and their respective catchments, with the intent to prohibit any infiltration of roadway runoff from either collector or arterial roads due to the salting practices applied at those locations.

## Etobicoke Exfiltration System (EES) Design

Within the Drummond development, there will be a total of **27** EESs implemented, to meet the aquifer recharge requirements outlined above. The EES units will be installed underneath storm sewers within the right-of-way (ROW) in specific areas as determined by David Schaeffer Engineering (DSEL) as a part of the development's detailed design. Each system will consist of one **250 mm** diameter perforated pipe surrounded by a **0.85 m** deep by **1.20 m** wide clear stone trench. Detailed drawings of the proposed EES units are provided in **Figure 1A**. The location and extent of each EES are indicated in **Figure 2**. **Figure 3** outlines the total drainage area to each of the units and the respective runoff coefficients.

Based on the areas provided in **Figure 3** the LID units (EES and CB trenches) will service a total drainage area of **16.83 ha (88%** of the total development), with **9.75 ha** of area treated by LID that drains to the Ridge Pond and **7.08 ha** treated by LID that drains to the Clarke Pond. Note that the application of EESs throughout the development is limited due to the presence of collector roads running through the southern extent and middle (north-south) of the development, although EESs have been implemented at all other practical locations within the site. **Table A1 to A3** in **Attachment A** provides a full summary of the design parameters for each EES. Note that there are no LID measures proposed on private property (residential rear yards) or within the parklands.

### Catch Basin Exfiltration Trench (CB Trench) Design

Also within the Drummond development, there will be a total of **8** Catch Basin Exfiltration Trenches, to meet the aquifer recharge requirements outlined above. These CB trenches will capture runoff from the local street and rear yards that drain to each CB, like conventional CB, but will also be equipped with a perforated pipe/exfiltration trench system connected near the sump of the CB that will allow runoff captured by the CB to flow to an exfiltration trench, where it can exfiltrate back into the ground. The ICD/lead pipe for each CB will be set above the top of this trench ensuring that all the storage volume within the trench will need to be used before any runoff is conveyed to the minor system. All of these trenches will be **1.2m** wide, **40m** long and **0.4m** deep, filled with clear stone and equipped with a **250 mm** perforated sub-drain pipe throughout the length of the trench. Detailed drawings of the proposed CB trenches have been provided in **Figure 1B**. The location and extent of each CB trench are indicated in **Figure 2**. **Figure 3** outlines the total drainage area to each of the units and the respective runoff coefficients. **Table A1 to A3** in **Attachment A** provides a full summary of the design parameters for each CB exfiltration Trench. Again note that there are no LID measures proposed on private property (residential rear yards) or within the parklands.

### Modelling Approach

The model used for this water budget analysis builds on the existing detailed PCSWMM model of the Drummond/Ridge development, which was created as a part of the stormwater management analysis. All components of this model remain unaltered, such as subcatchment parameters, SWM pond configuration, catch basins and the major and minor systems, with the only exception being the removal of the upstream portion of the model (Ridge development) which has no bearing on the water budget for the Drummond site, and significantly reduces model simulation run times.

The storage provided by each of the EESs and CB trenches has been represented in the model as storage nodes, with appropriate depth/area curves assigned to each LID based on the detailed design parameters. A porosity of **0.4** has been assumed for all LIDs, and as all units will contain a perforated PVC pipe to help disperse the runoff throughout the entire system, the storage volume provided by these pipes has also been accounted for in the LID storage volume curves.

The soil infiltration rate for the site, determined by Paterson Group (see below), was reduced by a factor of safety of **2.5** as per the guidance from Credit Valley and Toronto and Region Conservation Authorities on Low Impact Development. A specific outlet curve (depth/flow relationship) was developed for each LID, based on its respective geometry. Note that this analysis only considered infiltration through the bottom of the LID, resulting in a conservative estimate for the total infiltration benefits provided by each LID, as it is expected that runoff captured by the LID will be able to exfiltrate through the sides of the trench. The total flow through each outlet curve was then used to determine the total aquifer recharge provided by each LID.

The proposed EESs were connected to their respective maintenance holes in the model through an orifice of **250 mm** with a discharge coefficient of **0.82** (short pipe) to reflect any restriction that the proposed perforated pipe could have on conveying flow from the maintenance hole to the EES. Each perforated pipe has been reviewed for the more frequent events to ensure that the pipe inlet is not obstructing flows from getting into the system. Note that all EESs are named after the maintenance hole that they are connected to.

The proposed CB trenches are connected to their respective maintenance hole in the model through an orifice reflective of the proposed ICD to be implemented at each location, as mentioned above these orifices are set above the top of the trench to ensure the full storage volume of the trench is utilized before spilling to the minor system.

### Soil Infiltration Rate

Paterson Group conducted soil infiltration testing within the vicinity of the proposed LID measures, which determined a soil infiltration rate of **50 mm/hr** for the Drummond site. Email correspondence indicating the infiltration rate obtained by Paterson for the subject site has been included in **Attachment A**. For the subcatchments within the development, default Hortons infiltration values have been applied as per the City of Ottawa Sewer Design Guidelines (2012).

### Evaporation & Evapotranspiration Parameters

To ensure that the depression storage within the model subcatchments can regenerate after the first rainfall event, monthly evaporation rates have been applied. The Master Servicing Study provided no documentation on the surface evaporation rates used in that analysis, and as such monthly evaporation rates applied in this model are as per those specified in the City of Ottawa's PCSWMM Carp River model documentation. A summary of these monthly values can be found in **Attachment A Table A4**. To ensure that evapotranspiration is appropriately accounted for in the continuous simulation water budget, the groundwater routine within the model's hydrologic algorithm has been activated. Groundwater parameters have been applied as specified for type A soils in the J L Richards Master Servicing Study. Excerpts from this report regarding the groundwater parameters have been provided in **Attachment A**.

### EES Drawdown Times

As indicated above, all EES units will have a maximum depth of **850 mm** with an assumed porosity of **0.4**. Based on the site soil infiltration rate of **50 mm/hr**, determined by Paterson in the field, and assuming only bottom infiltration, this equates to a full EES having a drawdown time of approximately **6 hours**. Applying a safety factor of **2.5** to the site infiltration rate, the draw downtime is **17 hours**, with both values being substantially less than the 24 - 48-hour maximum drawdown times generally permitted.

### CB Trench Drawdown Times

As indicated above, all CB trench units will have a maximum depth of **400 mm** with an assumed porosity of **0.4**. Based on the site soil infiltration rate of **50 mm/hr**, determined by Paterson in the field, and assuming only bottom infiltration, this equates to a full CB trench having a drawdown time of approximately **3.2 hours**. Applying a safety factor of 2.5 to the site infiltration rate, the draw downtime is **8 hours**, with both values being substantially less than the 24 - 48-hour maximum drawdown times generally permitted.

## Continuous Simulations

The detailed PCSWMM model was run for **39** years, from 1967 to 2007, using hourly rainfall data from Environment Canada's Ottawa International Airport station. Note that there was no data available for the years 2001 and 2005 in this data set. The hourly rainfall data used in this analysis is a heavily reviewed and vetted product sold by Environment Canada, and only includes rainfall data and does not include any snowfall that occurred during this window.

**Table B1 in Attachment B** provides a full summary of the rainfall data used in this analysis. From this rainfall data, it is seen that the average yearly simulated rainfall for this window is **552.0 mm**. As specified by the Master Servicing Study, the proposed development should infiltrate **40%** of the annual runoff. As the hourly rainfall data used in this simulation does not extend the full year, the infiltration target for this analysis has been assumed to be **40%** of the average simulated rainfall volume (**552.0 mm**), which is calculated to be **220.8 mm** or **42,090 m<sup>3</sup>** based on the **19.06 ha** study area.

## Simulation Results

Error! Reference source not found. outlines the average simulated infiltration volumes for each of the proposed LIDs contained within the development, as per the model simulations from 1967 - 2007. From this analysis, it was found that on average all LIDs will infiltrate **26,949 m<sup>3</sup> / 141.4 mm** per year, based on the simulated window. The total annual infiltration volumes for each LID have been provided in **Tables B2 in Attachment B**. Also provided in **Attachment B** are full summaries of the surface runoff, surface infiltration and groundwater evapotranspiration for each of the subcatchments within the model for each simulated year. Note that the surface infiltration volumes have not been considered as "truly infiltrated" in this water budget analysis, as these volumes are simply an indicator of the rainfall volume that is passed to the groundwater module. This volume will then either evapotranspire or infiltrate into the groundwater aquifer, based on the program's groundwater algorithms, the volume that is considered to return to the groundwater aquifer per the modelling results is considered as infiltrated.

**Table 1** below outlines that the proposed LIDs within the development will on average infiltrate **26,949 m<sup>3</sup> / 141.4 mm** per year (**25.8%** of the total precipitation) for the **19.06 ha** area serviced by the LID units. **Table 2** outlines the water budget breakdown of the development based on the 39 years of simulations, this includes evaporation (wetting losses), evapotranspiration, infiltration, and runoff from the various components within the development. From this analysis, it is seen that the pervious surfaces within the development will infiltrate **19,810 m<sup>3</sup> / 103.9 mm** (**17.8%** of the total precipitation) for the full development area of **19.06 ha**. Adding the average infiltration volumes provided by the EESs and pervious surfaces results in the average total infiltration for the site of **46,759 m<sup>3</sup> / 245.3 mm** (**43.5%** of the total precipitation). This exceeds the **40%** infiltration requirement set out by the Master Servicing study by **3.5%** (**4,668 m<sup>3</sup> / 24.5 mm**). Based on the continuous simulations using **39** years of historical rainfall data it was determined that the proposed water budget for the Drummond subdivision would be **20%** surface runoff, **36.4%** evaporation and **43.5%** infiltration.

Table 1: The Drummond Development - LID  
Average Infiltration Values

EES ID	Average Annual Infiltration (m <sup>3</sup> )
MH-502	1,672
MH-503	551
MH-504	1,506
MH-508	745
MH-509	84
MH-510	144
MH-511	1,618
MH-513	1,526
MH-517	1,504
MH-520	599
MH-521	21
MH-522	705
MH-524	1,272
MH-5240	862
MH-525	668
MH-534	1,426
MH-547	862
MH-548	336
MH-549	226
MH-550	1,001
MH-551	771
MH-553	1,847
MH-556	799
MH-557	626
MH-558	187
MH-560	968
MH-565	1,461
CB-109	428
CB-111	366
CB-116	397
CB-12	350
CB-126	352
CB-16	430
CB-4	332
CB-94	307
<b>Average (m<sup>3</sup>)</b>	770
<b>Total (m<sup>3</sup>)</b>	26,949
<b>Average* (mm)</b>	4.0
<b>Total* (mm)</b>	141.4

\*Based on the 19.06 ha serviced by the EES units

Table 2: The Drummond Development - Water Budget Summary

Year	Rainfall		Subcatchments						Ground water				EES		Water Budget Summary					
	[1] (mm)	[2] (m³)	[3] Surface Runoff		[2]-[3]-[5] Surface Evaporation		[5] Surface Infiltration		[6] Evapotranspiration		[5]-[6] Subsurface		[7] EES Infiltration		[3]-[7] Total Runoff		[4]-[6] Total Evaporation		[5]-[6]+[7] Total Aquifer	
1967	373	71,100	34,464	48%	5,022	7%	31,614	44%	13,139	18%	18,475	26%	18,885	27%	15,579	22%	18,161	26%	37,360	53%
1968	520.6	99,235	46,380	47%	9,042	9%	43,813	44%	27,528	28%	16,285	16%	24,704	25%	21,676	22%	36,570	37%	40,989	41%
1969	499	95,118	42,866	45%	10,293	11%	41,959	44%	27,335	29%	14,624	15%	25,537	27%	17,329	18%	37,628	40%	40,161	42%
1970	538.1	102,571	48,125	47%	10,401	10%	44,044	43%	27,156	26%	16,889	16%	26,136	25%	21,989	21%	37,557	37%	43,025	42%
1971	491	93,593	40,359	43%	12,255	13%	40,978	44%	26,239	28%	14,740	16%	23,544	25%	16,815	18%	38,494	41%	38,284	41%
1972	764.1	145,650	70,794	49%	12,416	9%	62,439	43%	25,159	17%	37,281	26%	35,495	24%	35,299	24%	37,575	26%	72,776	50%
1973	670.1	127,732	60,556	47%	11,483	9%	55,694	44%	26,338	21%	29,356	23%	32,045	25%	28,511	22%	37,821	30%	61,401	48%
1974	332.1	63,304	26,320	42%	9,287	15%	27,697	44%	27,838	44%	-141	0%	19,297	30%	7,023	11%	37,125	59%	19,156	30%
1975	497.7	94,870	44,783	47%	8,896	9%	41,191	43%	27,903	29%	13,288	14%	23,761	25%	21,022	22%	36,799	39%	37,049	39%
1976	467.5	89,113	38,117	43%	11,307	13%	39,689	45%	26,602	30%	13,087	15%	24,858	28%	13,259	15%	37,909	43%	37,945	43%
1977	587.6	112,006	51,900	46%	10,391	9%	49,715	44%	26,829	24%	22,886	20%	30,428	27%	21,472	19%	37,220	33%	53,314	48%
1978	558.2	106,402	47,899	45%	11,911	11%	46,592	44%	26,307	25%	20,285	19%	27,819	26%	20,080	19%	38,218	36%	48,104	45%
1979	753.6	143,649	70,303	49%	10,942	8%	62,404	43%	26,571	18%	35,833	25%	33,031	23%	37,272	26%	37,513	26%	68,864	48%
1980	555	105,792	47,144	45%	11,329	11%	47,319	45%	26,473	25%	20,846	20%	28,986	27%	18,158	17%	37,802	36%	49,832	47%
1981	840.9	160,290	79,293	49%	13,780	9%	67,217	42%	24,723	15%	42,494	27%	36,487	23%	42,806	27%	38,502	24%	78,981	49%
1982	542.6	103,429	47,157	46%	10,041	10%	46,231	45%	27,278	26%	18,952	18%	29,147	28%	18,010	17%	37,319	36%	48,099	47%
1983	537	102,361	45,666	45%	10,797	11%	45,898	45%	26,933	26%	18,965	19%	28,501	28%	17,165	17%	37,731	37%	47,466	46%
1984	416.2	79,335	36,514	46%	7,454	9%	35,367	45%	29,064	37%	6,304	8%	21,167	27%	15,347	19%	36,517	46%	27,471	35%
1985	456	86,921	39,485	45%	9,041	10%	38,396	44%	27,726	32%	10,670	12%	21,875	25%	17,610	20%	36,767	42%	32,545	37%
1986	814	155,162	73,337	47%	12,505	8%	69,320	45%	25,313	16%	44,006	28%	38,107	25%	35,230	23%	37,818	24%	82,113	53%
1987	602.9	114,923	52,287	45%	11,635	10%	51,000	44%	26,246	23%	24,754	22%	30,751	27%	21,536	19%	37,881	33%	55,505	48%
1988	610.2	116,314	54,707	47%	10,992	9%	50,616	44%	26,519	23%	24,097	21%	29,488	25%	25,219	22%	37,510	32%	53,585	46%
1989	512.8	97,748	43,394	44%	11,065	11%	43,289	44%	26,823	27%	16,467	17%	25,746	26%	17,648	18%	37,887	39%	42,213	43%
1990	651.2	124,130	55,724	45%	13,354	11%	55,052	44%	25,279	20%	29,772	24%	31,550	25%	24,174	19%	38,633	31%	61,322	49%
1991	520.4	99,197	43,581	44%	11,319	11%	44,297	45%	26,740	27%	17,556	18%	27,358	28%	16,223	16%	38,059	38%	44,914	45%
1992	621.2	118,411	55,399	47%	11,656	10%	51,356	43%	25,810	22%	25,545	22%	30,202	26%	25,197	21%	37,467	32%	55,747	47%
1993	643.5	122,662	53,877	44%	13,877	11%	54,908	45%	25,296	21%	29,612	24%	33,525	27%	20,352	17%	39,174	32%	63,137	51%
1994	514.5	98,072	45,339	46%	9,536	10%	43,197	44%	27,374	28%	15,823	16%	24,179	25%	21,160	22%	36,910	38%	40,002	41%
1995	443.6	84,558	41,305	49%	6,053	7%	37,200	44%	29,936	35%	7,264	9%	16,823	20%	24,482	29%	35,988	43%	24,087	28%
1996	476.8	90,886	40,956	45%	9,565	11%	40,365	44%	27,510	30%	12,855	14%	24,508	27%	16,448	18%	37,075	41%	37,363	41%
1997	363.6	69,308	30,296	44%	8,062	12%	30,951	45%	28,502	41%	2,449	4%	20,094	29%	10,202	15%	36,564	53%	22,543	33%
1998	440.3	83,929	36,390	43%	10,289	12%	37,250	44%	26,914	32%	10,336	12%	21,902	26%	14,488	17%	37,202	44%	32,238	38%
1999	424.4	80,898	36,135	45%	8,890	11%	35,873	44%	27,987	35%	7,887	10%	21,116	26%	15,019	19%	36,876	46%	29,003	36%
2000	535.9	102,152	43,916	43%	12,885	13%	45,350	44%	25,475	25%	19,875	19%	25,793	25%	18,123	18%	38,360	38%	45,668	45%
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2002	551.5	105,125	51,653	49%	8,372	8%	45,100	43%	27,892	27%	17,209	16%	25,320	24%	26,333	25%	36,264	34%	42,529	40%
2003	554.6	105,716	46,852	44%	11,684	11%	47,180	45%	26,059	25%	21,121	20%	26,671	25%	20,181	19%	37,743	36%	47,792	45%
2004	573.3	109,281	54,081	49%	10,506	10%	44,694	41%	26,788	25%	17,907	16%	22,377	20%	31,704	29%	37,294	34%	40,284	37%
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2006	723.4	137,892	64,611	47%	11,382	8%	61,900	45%	25,718	19%	36,181	26%	36,660	27%	27,951	20%	37,100	27%	72,841	53%
2007	550.7	104,973	46,845	45%	11,568	11%	46,560	44%	25,804	25%	20,756	20%	27,130	26%	19,715	19%	37,372	36%	47,886	46%
<b>Average</b>	<b>552.0</b>	<b>105,226</b>	<b>48,431</b>	<b>45.8%</b>	<b>10,546</b>	<b>10.2%</b>	<b>46,249</b>	<b>44.0%</b>	<b>26,439</b>	<b>26.3%</b>	<b>19,810</b>	<b>17.8%</b>	<b>26,949</b>	<b>25.8%</b>	<b>21,482</b>	<b>20.0%</b>	<b>36,985</b>	<b>36.4%</b>	<b>46,759</b>	<b>43.5%</b>

Notes:

Total drainage area 19.06 ha

Surface Infiltration not considered as a part of the total aquifer recharge, as this value is simply the volume that is passed to the groundwater component



## Erosion & Sediment Control During & After Construction

Silt and erosion control strategies shall be implemented during construction activities to optimize the operations of the LID once implemented and minimize the siltation of the systems during construction. The following measures should be implemented:

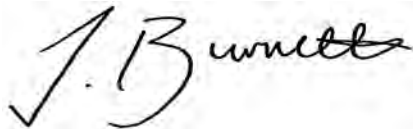
- Prior to site works, locations of the LIDs should be marked and vehicles to avoid this area other than during the installation of the LID drainage not to be directed to LID.
- Prior to the completion of landscape works, catch basins not connected to the LID practices can be used during construction for drainage.
- Heavy equipment and traffic should avoid travelling over the proposed location of the facility to minimize the compaction of the soil.
- To minimize siltation during construction, the EES units should be constructed with upstream and downstream plugs. During construction, these plugs will be implanted preventing sediments from entering the units. Once an occupancy of 80% is achieved, the upstream plug will then be removed and the EES units allow to operate as intended.
- Facilities should be kept “off-line” until construction is complete. They should never serve as a sediment control device during site construction. Sediment should be prevented from entering the infiltration facility using super silt fence, diversion berms or other means.
- Upland drainage areas need to be properly stabilized with a thick layer of vegetation, particularly immediately following construction, to reduce sediment loads.
- The facility should be excavated to design dimensions from the side using a backhoe or excavator. The base of the facility should be level or nearly level.
- The bottom of the facility should be scarified to improve infiltration. An optional 150 mm of sand could be spread for the bottom filter layer. The monitoring well should be anchored and stone should be added to the facility in 0.3-metre lifts.
- Geotextile fabric should be correctly installed in the soakaway or infiltration trench excavation. Large tree roots should be trimmed flush with the sides of the facility to prevent puncturing or tearing of the fabric during subsequent installation procedures. When laying out the geotextile, the width should include sufficient material to compensate for perimeter irregularities in the facility and for a 150 mm minimum top overlap. Voids may occur between the fabric and the excavated sides of the facility. Natural soils should be placed in any voids to ensure fabric conformity to the excavation sides

## Conclusion

In summary, the detailed PCSWMM model of the proposed Drummond development has been updated to include the LID measures proposed within the site. Continuous simulations using **39** years of historical rainfall data determined that the proposed water budget for the Drummond subdivision would be **20%** surface runoff, **36.4%** evaporation and **43.5%** infiltration. From this analysis, it was found that the proposed LIDs within the development will on average infiltrate **26,949 m<sup>3</sup> / 141.4 mm (25.8%** of the total precipitation) while the pervious surfaces within the development will infiltrate **19,810 m<sup>3</sup> / 103.9 mm (17.8%** of the total precipitation). Adding the infiltration provided by the LIDs and the pervious surfaces results in the average total infiltration for the site being **46,759 m<sup>3</sup> / 245.3 mm (43.5%** of the total precipitation). Exceeding the **40%** infiltration requirement set out by the Master Servicing study by **3.5%**.

It is important to consider that there are several conservative assumptions made within this analysis, that result in the simulated average infiltration values being lower than what is likely expected when the design is physically implemented. These assumptions include the reduction of the reported/observed soil infiltration rates by a factor of **2.5** and the consideration that exfiltration within the LID trenches only occurs through the bottom of the trench.

Yours truly,  
**J.F Sabourin and Associates Inc.**



Jonathon Burnett, B.Eng, P.Eng  
Water Resources Engineer



cc: J.F Sabourin, M.Eng, P.Eng  
Director of Water Resources Projects

## Figures

- Figure 1A: Exfiltration Trench System Details
- Figure 2A: Catchbasin Exfiltration Trench Details
- Figure 2: LID Locations
- Figure 3: Exfiltration System Drainage Areas

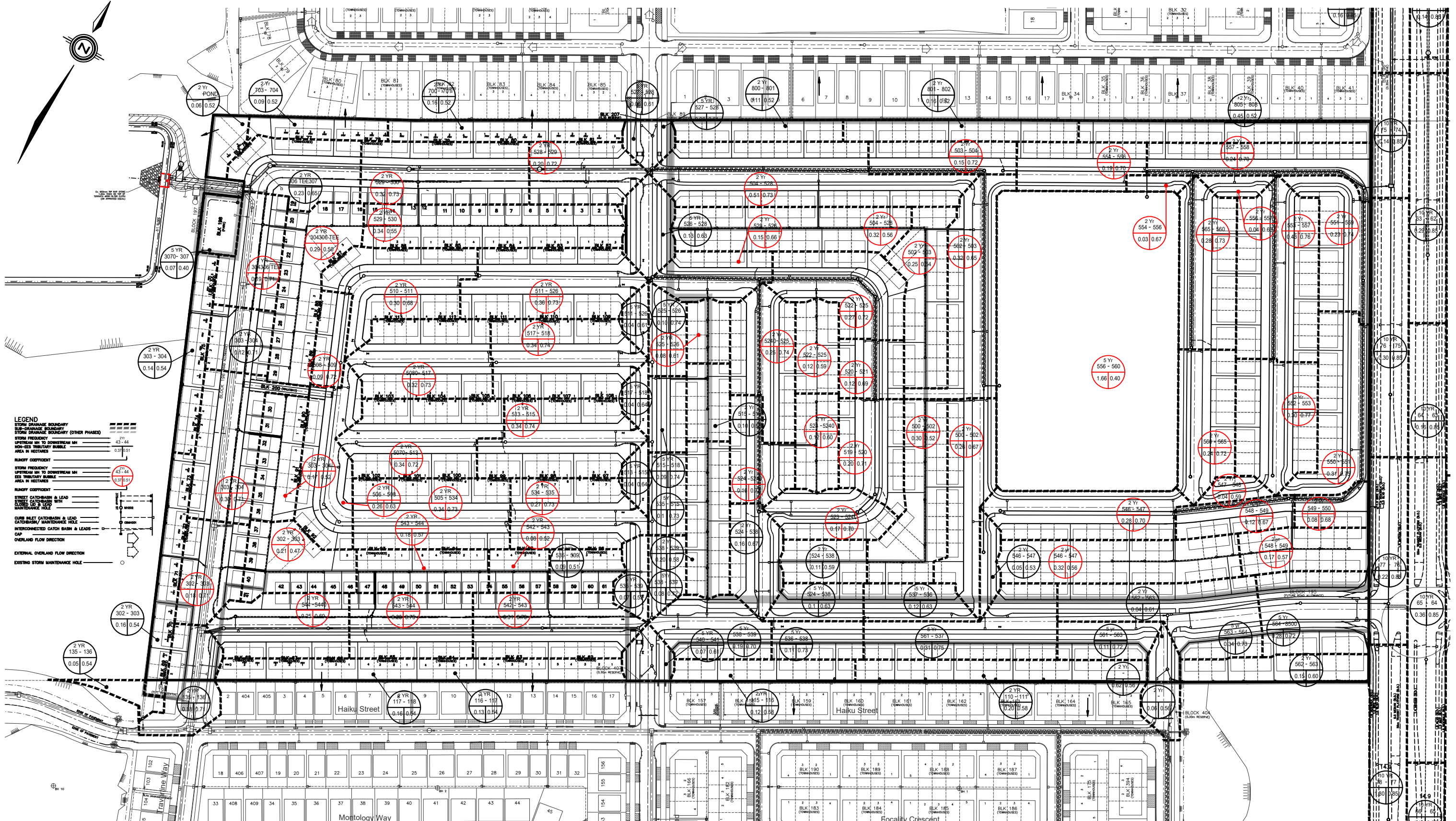
## Tables

- Table 1: LID Infiltration Summary
- Table 2: Water Budget Summary

## Attachments

- Attachment A: Continuous Simulation Parameters & Background Information
- Attachment B: Continuous Simulation Results



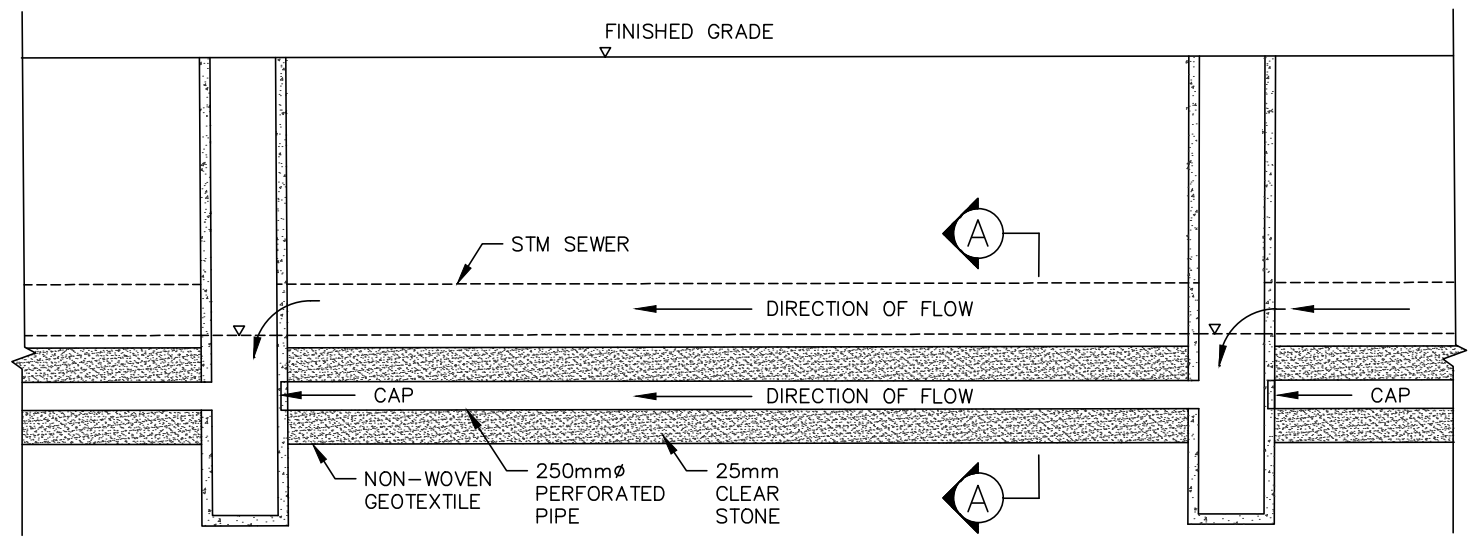


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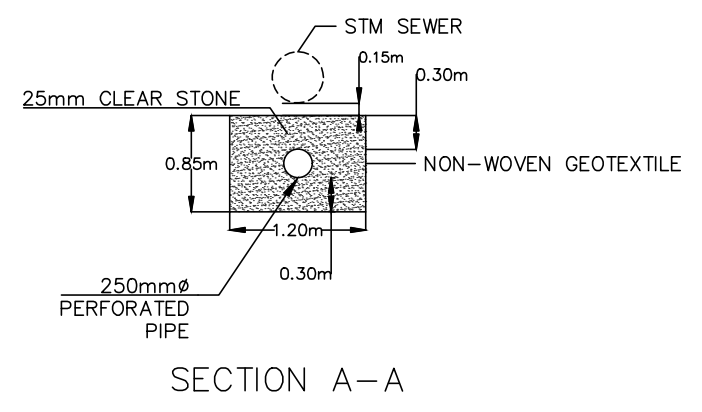
CAIVAN COMMUNITIES - THE RIDGE PHASE 3&4  
 CITY OF OTTAWA

EES DRAINAGE AREA FIGURE

SCALE:	1:2000	PROJECT No.:	19-1123
DATE:	JUNE 2023	FIGURE:	1



PROFILE  
SCALE N.T.S.



SECTION A-A

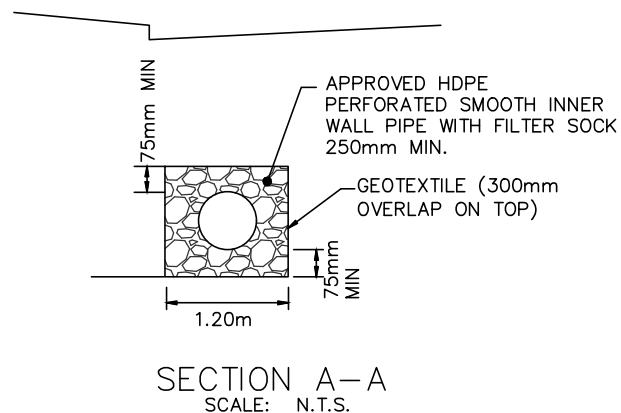
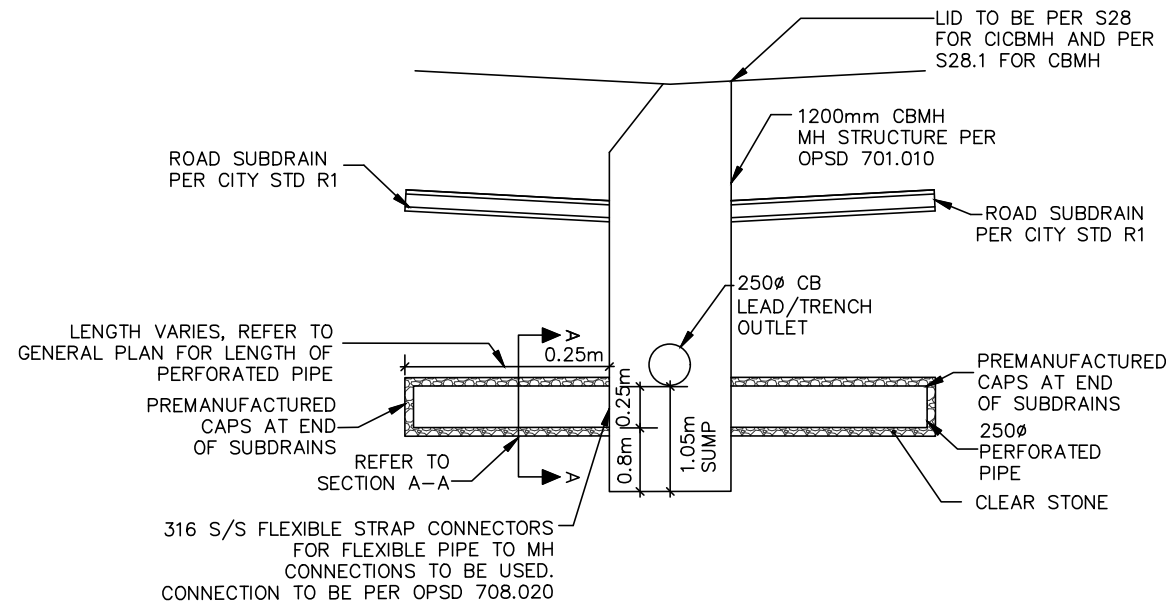
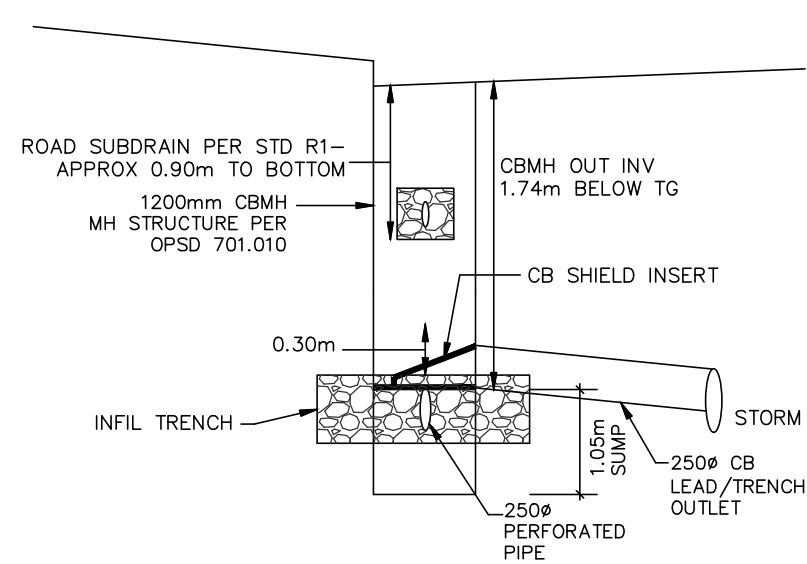


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Tel. (613) 836-0856  
Fax. (613) 836-7183  
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CITY OF OTTAWA

EXFILTRATION TRENCH DETAILS

SCALE:	N.T.S	PROJECT No.:	19-1123
DATE:	MAY 2022	FIGURE:	1A



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CAIVAN COMMUNITIES - THE RIDGE PHASE 3&4  
 CITY OF OTTAWA

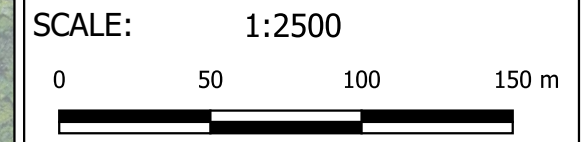

CBMH INFILTRATION TRENCH DETAILS			
SCALE:	N.T.S	PROJECT No.:	19-1123
DATE:	MAY 2022	FIGURE:	1B





### Legend

-  Etobicoke Exfiltration Systems (EES)
- Conduits**
-  STM
- Junctions**
-  MH
-  Catch Basin
-  Catch Basin Exfiltration Trench
-  Development Plan

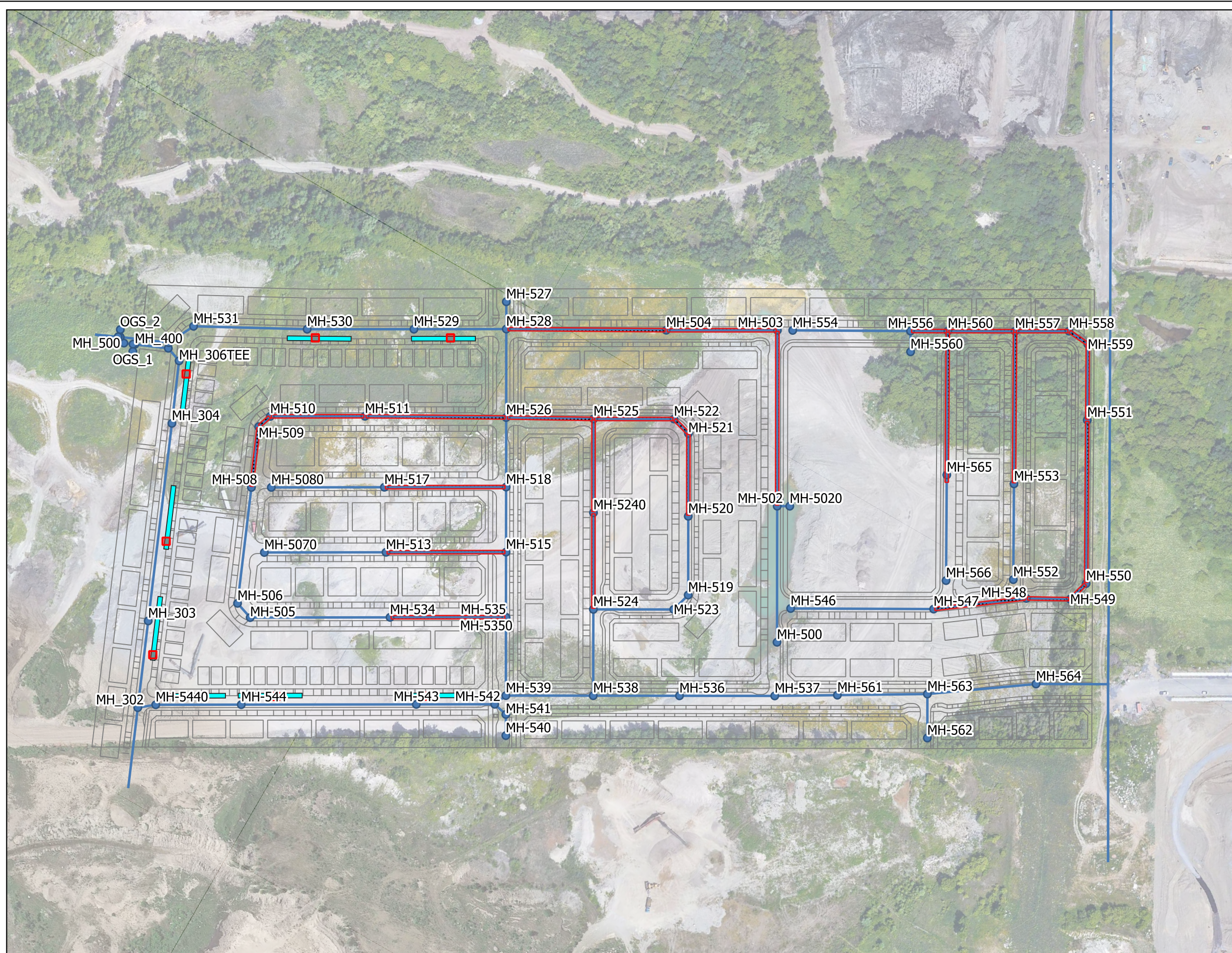
**J.F. Sabourin and Associates Inc.**  
 WATER RESOURCES AND ENVIRONMENTAL CONSULTANTS  
 52 Springbrook Drive  
 Ottawa, ON, K2S 1B9  
 (613) 836-3884  
 www.jfsa.com



Drummond Low Impact  
 Development (LID) Design

Figure 2: EES Locations

PROJECT	2226
DRAWN	ON
DATE	JUNE 2023







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52 Springbrook Drive,  
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T 613-836-3884 F 613-836-0332

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# Attachment A

Continuous Simulation Parameters & Background Information







**Table A2 - Monthly Evaporation Rates**

<b>Month</b>	<b>Evaporation Rate (mm/Day)</b>
January	0
February	0
March	0
April	1.133
May	2.516
June	3.933
July	4.516
August	3.871
September	2.367
October	1.387
November	0.2
December	0

Source: Table 10- MODEL DEVELOPMENT PROGRAM – CARP RIVER RESTORATION PLAN - Appendices, City of Ottawa (Feb 2014)

**From:** David Gilbert <[DGilbert@Patersongroup.ca](mailto:DGilbert@Patersongroup.ca)>

**Sent:** August 29, 2019 5:30 PM

**To:** Susan Murphy <[susan.murphy@caivan.com](mailto:susan.murphy@caivan.com)>; Steve Pichette <[SPichette@dsel.ca](mailto:SPichette@dsel.ca)>

**Cc:** Michael Killam <[MKillam@Patersongroup.ca](mailto:MKillam@Patersongroup.ca)>

**Subject:** Drummonds and Brazeau Pit - Infiltration information

Hi guys,

I spoke with Bobby Pettigrew at JL Richards and he used 40% of area precipitation to be infiltrated over a 30 year period using the infiltration system. Annual precipitation in water budget was noted to be 844 mm, so infiltration of 40% would be 338 mm. He noted that this amount was equivalent to full infiltration of a 22 mm rain event. The infiltration rate for system design for Brazeau Pit is 75 mm/hour and for Drummond Pit is 50 mm/hour. We are working on the groundwater contour plan based on our current groundwater observations for both sites. This drawing should be ready tomorrow.

Dave

David Gilbert, P.Eng.  
Senior Geotechnical Engineer

**patersongroup**  
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over 60 years serving our clients

154 Colonnade Road South  
Ottawa, Ontario, K2E 7J5  
Tel: (613) 226-7381 Ext. 205

### 3.0 GROUNDWATER

#### 3.1 Groundwater Parameters

Parameter	Units	Description																				
Aquifer Name	-	<p>Name of the aquifer representing soil conditions. Four Aquifers were created based on different soil conditions from OSG mapping. Only two of the aquifers are used within the study area.</p> <table border="1"> <thead> <tr> <th>Aquifer</th> <th>Description</th> <th>Clay content (%)</th> <th>Sand content (%)</th> </tr> </thead> <tbody> <tr> <td>A</td> <td>Sand</td> <td>5</td> <td>92</td> </tr> <tr> <td>B</td> <td>Sandy Loam</td> <td>10</td> <td>65</td> </tr> <tr> <td>C (not used)</td> <td>Sandy Clay Loam</td> <td>28</td> <td>60</td> </tr> <tr> <td>D (not used)</td> <td>Clay Loam</td> <td>34</td> <td>33</td> </tr> </tbody> </table>	Aquifer	Description	Clay content (%)	Sand content (%)	A	Sand	5	92	B	Sandy Loam	10	65	C (not used)	Sandy Clay Loam	28	60	D (not used)	Clay Loam	34	33
Aquifer	Description	Clay content (%)	Sand content (%)																			
A	Sand	5	92																			
B	Sandy Loam	10	65																			
C (not used)	Sandy Clay Loam	28	60																			
D (not used)	Clay Loam	34	33																			
Receiving Node	-	Name of the receiving node for groundwater outflow to baseflow. This is based on the groundwater subwatershed delineation.																				
Surface Elevation	m	<p>Elevation of the ground surface for the subcatchment was averaged from the Patterson report.</p> <p><b>Value: 107</b></p>																				
Coefficients		<p>The coefficients were set for the saturated groundwater zone to represent a storage reservoir where outflow is linear proportional to the water table depth without surface water interaction. It was considered that the nearest open water channels were sufficiently far to have negligible impact on groundwater levels. The groundwater equation used is:</p> $f_G = A1 (d_L - h_{sw})$ <p>Where:</p> <ul style="list-style-type: none"> <li><math>f_G</math> = groundwater flow</li> <li><math>d_L</math> = depth of the lower saturated subsurface zone</li> <li><math>h_{sw}</math> = height of surface water above the bottom of the groundwater zone</li> <li>A1 = Calibration factor (estimated at 0.05)</li> </ul> <p><b>Value: 0.05</b></p>																				
Surface Water Depth	m	<p>Set as 0.5 metres to allow flow from the water table to surrounding watercourses.</p> <p><b>Value: 0.5</b></p>																				

Parameter	Units	Description
Initial Elevation	m	Initial elevation of the water table  <b>Value: 95.5</b>
		All other parameters used as per the receiving node or aquifer

### 3.2 Aquifer Parameters

Parameter	Units	Description / Values										
Porosity	Fraction	<p>The following values were used for the volumetric water content of the soil at saturation (i.e. volume of water per total volume):</p> <table border="1"> <thead> <tr> <th>Soil Group</th> <th>A</th> <th>B</th> <th>C</th> <th>D</th> </tr> </thead> <tbody> <tr> <td>Porosity</td> <td>0.436</td> <td>0.450</td> <td>0.432</td> <td>0.472</td> </tr> </tbody> </table> <p>(Source: SPAW Calculator)</p>	Soil Group	A	B	C	D	Porosity	0.436	0.450	0.432	0.472
Soil Group	A	B	C	D								
Porosity	0.436	0.450	0.432	0.472								
Wilting Point	Fraction	<p>This is soil moisture contact at which plants cannot obtain sufficient moisture from the soil to meet transpiration requirements and they will die. It is roughly equivalent to the moisture content of soil at 15 atmospheres. The following values were used:</p> <table border="1"> <thead> <tr> <th>Soil Group</th> <th>A</th> <th>B</th> <th>C</th> <th>D</th> </tr> </thead> <tbody> <tr> <td>Wilting Point</td> <td>0.050</td> <td>0.081</td> <td>0.183</td> <td>0.213</td> </tr> </tbody> </table> <p>(Source: SPAW Calculator)</p>	Soil Group	A	B	C	D	Wilting Point	0.050	0.081	0.183	0.213
Soil Group	A	B	C	D								
Wilting Point	0.050	0.081	0.183	0.213								
Field Capacity	Fraction	<p>Considered to be the amount of water a well-drained soil holds after free water has drained off. The following values were used:</p> <table border="1"> <thead> <tr> <th>Soil Group</th> <th>A</th> <th>B</th> <th>C</th> <th>D</th> </tr> </thead> <tbody> <tr> <td>Field Capacity</td> <td>0.094</td> <td>0.179</td> <td>0.283</td> <td>0.350</td> </tr> </tbody> </table> <p>(Source: SPAW Calculator)</p>	Soil Group	A	B	C	D	Field Capacity	0.094	0.179	0.283	0.350
Soil Group	A	B	C	D								
Field Capacity	0.094	0.179	0.283	0.350								
Conductivity	mm/hr	<p>Within the Aquifer Parameters, the soil saturated conductivity is a governing parameter of the percolation rate between the upper unsaturated soil layer and the lower saturated soil layer. This is not the same as any hydraulic conductivity used for the surface infiltration. The values have been selected from the SPAW calculator and are:</p> <table border="1"> <thead> <tr> <th>Soil Group</th> <th>A</th> <th>B</th> <th>C</th> <th>D</th> </tr> </thead> <tbody> <tr> <td>Conductivity (mm/hr)</td> <td>114</td> <td>50.3</td> <td>7.8</td> <td>4.6</td> </tr> </tbody> </table> <p>(Source: SPAW Calculator)</p>	Soil Group	A	B	C	D	Conductivity (mm/hr)	114	50.3	7.8	4.6
Soil Group	A	B	C	D								
Conductivity (mm/hr)	114	50.3	7.8	4.6								

Parameter	Units	Description / Values										
Conductivity Slope	-	<p>Conductivity slope measures the rate at which a soil's hydraulic conductivity decreases with decreasing moisture content. Regression analysis has shown it can be estimated with the following relationship:</p> <p>Conductivity Slope = 0.48(% Sand) + 0.85(% Clay)</p> <p>Based on this relationship the following values were used:</p> <table border="1"> <thead> <tr> <th>Soil Group</th> <th>A</th> <th>B</th> <th>C</th> <th>D</th> </tr> </thead> <tbody> <tr> <td>Conductivity Slope</td> <td>48</td> <td>40</td> <td>53</td> <td>45</td> </tr> </tbody> </table>	Soil Group	A	B	C	D	Conductivity Slope	48	40	53	45
Soil Group	A	B	C	D								
Conductivity Slope	48	40	53	45								
Tension Slope		Used for backward compatibility in the software and not used in this model										
Upper Evaporation Factor	Fraction	<p>This factor determines the fraction of available subsurface evaporation rate used in the upper subsurface zone (compared to the lower subsurface zone). A higher evaporation rate is associated with looser soils, lower water table elevations and shallow root zones. It was assumed that in all soils 80% of the available subsurface evaporation would be used in the upper zone due to the depth of the water table.</p> <p><b>Value: 0.8</b></p>										
Lower Evaporative Depth	m	<p>The depth of the lower subsurface zone which can be used for evapotranspiration should be approximate to the expected average depth of root penetration. The following values were used:</p> <table border="1"> <thead> <tr> <th>Soil Group</th> <th>A</th> <th>B</th> <th>C</th> <th>D</th> </tr> </thead> <tbody> <tr> <td>Evaporative Depth (m)</td> <td>1.5</td> <td>2.4</td> <td>3.0</td> <td>5.2</td> </tr> </tbody> </table> <p><i>(Source: Shah et al 2007 from EPA 2015)</i></p>	Soil Group	A	B	C	D	Evaporative Depth (m)	1.5	2.4	3.0	5.2
Soil Group	A	B	C	D								
Evaporative Depth (m)	1.5	2.4	3.0	5.2								
Lower Groundwater Loss Rate	mm/hr	<p>This is the rate of percolation from the lower subsurface zone to a deep aquifer and is approximate to the rate at which the water table elevation will drop over a prolonged dry period. The saturated hydraulic conductivity of a compacted clay soil was used in all cases.</p> <p><b>Value: 0.004</b></p>										
Bottom Elevation	m	<p>The elevation of the bedrock as averaged from the Patterson 2016 report.</p> <p><b>Value: 85</b></p>										



Parameter	Units	Description / Values				
Unsaturated Zone Moisture		The moisture content of the unsaturated upper subsurface zone at the start of the simulation. Cannot be less than the wilting point and cannot be more than porosity. Assumed to be an approximate value between the wilting point and porosity fractions.				
		<b>Soil Group</b>	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>
		Evaporative Depth (m)	0.25	0.22	0.32	0.35

# Attachment B

## Continuous Simulation Results

**Table B1 - Yearly Precipitation**

Year	Rainfall	
	(mm)	(m <sup>3</sup> )
1967	373	71,100
1968	520.6	99,235
1969	499	95,118
1970	538.1	102,571
1971	491	93,593
1972	764.1	145,650
1973	670.1	127,732
1974	332.1	63,304
1975	497.7	94,870
1976	467.5	89,113
1977	587.6	112,006
1978	558.2	106,402
1979	753.6	143,649
1980	555	105,792
1981	840.9	160,290
1982	542.6	103,429
1983	537	102,361
1984	416.2	79,335
1985	456	86,921
1986	814	155,162
1987	602.9	114,923
1988	610.2	116,314
1989	512.8	97,748
1990	651.2	124,130
1991	520.4	99,197
1992	621.2	118,411
1993	643.5	122,662
1994	514.5	98,072
1995	443.6	84,558
1996	476.8	90,886
1997	363.6	69,308
1998	440.3	83,929
1999	424.4	80,898
2000	535.9	102,152
2001	-	-
2002	551.5	105,125
2003	554.6	105,716
2004	573.3	109,281
2005	-	-
2006	723.4	137,892
2007	550.7	104,973
<b>Average</b>	<b>552.0</b>	<b>105,226</b>

Notes:

Total drainage area 19.06 ha



Table B3 - Subcatchments

Node	Area	Yearly Runoff Volumes (m <sup>3</sup> )																				Average																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
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Table B4 - Subcatchments

Node	Area	Yearly Surface Infiltration Volumes (L/s)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
		1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100	2101	2102	2103	2104	2105	2106	2107	2108	2109	2110	2111	2112	2113	2114	2115	2116	2117	2118	2119	2120	2121	2122	2123	2124	2125	2126	2127	2128	2129	2130	2131	2132	2133	2134	2135	2136	2137	2138	2139	2140	2141	2142	2143	2144	2145	2146	2147	2148	2149	2150	2151	2152	2153	2154	2155	2156	2157	2158	2159	2160	2161	2162	2163	2164	2165	2166	2167	2168	2169	2170	2171	2172	2173	2174	2175	2176	2177	2178	2179	2180	2181	2182	2183	2184	2185	2186	2187	2188	2189	2190	2191	2192	2193	2194	2195	2196	2197	2198	2199	2200	2201	2202	2203	2204	2205	2206	2207	2208	2209	2210	2211	2212	2213	2214	2215	2216	2217	2218	2219	2220	2221	2222	2223	2224	2225	2226	2227	2228	2229	2230	2231	2232	2233	2234	2235	2236	2237	2238	2239	2240	2241	2242	2243	2244	2245	2246	2247	2248	2249	2250	2251	2252	2253	2254	2255	2256	2257	2258	2259	2260	2261	2262	2263	2264	2265	2266	2267	2268	2269	2270	2271	2272	2273	2274	2275	2276	2277	2278	2279	2280	2281	2282	2283	2284	2285	2286	2287	2288	2289	2290	2291	2292	2293	2294	2295	2296	2297	2298	2299	2300	2301	2302	2303	2304	2305	2306	2307	2308	2309	2310	2311	2312	2313	2314	2315	2316	2317	2318	2319	2320	2321	2322	2323	2324	2325	2326	2327	2328	2329	2330	2331	2332	2333	2334	2335	2336	2337	2338	2339	2340	2341	2342	2343	2344	2345	2346	2347	2348	2349	2350	2351	2352	2353	2354	2355	2356	2357	2358	2359	2360	2361	2362	2363	2364	2365	2366	2367	2368	2369	2370	2371	2372	2373	2374	2375	2376	2377	2378	2379	2380	2381	2382	2383	2384	2385	2386	2387	2388	2389	2390	2391	2392	2393	2394	2395	2396	2397	2398	2399	2400	2401	2402	2403	2404	2405	2406	2407	2408	2409	2410	2411	2412	2413	2414	2415	2416	2417	2418	2419	2420	2421	2422	2423	2424	2425	2426	2427	2428	2429	2430	2431	2432	2433	2434	2435	2436	2437	2438	2439	2440	2441	2442	2443	2444	2445	2446	2447	2448	2449	2450	2451	2452	2453	2454	2455	2456	2457	2458	2459	2460	2461	2462	2463	2464	2465	2466	2467	2468	2469	2470	2471	2472	2473	2474	2475	2476	2477	2478	2479	2480	2481	2482	2483	2484	2485	2486	2487	2488	2489	2490	2491	2492	2493	2494	2495	2496	2497	2498	2499	2500	2501	2502	2503	2504	2505	2506	2507	2508	2509	2510	2511	2512	2513	2514	2515	2516	2517	2518	2519	2520	2521	2522	2523	2524	2525	2526	2527	2528	2529	2530	2531	2532	2533	2534	2535	2536	2537	2538	2539	2540	2541	2542	2543	2544	2545	2546	2547	2548	2549	2550	2551	2552	2553	2554	2555	2556	2557	2558	2559	2560	2561	2562	2563	2564	2565	2566	2567	2568	2569	2570	2571	2572	2573	2574	2575	2576	2577	2578	2579	2580	2581	2582	2583	2584	2585	2586	2587	2588	2589	2590	2591	2592	2593	2594	2595	2596	2597	2598	2599	2600	2601	2602	2603	2604	2605	2606	2607	2608	2609	2610	2611	2612	2613	2614	2615	2616	2617	2618	2619	2620	2621	2622	2623	2624	2625	2626	2627	2628	2629	2630	2631	2632	2633	2634	2635	2636	2637	2638	2639	2640	2641	2642	2643	2644	2645	2646	2647	2648	2649	2650	2651	2652	2653	2654	2655	2656	2657	2658	2659	2660	2661	2662	2663	2664	2665	2666	2667	2668	2669	2670	2671	2672	2673	2674	2675	2676	2677	2678	2679	2680	2681	2682	2683	2684	2685	2686	2687	2688	2689	2690	2691	2692	2693	2694	2695	2696	2697	2698	2699	2700	2701	2702	2703	2704	2705	2706	2707	2708	2709	2710	2711	2712	2713	2714	2715	2716	2717	2718	2719	2720	2721	2722	2723	2724	2725	2726	2727	2728	2729	2730	2731	2732	2733	2734	2735	2736	2737	2738	2739	2740	2741	2742	2743	2744	2745	2746	2747	2748	2749	2750	2751	2752	2753	2754	2755	2756	2757	2758	2759	2760	2761	2762	2763	2764	2765	2766	2767	2768	2769	2770	2771	2772	2773	2774	2775	2776	2777	2778	2779	2780	2781	2782	2783	2784	2785	2786	2787	2788	2789	2790	2791	2792	2793	2794	2795	2796	2797	2798	2799	2800	2801	2802	2803	2804	2805	2806	2807	2808	2809	2810	2811	2812	2813	2814	2815	2816	2817	2818	2819	2820	2821	2822	2823	2824	2825	2826	2827	2828	2829	2830	2831	2832	2833	2834	2835	2836	2837	2838	2839	2840	2841	2842	2843	2844	2845	2846	2847	2848	2849	2850	2851	2852	2853	2854	2855	2856	2857	2858	2859	2860	2861	2862	2863	2864	2865	2866	2867	2868	2869	2870	2871	2872	2873	2874	2875	2876	2877	2878	2879	2880	2881	2882	2883	2884	2885	2886	2887	2888	2889	2890	2891	2892	2893	2894	2895	2896	2897	2898	2899	2900	2901	2902	2903	2904	2905	2906	2907	2908	2909	2910	2911	2912	2913	2914	2915	2916	2917	2918	2919	2920	2921	2922	2923	2924	2925	2926	2927	2928	2929	2930	2931	2932	2933	2934	2935	2936	2937	2938	2939	2940	2941	2942	2943	2944	2945	2946	2947	2948	2949	2950	2951	2952	2953	2954	2955	2956	2957	2958	2959	2960	2961	2962	2963	2964	2965	2966	2967	2968	2969	2970	2971	2972	2973	2974	2975	2976	2977	2978	2979	2980	2981	2982	2983	2984	2985	2986	2987	2988	2989	2990	2991	2992	2993	2994	2995	2996	2997	2998	2999	3000	3001	3002	3003	3004	3005	3006	3007	3008	3009	3010	3011	3012	3013	3014	3015	3016	3017	3018	3019	3020	3021	3022	3023	3024	3025	3026	3027	3028	3029	3030	3031	3032	3033	3034	3035	3036	3037	3038	3039	3040	3041	3042	3043	3044	3045	3046	3047	3048	3049	3050	3051	3052	3053	3054	3055	3056	3057	3058	3059	3060	3061	3062	3063	3064	3065	3066	3067	3068	3069	3070	3071	3072	3073	3074	3075	3076	3077	3078	3079	3080	3081	3082	3083	3084	3085	3086	3087	3088	3089	3090	3091	3092	3093	3094	3095	3096	3097	3098	3099	3100	3101	3102	3103	3104	3105	3106	3107	3108	3109	3110	3111	3112	3113	3114	3115	3116	3117	3118	3119	3120	3121	3122	3123	3124	3125	3126	3127	3128	3129	3130	3131	3132	3133	3134	3135	3136	3137	3138	3139	3140	3141	3142	3143	3144	3145	3146	3147	3148	3149	3150	3151	3152	3153	3154	3155	3156	3157	3158	3159	3160	3161	3162	3163	3164	3165	3166	3167	3168	3169	3170	3171	3172	3173	3174	3175	3176	3177	3178	3179	3180	3181	3182	3183	3184	3185	3186	3187	3188	3189	3190	3191	3192	3193	3194	3195	3196	3197	3198	3199	3200	3201	3202	3203	3204	3205	3206	3207	3208	3209	3210	3211	3212	3213	3214	3215	3216	3217	3218	3219	3220	3221	3222	3223	3224	3225	3226	3227	3228	3229	3230	3231	3232	3233	3234	3235	3236	3237	3238	3239	3240	3241	3242	3243	3244	3245	3246	3247	3248	3249	3250	3251	3252	3253	3254	3255	3256	3257	3258	3259	3260	3261	3262	3263	3264	3265	3266	3267	3268	3269	3270	3271	3272	3273	3274	3275	3276	3277	3278	3279	3280	3281	3282	3283	3284	3285	3286	3287	3288	3289	3290	3291	3292	3293	3294	3295	3296	3297	3298	3299	3300	3301	3302	3303	3304	3305	3306	3307	3308	3309	3310	3311	3312	3313	3314	3315	3316	3317	3318	3319	3320	3321	3322	3323	3324	3325	3326

Table B5 - Groundwater  
Yearly Site Surface Evap. Volumes (cu ft)

Node	Area	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Average
A130NE	0.026	30	62	62	62	60	58	60	63	63	61	61	60	61	60	57	62	61	65	63	58	60	60	61	58	61	58	62	67	62	64	61	63	58	60	61	63	60	61	63	59	59	60	37	37	39
A302NE	0.042	19	40	40	40	38	36	38	41	41	39	39	39	39	36	40	39	43	41	37	38	39	39	37	39	38	36	40	45	40	42	39	41	37	-	41	38	39	-	37	37	39				
A302NW	0.043	21	45	44	44	42	40	42	45	45	43	43	42	43	43	44	44	48	45	41	42	43	43	40	43	40	44	49	45	47	43	46	41	-	46	42	43	-	41	41	43	41	41	43		
A302SE	0.044	173	173	177	177	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173		
A302S	0.066	258	538	536	535	521	504	521	544	544	526	529	523	526	524	498	535	531	560	542	506	521	524	528	506	527	512	508	536	572	532	552	531	546	509	-	542	517	528	-	511	513	521			
A302R3	0.064	57	119	118	117	113	107	113	121	121	115	116	113	114	105	118	116	127	120	108	113	114	116	108	115	111	108	119	131	119	124	116	122	109	-	121	112	116	-	110	111	114				
A302R2	0.081	63	131	131	129	124	119	125	134	134	127	128	125	126	126	116	130	128	141	133	120	126	128	119	130	126	128	119	131	145	132	137	128	134	124	128	122	122	122	126	126	126	126	126		
A303W	0.053	23	49	49	48	46	44	47	50	50	47	48	46	47	43	48	48	52	49	44	46	47	47	44	47	45	44	49	54	49	51	48	50	45	-	50	46	47	-	45	45	47				
A303R1	0.016	14	29	29	29	26	26	28	30	30	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28			
A303R2	0.081	23	131	131	129	124	119	125	134	134	127	128	125	126	126	116	130	128	141	133	120	126	128	119	130	126	128	119	131	145	132	137	128	134	124	128	122	122	126	126	126	126	126	126		
A303R3	0.168	174	364	361	359	347	333	348	368	369	352	355	348	352	341	351	328	361	356	384	367	335	348	350	355	353	354	342	335	362	395	364	376	356	370	337	-	369	345	354	-	340	342	350		
A303SE	0.041	40	84	83	83	79	76	80	85	86	81	82	79	81	80	74	83	80	85	76	79	80	85	76	79	80	82	76	81	78	76	84	83	88	82	86	77	-	86	79	81	-	78	78	80	
A303SW	0.091	57	105	104	103	99	95	100	107	107	102	102	102	102	93	104	103	106	106	95	99	106	102	106	95	99	106	102	106	102	107	95	105	116	105	110	102	107	107	-	107	99	102	-	101	101
A304NE	0.083	38	80	79	78	76	76	81	81	77	78	75	77	76	70	79	78	85	81	72	75	76	77	72	77	72	77	74	72	79	88	80	83	78	81	73	-	81	75	77	-	74	74	76		
A304R1	0.231	277	578	576	574	558	539	559	585	585	564	567	560	563	562	532	574	569	604	583	542	558	561	567	541	566	549	543	576	618	578	594	570	587	545	-	583	554	566	-	547	549	559			
A304R2	0.059	51	108	107	106	102	97	102	109	109	103	104	102	103	103	95	106	105	115	108	98	102	103	104	97	104	100	97	107	118	108	112	105	110	98	-	109	101	104	-	99	100	103			
A304NE	0.095	79	166	164	163	156	149	157	168	168	159	160	157	158	146	164	161	176	167	150	156	158	161	150	160	154	149	164	182	165	172	161	168	151	-	168	155	160	-	153	154	158				
A306NW	0.136	74	156	155	154	148	140	148	159	159	150	151	147	150	149	137	155	152	167	158	141	147	150	142	151	145	141	151	156	163	152	159	142	-	159	146	151	-	144	145	149					
A306SE	0.027	8	17	16	16	15	16	17	17	16	16	16	16	16	16	15	16	16	18	17	15	16	16	16	15	15	15	15	15	15	17	17	16	15	-	17	16	15	-	15	15	16				
A307W	1.070	144	295	297	297	292	287	292	297	298	294	295	294	293	286	293	295	301	297	287	287	293	294	287	293	287	293	287	293	287	290	296	304	295	299	288	-	295	290	293	-	288	288	290		
A307R1	0.038	64	63	63	60	57	61	65	65	61	62	60	61	61	56	63	62	68	64	58	60	61	62	58	60	61	62	58	58	63	70	64	66	62	65	58	-	65	60	62	-	59	59	61		
A308NE	0.091	70	148	146	145	140	133	140	150	150	142	143	140	142	141	130	146	144	158	149	134	140	141	144	134	143	137	134	147	163	148	154	144	151	135	-	150	139	143	-	137	137	141			
A308NW	0.091	70	148	146	145	140	133	140	150	150	142	143	140	142	141	130	146	144	158	149	134	140	141	144	134	143	137	134	147	163	148	154	144	151	135	-	150	139	143	-	137	137	141			
A308R1	0.087	74	155	154	152	147	140	147	157	157	149	150	147	149	148	137	153	151	165	156	141	147	148	151	140	150	144	140	154	171	155	162	151	158	142	-	158	146	150	-	143	144	148			
A308R2	0.147	164	343	341	340	329	318	330	347	347	334	336	331	343	332	313	341	337	360	346	319	330	332	336	318	335	324	319	342	369	343	354	337	349	321	-	347	337	335	-	323	324	331			
A308R3	0.058	74	155	155	154	150	146	150	156	157	152	151	151	151	145	154	153	161	156	146	150	151	152	146	152	148	147	154	164	155	159	153	157	147	-	156	148	152	-	147	148	150				
A308SE	0.049	67	57	56	56	54	54	54	58	58	54	54	54	54	50	56	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54		
A309NE	0.104	6	13	13	13	12	12	13	13	12	12	12	12	12	11	13	14	13	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12		
A309NE	0.073	42	88	87	86	83	79	83	89	89	84	85	83	84	83	84	83	87	85	93	88	79	83	84	85	79	85	81	79	87	97	87	91	85	89	80	-	89	82	85	-	81	81	84		
A309NW	0.029	32	67	67	66	65	65	65	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	
A309R1	0.200	201	422	419	416	402	385	403	427	428	408	411	403	407	378	418	413	447	426	388	402	406	411	387	410	396	387	420	460	422	437	413	430	390	-	428	400	411	-	394	395	405				
A309R2	0.051	41	87	86	85	82	78	83	88	88	84	84	82	83	83	83	87	85	93	88	79	82	83	84	79	84	81	79	86	96	87	91	85	89	79	-	88	82	84	-	80	81	83			
A309S1	0.083	69	145	143	142	137	130	137	147	147	139	140	137	139	138	127	143	141	154	146	131	137	138	140	131	144	134	131	144	159	145	151	141	147	132	-	147	136	140	-	134	134	138			
A309SE	0.034	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43		
A309SW	0.101	50	105	104	103	99	95	100	107	107	101	102	100	101	100	93	104	102	112	106	95	99	101	102	95	103	98	95	105	116	105	110														

Table 85 - Groundwater

Node	Area	Yearly Sub-Surface Exp. Volumes (m <sup>3</sup> )																												Average															
		1987	1988	1989	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994		1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007		
A333NE	0.068	68	144	143	142	137	131	137	145	146	139	140	137	139	138	129	142	140	152	145	132	137	138	140	132	139	135	132	143	156	144	149	141	146	133	146	136	140	134	135	138				
A335SW	0.096	42	89	88	87	84	80	84	90	90	85	86	84	85	86	84	85	78	88	87	95	90	81	84	85	86	80	88	98	89	93	86	91	81	-	101	93	86	-	82	82	85			
A339NE	0.107	47	99	98	97	94	89	94	100	101	95	96	94	95	94	87	98	96	106	100	90	93	95	96	90	96	92	89	98	109	99	103	96	101	90	-	101	93	96	-	92	92	95		
A337NE	0.117	84	176	175	173	166	158	167	179	179	169	171	167	169	168	155	174	172	188	178	160	167	169	171	160	170	164	159	175	195	176	176	172	180	161	-	179	165	171	-	163	164	169		
A338NE	0.126	51	107	106	105	101	96	102	108	109	103	104	101	102	102	102	104	106	104	114	108	97	101	102	104	97	103	99	97	106	118	107	112	104	109	97	-	109	100	104	-	99	99	102	
A338NW	0.083	40	83	83	82	79	75	79	84	85	80	81	79	80	79	73	82	81	89	84	75	79	80	81	75	80	87	75	83	92	83	87	81	85	76	-	85	78	81	-	77	77	80		
A338R1	0.024	50	106	105	104	103	100	103	107	108	101	101	93	105	103	113	107	106	110	103	96	103	98	96	105	111	106	111	106	110	108	97	-	108	98	103	-	98	98	103	-	98	98	101	
A338R2	0.143	134	261	258	256	246	235	247	264	265	250	253	247	250	249	230	258	254	278	263	236	247	249	249	253	236	252	242	236	259	287	261	271	254	265	238	-	265	245	253	-	241	242	249	
A338SE	0.034	27	57	56	56	54	51	54	57	58	54	55	54	54	54	50	56	55	60	57	51	54	54	55	51	55	53	51	56	62	57	59	55	58	52	-	58	53	55	-	52	53	54		
A338SW	0.032	28	58	58	57	55	53	55	59	59	56	57	55	56	56	51	58	57	62	59	53	55	56	57	53	56	54	53	58	64	58	61	57	59	53	-	59	55	57	-	54	54	56		
A340NE	0.031	23	49	48	48	46	44	46	49	47	47	46	47	46	43	48	47	52	49	44	46	47	44	47	45	44	48	54	49	51	47	49	44	-	49	46	47	-	45	45	45				
A340NW	0.034	27	57	56	56	54	51	54	57	58	54	55	54	54	54	50	56	55	60	57	51	54	54	55	51	55	53	51	56	62	57	59	55	58	52	-	58	53	55	-	52	53	54		
A340R1	0.028	42	87	87	87	85	83	85	88	88	86	86	86	86	86	86	86	83	87	87	87	87	80	88	84	86	86	84	84	84	87	91	87	89	87	89	84	-	88	85	86	-	84	84	85
A340R2	0.028	42	87	87	87	85	83	85	88	88	86	86	86	86	86	86	86	86	83	87	87	87	80	88	84	86	86	84	84	87	91	87	89	87	89	84	-	88	85	86	-	84	84	85	
A342NE	0.075	34	72	72	71	68	65	69	73	73	69	70	68	69	69	64	72	70	77	73	65	68	69	70	65	70	67	65	72	80	72	75	70	74	66	-	74	68	70	-	67	67	69		
A342NW	0.072	37	78	77	76	73	70	74	79	79	75	75	74	74	74	68	77	76	83	78	70	73	74	75	70	75	72	70	77	86	78	81	76	79	71	-	79	73	75	-	72	72	74		
A342R1	0.060	53	112	111	110	106	103	113	113	107	108	106	107	109	110	109	119	109	119	113	101	103	107	108	101	108	104	101	111	123	112	116	109	114	102	-	114	105	108	-	109	104	107		
A342R2	0.114	101	212	210	209	201	191	202	215	216	204	206	201	204	203	187	210	207	226	214	193	201	203	206	192	205	197	192	211	234	212	221	207	216	194	-	216	199	206	-	196	197	203		
A342SE	0.086	36	76	76	75	72	68	72	77	77	73	74	72	73	73	67	75	74	81	77	69	72	73	74	69	74	71	69	76	84	76	80	74	78	69	-	78	71	74	-	70	71	73		
A342SW	0.079	36	76	75	75	72	68	72	77	77	73	74	72	73	72	67	75	74	81	77	69	72	73	74	69	73	71	69	76	84	76	79	74	78	69	-	77	71	74	-	70	70	73		
A343NE	0.100	46	96	95	95	91	86	91	98	98	92	93	91	92	92	85	95	94	103	97	91	92	93	89	87	91	89	87	96	107	96	101	94	98	88	-	98	90	93	-	89	89	92		
A343NW	0.059	3	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6		
A343R2	0.175	155	326	323	320	308	294	309	330	331	313	316	308	313	311	287	322	317	347	329	296	308	312	316	295	315	303	295	324	359	326	339	318	332	298	-	331	306	316	-	301	303	312		
A343SE	0.113	43	91	90	90	86	82	87	93	93	88	89	86	87	87	80	90	89	97	92	83	86	87	88	83	88	85	82	91	101	91	95	89	93	83	-	93	85	88	-	84	84	87		
A343SW	0.055	13	28	28	27	26	25	26	28	28	27	27	25	28	27	27	25	28	27	30	28	25	27	27	25	27	26	25	28	31	28	29	27	28	25	-	28	26	27	-	26	26	27		
A344NE	0.117	10	190	188	187	179	171	180	193	193	182	184	180	182	181	167	188	185	203	192	172	180	182	184	172	184	177	172	189	210	198	185	194	173	-	193	178	184	-	176	176	182			
A344SW	0.136	57	121	119	118	114	108	114	122	122	116	117	114	115	115	106	119	117	129	121	109	114	115	117	109	116	112	109	120	133	121	126	117	123	110	-	123	113	117	-	111	112	115		
A344SE	0.063	36	76	75	74	71	68	72	77	77	72	73	71	72	72	66	75	73	80	76	68	71	72	73	68	73	70	68	75	83	75	79	73	77	69	-	77	71	73	-	70	70	72		
A346NW	0.067	29	62	61	61	59	56	59	63	63	60	60	59	59	59	55	61	60	62	56	62	56	60	56	60	56	60	56	60	63	57	60	58	60	57	-	65	60	57	-	57	57	60		
A346R1	0.178	138	290	287	285	274	261	275	294	294	278	281	274	278	277	255	287	282	309	292	263	274	277	281	262	280	269	262	288	319	290	302	282	295	265	-	295	272	281	-	268	269	277		
A346R2	0.148	149	312	310	308	297	285	298	316	317	302	304	298	301	300	280	309	305	330	315	287	298	300	304	286	303	293	286	311	340	312	323	306	318	289	-	317	296	304	-	291	292	300		
A346SE	0.114	63	132	131	130	128	119	130	140	140	137	138	137	138	137	126	141	136	154	138	110	120	136	138	130	136	134	130	138	138	138	138	138	138	138	-	138	138	138	-	132	132	138		
A346SW	0.053	53	112	111	110	107	102	107	113	113	108	109	107	108	100	111	109	118	113	103	107	108	109	103	109	105	103	111	122	112	116	110	114	104	-	113	106	109	-	104	105	107			
A346W1	0.037	20	41	41	41	39	37	39	42	40	40	40	40	40	36	41	40	44	42	38	39	40	40	37	40	37	41	46	41	43	40	42	38	-	42	39	40	-	38	38	40				
A347NE	0.043	35	73	73	72	69	66	70	74	74	70	71	69	70	65	73	71	78	73	71	78	74	66	69	70	71	68	66	73	81	73	76	71	75	67	-	75	69	71	-	68	68	70		
A347NE	0.119	72	152	150	149	143	136	144	154	154	146	147	143	145	145	133	150	148	162	153	137	143	145	147	147	141	137	151	167	152	158	147	154	138	-	154	147	147	-	140	141	145			
A348R1	0.171																																												