J.F. Sabourin and Associates Inc.
52 Springbrook Drive,
Ottawa, ON K2S 1B9
T 613-836-3884 F 613-836-0332

Ottawa. ON
Paris. ON
Gatineau. QC
Montréal. QC

July 09, 2020 Project Number: P1581-17

David Schaeffer Engineering

120 Iber Road, Unit 103

Stittsville, ON K2S 1E9

Attention: **Kevin Murphy, P.Eng.**

Subject: **Downstream of 7000 Campeau Drive – Hydrologic Assessment**

Introduction

In support of the proposed residential development at 7000 Campeau Drive in Kanata, Ontario, J.F Sabourin and Associates (JFSA) were commissioned to complete a downstream hydrologic assessment, to ensure that the proposed development will not result in or exacerbate any existing adverse effects on downstream lands and infrastructure, with regards to flooding and erosion. This memo will assess pre- and post-development flows on the Kizell Drain and Watts Creek under the full suite of design storms (2 to100 year events) to assess any flooding concerns. Continuous simulations were also completed to assess potential erosion concerns on the watercourse downstream of the development.

Background

The modelling work outlined in this memo builds on the 2017 Mississippi Valley Conservation Authority (MVCA) Watts Creek hydrologic (SWMHYMO) model, which was updated by JFSA in July 2020 to provide a better fit with the field-gathered data obtained in 2019 at the Beaver Pond and upstream storm sewer network. This model was also updated downstream of the development on Watts Creek to use subcatchment parameters that were more representative of field observed conditions obtained by C. Brennan et al and described in their September 2017 journal article “Continuous prediction of clay‐bed stream erosion in response to climate model output for a small urban watershed”. Full details of this model calibration process have been documented in JFSA’s July 2020 “Kanata Golf & Country Club 2019 Monitoring & Hydrologic Model Calibration Report”.

Design Scenarios

The following section outlines the various scenarios assessed as a part of this downstream impact analysis. This analysis includes the Future MVCA model of record, the updated JFSA existing conditions model, the proposed redevelopment of the Kanata Golf and Country Club (with SWM ponds designed to ensure no upstream or downstream impacts), the proposed redevelopment of Kanata Golf and Country Club with SWM ponds and conceptual LIDs, and the Kanata Lakes North (KNL) Stage 9 development. In total there are 9 different scenarios assessed in this report that are a mix of the various items addressed above. The following section discusses in detail each of the various scenarios and provides the model reference code.

1. **MVCA Future Conditions**- *(MVCA):*

   MVCA 2017 model of record reflective of future conditions, used for floodplain mapping purposes.

2. **Existing Conditions-** *(KWEX):*

   Reflective of the current conditions (2019) with various model parameters adjusted to reflect the field-collected data more accurately. Refer to JFSA's July 2020, "Kanata Golf & Country Club 2019 Monitoring & Hydrologic Model Calibration Report" for full details on the calibration process.

3. **KNL Development -** *(KWEX_KNL9):*

   Reflective of existing conditions with the inclusion of the KNL Development Stage 9 in place as per IBI's detailed design. Stage 7 & 8 of the KNL have been left undeveloped since these Stages have yet to be approved by the City.

4. **The Kanata Golf and Country Club Development with SWM controls-** *(KWEX_KGC):*

   Reflective of existing conditions with the proposed redevelopment of the Kanata Golf and Country Club in place with Storm Water Management (SWM) ponds sized to mitigate impacts both upstream and downstream of the development.

5. **The Kanata Golf and Country Club Development with SWM controls + KNL Development -** *(KWEX_KGC_KNL9):*

   Reflective of existing conditions with the proposed redevelopment of the Kanata Golf and Country Club in place with Storm Water Management (SWM) ponds sized to mitigate impacts both upstream and downstream of the development. Includes the KNL Development Stage 9 in place as per IBI's detailed design. Stage 7 & 8 of KNL have been left undeveloped as directed by the City.

6. **The Kanata Golf and Country Club Development with SWM controls with 3mm equivalent LIDs** - *(KWEX_KGC- LIDs3mm):*

   Reflective of existing conditions with the proposed redevelopment of the Kanata Golf and Country Club in place with Storm Water Management (SWM) ponds sized to mitigate impacts both upstream and downstream of the development along with LID's implemented within the site to capture 3 mm of runoff.

7. **The Kanata Golf and Country Club Development with SWM controls with 5mm equivalent LIDs -** *(KWEX_KGC-LIDs5mm):*

   Reflective of existing conditions with the proposed redevelopment of the Kanata Golf and Country Club in place with Storm Water Management (SWM) ponds sized to mitigate impacts both upstream and downstream of the development along with LID's implemented within the site to capture 5 mm of runoff.

8. **The Kanata Golf and Country Club Development with SWM controls with 3mm equivalent LIDs + KNL Development -** *(KWEX_KGC- LIDs3mm_KNL9):*

   Reflective of existing conditions with the proposed redevelopment of the Kanata Golf and Country Club in place with Storm Water Management (SWM) ponds sized to mitigate impacts both upstream and downstream of the development along with LID's implemented within the site to capture 3 mm of runoff. Includes the KNL Development Stage 9 in place as per IBI's detailed design. Stage 7 & 8 of KNL have been left undeveloped as directed by the City.

9. **The Kanata Golf and Country Club Development with SWM controls with 5mm equivalent LIDs + KNL Development -** *(KWEX_KGC-LIDs5mm_KNL9):*

   Reflective of existing conditions with the proposed redevelopment of the Kanata Golf and Country Club in place with Storm Water Management (SWM) ponds sized to mitigate impacts both upstream and downstream of the development along with LID's implemented within the site to capture 5 mm of runoff. Includes the KNL Development Stage 9 in place as per IBI's detailed design. Stage 7 & 8 of KNL have been left undeveloped as directed by the City.

Design Storms

The various scenarios discussed above were assessed using a range of design storms, which include the 12 Hour SCS, 24 Hour SCS and 3 Hour Chicago storms. Flows into and out of the Beaver Pond were extracted from the various models and have been provided in Tables 1A and 1B below. Flows at the downstream extent of the model, at Watts Creek's confluence with the Ottawa River, are provided in Tables 2A and 2B below. To provide some context to the calibration process, the results from the 2017 MVCA Future conditions model (MVCA) have also been provided. The updated calibrated existing conditions model (KWEX) was considered as the baseline scenario and used to set the targets for matching post-development flows. It was assumed that no quantity controls will be implemented on the KNL Stage 9 development and as such for scenarios that include the KNL Stage 9 development, the scenario (KWEX_KNL9) is considered to be the baseline condition, as the Kanata Golf and Country Club Redevelopment should not be required to offset the impacts of the KNL development.

Comparing the results of the existing calibrated model (KWEX) to the scenario where the Kanata Golf and Country Club is redeveloped with SWM ponds in place (KWEX_KGC), the peak flows out of the Beaver Pond are reduced for all events except the 5 and 10 Year SCS 24 Hour event, which sees a marginal increase of 1.004 and 1.003 respectively. Downstream at the Ottawa River, this scenario results in a reduction in peak flows for all events, generally in the range of 0.997-0.999.

Comparing the peak flow results of the existing calibrated model (KWEX) to the scenario where only KNL Stage 9 is developed (KWEX_KNL9) an increase in peak flows out of the Beaver Pond is observed for all events in the range of 1.032-1.245. This increase continues all the way downstream to the Ottawa River where these increases in peak flows are in the range of 1.003 - 1.006.

When both Kanata Golf and Country Club and KNL Stage 9 developments are in place (KWEX_KGC_KNL9), the peak flows for all events are slightly less than KNL Stage 9 alone, but still see an increase in the existing condition of 1.013-1.216 out of the Beaver Pond. Note that the 100-year peak flows out of the Beaver Pond for KWEX_KGC, KWEX_KNL9 and KWEX_KGC_KNL9 are all less than 0.96 m^3/s as specified in the Certificate of Approval for the Beaver Pond issued in 2008.

When LID's are implemented that will infiltrate 3 mm of runoff from the Kanata Golf and Country Club development, the peak flows out of the Beaver Pond for all events are below existing conditions by a factor of 0.929-0.998. Increasing the conceptual LIDs capacity further to capture 5mm of runoff from the development, the peak flows out of the Beaver Pond are further reduced for all events by a factor of 0.916 - 0.994. When the Kanata Golf and Country Club development is introduced with the 3 mm (KWEX_KGC-LIDs3mm_KNL9) and 5 mm (KWEX_KGC-LIDs5mm_KNL9) LID's respectively, the peak flows out of the Beaver Pond are reduced by a factor of 0.917-0.999 and 0.892-0.999 when compared to KNL Stage 9 development alone.

Table 1A: Beaver Pond Inflow/Outflow Summary

Design Storms	MVCA				KWEX				KWEX_KNL9					KWEX_KGC					KWEX_KGC_KNL9					
	Area (ha)	Qp In (m^3/s)	Qp Out (m^3/s)	Runoff (mm)	Area (ha)	Qp In (m^3/s)	Qp Out (m^3/s)	Runoff (mm)	Area (ha)	Qp In (m^3/s)	Qp Out (m^3/s)	Runoff (mm)	Qp/Qp_{KWEX}	Area (ha)	Qp In (m^3/s)	Qp Out (m^3/s)	Runoff (mm)	Qp/Qp_{KWEX}	Area (ha)	Qp In (m^3/s)	Qp Out (m^3/s)	Runoff (mm)	Qp/Qp_{KWEX}	Qp/Qp_{KNL9}
25 mm CHI 4Hr	n/a	n/a	n/a	n/a	415.850	4.626	0.139	3.570	430.020	5.878	0.173	4.020	1.245	422.910	4.610	0.135	6.180	0.971	437.090	5.862	0.169	6.540	1.216	0.977
2Yr SCS 12 hour	477.350	1.352	0.454	18.140	415.850	4.644	0.314	7.360	430.020	5.811	0.369	8.180	1.175	422.910	4.635	0.301	11.730	0.959	437.090	5.801	0.354	12.390	1.127	0.959
5Yr SCS 12 hour	477.350	2.439	0.615	26.800	415.850	7.164	0.486	11.680	430.020	9.071	0.538	12.840	1.107	422.910	6.976	0.486	17.570	1.000	437.090	8.884	0.541	18.510	1.113	1.006
10Yr SCS 12 hour	473.450	3.248	0.671	33.000	415.850	9.686	0.599	15.680	430.020	12.049	0.640	17.040	1.068	422.910	9.145	0.598	22.620	0.998	437.090	11.516	0.644	23.690	1.075	1.006
25Yr SCS 12 hour	466.660	5.342	0.775	41.160	415.850	13.964	0.718	21.710	430.020	16.894	0.757	23.280	1.054	422.910	12.818	0.710	29.770	0.989	437.090	15.872	0.754	31.020	1.050	0.996
50Yr SCS 12 hour	462.310	7.378	0.859	47.110	415.850	17.893	0.792	26.340	429.920	20.057	0.826	28.040	1.043	422.810	16.207	0.776	35.080	0.980	436.980	18.721	0.817	36.400	1.032	0.989
100Yr SCS 12 hour	458.300	9.941	0.924	53.220	415.800	24.521	0.854	31.250	429.460	27.228	0.889	33.050	1.041	422.360	22.463	0.829	40.540	0.971	436.530	25.285	0.873	41.940	1.022	0.982
2Yr SCS 24 hour	n/a	n/a	n/a	n/a	415.850	6.603	0.358	9.390	430.020	8.420	0.414	10.310	1.156	422.910	6.531	0.345	14.170	0.964	437.090	8.348	0.401	14.900	1.120	0.969
5Yr SCS 24 hour	n/a	n/a	n/a	n/a	415.850	10.871	0.548	15.280	430.020	13.567	0.589	16.480	1.075	422.910	10.447	0.550	21.570	1.004	437.090	13.145	0.593	22.520	1.082	1.007
10Yr SCS 24 hour	n/a	n/a	n/a	n/a	415.850	14.605	0.642	19.840	430.020	17.877	0.684	21.200	1.065	422.910	13.705	0.644	27.000	1.003	437.090	17.003	0.690	28.060	1.075	1.009
25Yr SCS 24 hour	n/a	n/a	n/a	n/a	415.850	19.100	0.745	26.090	429.660	23.390	0.783	27.620	1.051	422.560	17.703	0.740	34.170	0.993	436.730	22.127	0.786	35.300	1.055	1.004
50Yr SCS 24 hour	n/a	n/a	n/a	n/a	415.480	23.303	0.813	31.260	428.680	27.929	0.846	32.900	1.041	421.570	21.150	0.804	39.780	0.989	435.750	25.811	0.846	41.050	1.041	1.000
100Yr SCS 24 hour	n/a	n/a	n/a	n/a	415.010	34.161	0.881	37.050	428.230	37.596	0.911	38.780	1.034	421.120	31.104	0.863	45.960	0.980	435.300	34.662	0.905	47.250	1.027	0.993
2Yr CHI 3Hr	n/a	n/a	n/a	n/a	415.850	7.098	0.238	5.290	430.020	8.959	0.288	5.920	1.210	422.910	7.063	0.224	8.940	0.941	437.090	8.924	0.274	9.390	1.151	0.951
5Yr CHI 3Hr	n/a	n/a	n/a	n/a	415.850	12.180	0.437	9.240	430.020	15.038	0.480	10.110	1.098	422.910	11.968	0.431	14.610	0.986	437.090	14.827	0.478	15.250	1.094	0.996
10Yr CHI 3Hr	n/a	n/a	n/a	n/a	415.850	15.175	0.533	12.140	429.780	19.126	0.578	13.170	1.084	422.680	14.609	0.530	18.610	0.994	436.850	18.563	0.582	19.370	1.092	1.007
25Yr CHI 3Hr	n/a	n/a	n/a	n/a	415.680	19.916	0.626	16.000	428.370	24.857	0.667	17.230	1.065	421.260	18.521	0.621	23.790	0.992	435.440	23.466	0.672	24.680	1.073	1.007
50Yr CHI 3Hr	n/a	n/a	n/a	n/a	415.090	25.585	0.692	19.130	427.580	29.438	0.728	20.520	1.052	420.470	24.101	0.682	27.880	0.986	434.650	27.734	0.727	28.850	1.051	0.999
100Yr CHI 3Hr	n/a	n/a	n/a	n/a	414.440	29.457	0.750	22.650	426.980	35.943	0.790	24.180	1.053	419.870	27.388	0.733	32.310	0.977	434.040	33.955	0.785	33.380	1.047	0.994
100Yr SCS 24Hr + 20%	n/a	n/a	n/a	n/a	413.860	50.926	1.007	50.190	427.240	57.648	1.039	52.080	1.032	420.130	46.983	0.969	59.390	0.962	434.300	53.839	1.020	60.750	1.013	0.982

Scenario Summary:

MVCA	MVCA 2017 Future Conditions Model of Record
KWEX	JFSA updated Existing Conditions
KWEX_KNL9	JFSA updated Existing Conditions + KNL Stage 9 Development
KWEX_KGC	JFSA updated Existing Conditions + The Kanata Golf and Country Club Development with SWM controls
KWEX_KGC_KNL9	JFSA updated Existing Conditions + The Kanata Golf and Country Club Development with SWM controls + KNL Stage 9 Development
KWEX_KGC- LIDs3mm	JFSA updated Existing Conditions + The Kanata Golf and Country Club Development with SWM controls with 3mm equivalent LIDs
KWEX_KGC- LIDs5mm	JFSA updated Existing Conditions + The Kanata Golf and Country Club Development with SWM controls with 5mm equivalent LIDs
KWEX_KGC- LIDs3mm_KNL9	JFSA updated Existing Conditions + The Kanata Golf and Country Club Development with SWM controls with 3mm equivalent LIDs + KNL Stage 9 Development
KWEX_KGC- LIDs5mm_KNL9	JFSA updated Existing Conditions + The Kanata Golf and Country Club Development with SWM controls with 5mm equivalent LIDs + KNL Stage 9 Development

Tabl 1B: Beaver Pond Inflow/Outflow Summary - With LIDs

Design storms	KWEX_KGC- LIDs3mm					KWEX_KGC- LIDs5mm					KWEX_KGC- LIDs3mm_KNL9						KWEX_KGC- LIDs5mm_KNL9					
	Area (ha)	Qp In (m^3/s)	Qp Out (m^3/s)	Runoff (mm)	Qp/Qp_{KWEX}	Area (ha)	Qp In (m^3/s)	Qp Out (m^3/s)	Runoff (mm)	Qp/Qp_{KWEX}	Area (ha)	Qp In (m^3/s)	Qp Out (m^3/s)	Runoff (mm)	Qp/Qp_{KWEX}	Qp/Qp_{KNL9}	Area (ha)	Qp In (m^3/s)	Qp Out (m^3/s)	Runoff (mm)	Qp/Qp_{KWEX}	Qp/Qp_{KNL9}
25 mm CHI 4Hr	422.910	4.579	0.132	5.860	0.950	422.910	4.499	0.129	5.590	0.928	437.090	5.765	0.160	6.140	1.151	0.925	437.090	5.546	0.155	5.830	1.115	0.896
2Yr SCS 12 hour	422.910	4.604	0.293	11.370	0.933	422.910	4.552	0.288	11.120	0.917	437.090	5.714	0.342	11.940	1.089	0.927	437.090	5.590	0.334	11.640	1.064	0.905
5Yr SCS 12 hour	422.910	6.946	0.479	17.250	0.986	422.910	6.925	0.474	16.960	0.975	437.090	8.796	0.530	18.070	1.091	0.985	437.090	8.665	0.523	17.760	1.076	0.972
10Yr SCS 12 hour	422.910	9.112	0.594	22.240	0.992	422.910	9.086	0.591	22.000	0.987	437.090	11.427	0.638	23.270	1.065	0.997	437.090	11.361	0.634	22.980	1.058	0.991
25Yr SCS 12 hour	422.910	12.781	0.708	29.490	0.986	422.910	12.752	0.706	29.220	0.983	437.090	15.784	0.750	30.640	1.045	0.991	437.090	15.716	0.748	30.370	1.042	0.988
50Yr SCS 12 hour	422.810	16.187	0.774	34.810	0.977	422.810	16.172	0.772	34.540	0.975	436.980	18.661	0.814	36.050	1.028	0.985	436.980	18.610	0.813	35.800	1.027	0.984
100Yr SCS 12 hour	422.360	22.445	0.828	40.200	0.970	422.360	22.432	0.827	40.000	0.968	436.530	25.249	0.871	41.590	1.020	0.980	436.530	25.218	0.869	41.350	1.018	0.978
2Yr SCS 24 hour	422.910	6.502	0.337	13.860	0.941	422.910	6.486	0.332	13.630	0.927	437.090	8.262	0.389	14.500	1.087	0.940	437.090	8.116	0.382	14.250	1.067	0.923
5Yr SCS 24 hour	422.910	10.425	0.545	21.290	0.995	422.910	10.404	0.540	21.030	0.985	437.090	13.081	0.587	22.160	1.071	0.997	437.090	13.026	0.583	21.880	1.064	0.990
10Yr SCS 24 hour	422.910	13.669	0.641	26.740	0.998	422.910	13.646	0.638	26.490	0.994	437.090	16.922	0.683	27.710	1.064	0.999	437.090	16.870	0.683	27.470	1.064	0.999
25Yr SCS 24 hour	422.560	17.678	0.738	33.910	0.991	422.560	17.661	0.736	33.630	0.988	436.730	22.087	0.782	34.980	1.050	0.999	436.730	22.052	0.780	34.760	1.047	0.996
50Yr SCS 24 hour	421.570	21.137	0.802	39.520	0.986	421.570	21.128	0.801	39.270	0.985	435.750	25.789	0.843	40.720	1.037	0.996	435.750	25.768	0.842	40.510	1.036	0.995
100Yr SCS 24 hour	421.120	31.092	0.861	45.710	0.977	421.120	31.084	0.860	45.410	0.976	435.300	34.650	0.903	46.940	1.025	0.991	435.300	34.641	0.902	46.730	1.024	0.990
2Yr CHI 3Hr	422.910	7.032	0.221	8.560	0.929	422.910	6.980	0.218	8.310	0.916	437.090	8.838	0.264	8.960	1.109	0.917	437.090	8.635	0.257	8.650	1.080	0.892
5Yr CHI 3Hr	422.910	11.924	0.424	14.210	0.970	422.910	11.887	0.420	13.950	0.961	437.090	14.728	0.467	14.800	1.069	0.973	437.090	14.626	0.459	14.490	1.050	0.956
10Yr CHI 3Hr	422.680	14.567	0.525	18.270	0.985	422.680	14.534	0.521	17.940	0.977	436.850	18.012	0.576	18.910	1.081	0.997	436.850	17.927	0.572	18.600	1.073	0.990
25Yr CHI 3Hr	421.260	18.474	0.617	23.440	0.986	421.260	18.442	0.615	23.080	0.982	435.440	23.335	0.666	24.210	1.064	0.999	435.440	23.235	0.662	23.890	1.058	0.993
50Yr CHI 3Hr	420.470	24.032	0.679	27.520	0.981	420.470	23.989	0.676	27.120	0.977	434.650	27.596	0.723	28.370	1.045	0.993	434.650	27.494	0.720	28.050	1.040	0.989
100Yr CHI 3Hr	419.870	27.329	0.730	31.940	0.973	419.870	27.288	0.729	31.540	0.972	434.040	33.782	0.780	32.900	1.040	0.987	434.040	33.668	0.777	32.580	1.036	0.984
100Yr SCS 24Hr + 20%	420.130	46.971	0.968	59.150	0.961	420.130	46.963	0.967	58.770	0.960	434.300	53.829	1.019	60.440	1.012	0.981	434.300	53.822	1.018	60.240	1.011	0.980

Scenario Summary:

MVCA	MVCA 2017 Future Conditions Model of Record
KWEX	JFSA updated Existing Conditions
KWEX_KNL9	JFSA updated Existing Conditions + KNL Stage 9 Development
KWEX_KGC	JFSA updated Existing Conditions + The Kanata Golf and Country Club Development with SWM controls
KWEX_KGC_KNL9	JFSA updated Existing Conditions + The Kanata Golf and Country Club Development with SWM controls + KNL Stage 9 Development
KWEX_KGC- LIDs3mm	JFSA updated Existing Conditions + The Kanata Golf and Country Club Development with SWM controls with 3mm equivalent LIDs
KWEX_KGC- LIDs5mm	JFSA updated Existing Conditions + The Kanata Golf and Country Club Development with SWM controls with 5mm equivalent LIDs
KWEX_KGC- LIDs3mm_KNL9	JFSA updated Existing Conditions + The Kanata Golf and Country Club Development with SWM controls with 3mm equivalent LIDs + KNL Stage 9 Development
KWEX_KGC- LIDs5mm_KNL9	JFSA updated Existing Conditions + The Kanata Golf and Country Club Development with SWM controls with 5mm equivalent LIDs + KNL Stage 9 Development

Table 2A: Outlet to Ottawa River Summary

Design Storms	MVCA			KWEX			KWEX_KNL9				KWEX_KGC				KWEX_KGC_KNL9				
	Area (ha)	Qp (m^3/s)	Runoff (mm)	Area (ha)	Qp (m^3/s)	Runoff (mm)	Area (ha)	Qp (m^3/s)	Runoff (mm)	Qp/Qp_{KWEX}	Area (ha)	Qp (m^3/s)	Runoff (mm)	Qp/Qp_{KWEX}	Area (ha)	Qp (m^3/s)	Runoff (mm)	Qp/Qp_{KWEX}	Qp/Qp_{KNL9}
25 mm CHI 4Hr	n/a	n/a	n/a	2550.680	3.572	3.470	2549.940	3.573	4.020	1.0003	2550.680	3.568	3.900	0.999	2549.940	3.573	4.020	1.000	1.000
2Yr SCS 12 hour	2590.480	8.051	16.290	2550.680	6.176	7.630	2549.940	6.186	8.570	1.002	2550.680	6.164	8.350	0.998	2549.940	6.186	8.570	1.002	1.000
5Yr SCS 12 hour	2590.480	12.467	25.080	2550.680	9.396	11.880	2549.940	9.437	13.180	1.004	2550.680	9.379	12.860	0.998	2549.940	9.437	13.180	1.004	1.000
10Yr SCS 12 hour	2586.580	15.905	31.460	2550.680	11.946	15.470	2549.940	11.997	16.990	1.004	2550.680	11.925	16.630	0.998	2549.940	11.997	16.990	1.004	1.000
25Yr SCS 12 hour	2579.790	20.780	39.920	2550.680	16.548	21.150	2549.940	16.645	22.930	1.006	2550.680	16.508	22.490	0.998	2549.940	16.645	22.930	1.006	1.000
50Yr SCS 12 hour	2575.440	24.531	46.120	2550.570	20.883	25.910	2549.830	21.018	27.840	1.006	2550.580	20.832	27.360	0.998	2549.830	21.018	27.840	1.006	1.000
100Yr SCS 12 hour	2571.430	28.263	52.480	2550.120	25.754	31.120	2549.380	25.900	33.170	1.006	2550.130	25.703	32.660	0.998	2549.380	25.900	33.170	1.006	1.000
2Yr SCS 24 hour	n/a	n/a	n/a	2550.680	6.225	9.340	2549.940	6.232	10.380	1.001	2550.680	6.213	10.130	0.998	2549.940	6.232	10.380	1.001	1.000
5Yr SCS 24 hour	n/a	n/a	n/a	2550.680	9.900	15.050	2549.940	9.942	16.430	1.004	2550.680	9.869	16.100	0.997	2549.940	9.942	16.430	1.004	1.000
10Yr SCS 24 hour	n/a	n/a	n/a	2550.680	13.432	19.800	2549.940	13.507	21.360	1.006	2550.680	13.399	20.980	0.998	2549.940	13.507	21.360	1.006	1.000
25Yr SCS 24 hour	n/a	n/a	n/a	2550.320	18.763	26.310	2549.580	18.868	28.080	1.006	2550.330	18.721	27.650	0.998	2549.580	18.868	28.080	1.006	1.000
50Yr SCS 24 hour	n/a	n/a	n/a	2549.340	23.492	31.870	2548.600	23.617	33.740	1.005	2549.340	23.443	33.270	0.998	2548.600	23.617	33.740	1.005	1.000
100Yr SCS 24 hour	n/a	n/a	n/a	2548.890	28.781	38.250	2548.150	28.927	40.210	1.005	2548.890	28.721	39.720	0.998	2548.150	28.927	40.210	1.005	1.000
2Yr CHI 3Hr	n/a	n/a	n/a	2550.680	4.959	4.890	2549.940	4.963	5.660	1.001	2550.680	4.951	5.490	0.998	2549.940	4.963	5.660	1.001	1.000
5Yr CHI 3Hr	n/a	n/a	n/a	2550.680	7.749	8.210	2549.940	7.768	9.340	1.002	2550.680	7.734	9.100	0.998	2549.940	7.768	9.340	1.002	1.000
10Yr CHI 3Hr	n/a	n/a	n/a	2550.440	10.781	11.190	2549.700	10.816	12.560	1.003	2550.450	10.760	12.260	0.998	2549.700	10.816	12.560	1.003	1.000
25Yr CHI 3Hr	n/a	n/a	n/a	2549.030	15.301	15.250	2548.290	15.373	16.880	1.005	2549.030	15.270	16.520	0.998	2548.290	15.373	16.880	1.005	1.000
50Yr CHI 3Hr	n/a	n/a	n/a	2548.240	19.003	18.510	2547.500	19.097	20.340	1.005	2548.240	18.967	19.940	0.998	2547.500	19.097	20.340	1.005	1.000
100Yr CHI 3Hr	n/a	n/a	n/a	2547.640	22.967	22.110	2546.890	23.074	24.130	1.005	2547.640	22.931	23.680	0.998	2546.890	23.074	24.130	1.005	1.000
100Yr SCS 24Hr + 20%	n/a	n/a	n/a	2547.900	41.079	52.640	2547.150	41.245	54.690	1.004	2547.900	41.024	54.160	0.999	2547.150	41.245	54.690	1.004	1.000

Scenario Summary:

MVCA	MVCA 2017 Future Conditions Model of Record
KWEX	JFSA updated Existing Conditions
KWEX_KNL9	JFSA updated Existing Conditions + KNL Stage 9 Development
KWEX_KGC	JFSA updated Existing Conditions + The Kanata Golf and Country Club Development with SWM controls
KWEX_KGC_KNL9	JFSA updated Existing Conditions + The Kanata Golf and Country Club Development with SWM controls + KNL Stage 9 Development
KWEX_KGC- LIDs3mm	JFSA updated Existing Conditions + The Kanata Golf and Country Club Development with SWM controls with 3mm equivalent LIDs
KWEX_KGC- LIDs5mm	JFSA updated Existing Conditions + The Kanata Golf and Country Club Development with SWM controls with 5mm equivalent LIDs
KWEX_KGC- LIDs3mm_KNL9	JFSA updated Existing Conditions + The Kanata Golf and Country Club Development with SWM controls with 3mm equivalent LIDs + KNL Stage 9 Development
KWEX_KGC- LIDs5mm_KNL9	JFSA updated Existing Conditions + The Kanata Golf and Country Club Development with SWM controls with 5mm equivalent LIDs + KNL Stage 9 Development

Table 2B: Outlet to Ottawa River Summary - With LID's

Design Storms	KWEX_KGC- LIDs3mm				KWEX_KGC- LIDs5mm				KWEX_KGC- LIDs3mm_KNL9					KWEX_KGC- LIDs5mm_KNL9				
	Area (ha)	Qp (m^3/s)	Runoff (mm)	Qp/Qp_{KWEX}	Area (ha)	Qp (m^3/s)	Runoff (mm)	Qp/Qp_{KWEX}	Area (ha)	Qp (m^3/s)	Runoff (mm)	Qp/Qp_{KWEX}	Qp/Qp_{KNL9}	Area (ha)	Qp (m^3/s)	Runoff (mm)	Qp/Qp_{KWEX}	Qp/Qp_{KNL9}
25 mm CHI 4Hr	2550.680	3.568	3.840	0.999	2550.680	3.568	3.800	0.999	2549.940	3.571	3.950	1.000	0.999	2549.940	3.571	3.890	1.000	0.999
2Yr SCS 12 hour	2550.680	6.163	8.290	0.998	2550.680	6.163	8.250	0.998	2549.940	6.180	8.490	1.001	0.999	2549.940	6.177	8.430	1.000	0.999
5Yr SCS 12 hour	2550.680	9.378	12.810	0.998	2550.680	9.378	12.760	0.998	2549.940	9.429	13.100	1.004	0.999	2549.940	9.424	13.040	1.003	0.999
10Yr SCS 12 hour	2550.680	11.924	16.560	0.998	2550.680	11.923	16.530	0.998	2549.940	11.989	16.920	1.004	0.999	2549.940	11.983	16.860	1.003	0.999
25Yr SCS 12 hour	2550.680	16.506	22.450	0.997	2550.680	16.506	22.410	0.997	2549.940	16.635	22.860	1.005	0.999	2549.940	16.627	22.810	1.005	0.999
50Yr SCS 12 hour	2550.580	20.830	27.320	0.997	2550.580	20.829	27.270	0.997	2549.830	21.006	27.770	1.006	0.999	2549.830	20.997	27.720	1.005	0.999
100Yr SCS 12 hour	2550.130	25.701	32.610	0.998	2550.130	25.700	32.580	0.998	2549.380	25.889	33.110	1.005	1.000	2549.380	25.881	33.070	1.005	0.999
2Yr SCS 24 hour	2550.680	6.212	10.080	0.998	2550.680	6.212	10.050	0.998	2549.940	6.227	10.310	1.000	0.999	2549.940	6.223	10.260	1.000	0.999
5Yr SCS 24 hour	2550.680	9.867	16.050	0.997	2550.680	9.866	16.010	0.997	2549.940	9.936	16.360	1.004	0.999	2549.940	9.931	16.310	1.003	0.999
10Yr SCS 24 hour	2550.680	13.396	20.940	0.997	2550.680	13.395	20.910	0.997	2549.940	13.499	21.300	1.005	0.999	2549.940	13.493	21.260	1.005	0.999
25Yr SCS 24 hour	2550.330	18.718	27.610	0.998	2550.330	18.716	27.580	0.997	2549.580	18.860	28.020	1.005	1.000	2549.580	18.853	27.970	1.005	0.999
50Yr SCS 24 hour	2549.340	23.440	33.230	0.998	2549.340	23.438	33.200	0.998	2548.600	23.608	33.680	1.005	1.000	2548.600	23.603	33.640	1.005	0.999
100Yr SCS 24 hour	2548.890	28.718	39.680	0.998	2548.890	28.701	39.650	0.997	2548.150	28.919	40.150	1.005	1.000	2548.150	28.913	40.110	1.005	1.000
2Yr CHI 3Hr	2550.680	4.951	5.430	0.998	2550.680	4.951	5.390	0.998	2549.940	4.961	5.580	1.000	1.000	2549.940	4.959	5.520	1.000	0.999
5Yr CHI 3Hr	2550.680	7.734	9.030	0.998	2550.680	7.733	8.990	0.998	2549.940	7.764	9.260	1.002	0.999	2549.940	7.761	9.200	1.002	0.999
10Yr CHI 3Hr	2550.450	10.759	12.200	0.998	2550.450	10.759	12.150	0.998	2549.700	10.811	12.470	1.003	1.000	2549.700	10.808	12.410	1.003	0.999
25Yr CHI 3Hr	2549.030	15.270	16.470	0.998	2549.030	15.270	16.420	0.998	2548.290	15.365	16.790	1.004	0.999	2548.290	15.360	16.730	1.004	0.999
50Yr CHI 3Hr	2548.240	18.966	19.880	0.998	2548.240	18.966	19.830	0.998	2547.500	19.088	20.250	1.004	1.000	2547.500	19.082	20.190	1.004	0.999
100Yr CHI 3Hr	2547.640	22.931	23.630	0.998	2547.640	22.931	23.590	0.998	2546.890	23.065	24.040	1.004	1.000	2546.890	23.059	23.980	1.004	0.999
100Yr SCS 24Hr + 20%	2547.900	41.020	54.120	0.999	2547.900	41.018	54.090	0.999	2547.150	41.235	54.640	1.004	1.000	2547.150	41.228	54.600	1.004	1.000

Scenario Summary:

MVCA	MVCA 2017 Future Conditions Model of Record
KWEX	JFSA updated Existing Conditions
KWEX_KNL9	JFSA updated Existing Conditions + KNL Stage 9 Development
KWEX_KGC	JFSA updated Existing Conditions + The Kanata Golf and Country Club Development with SWM controls
KWEX_KGC_KNL9	JFSA updated Existing Conditions + The Kanata Golf and Country Club Development with SWM controls + KNL Stage 9 Development
KWEX_KGC- LIDs3mm	JFSA updated Existing Conditions + The Kanata Golf and Country Club Development with SWM controls with 3mm equivalent LIDs
KWEX_KGC- LIDs5mm	JFSA updated Existing Conditions + The Kanata Golf and Country Club Development with SWM controls with 5mm equivalent LIDs
KWEX_KGC- LIDs3mm_KNL9	JFSA updated Existing Conditions + The Kanata Golf and Country Club Development with SWM controls with 3mm equivalent LIDs + KNL Stage 9 Development
KWEX_KGC- LIDs5mm_KNL9	JFSA updated Existing Conditions + The Kanata Golf and Country Club Development with SWM controls with 5mm equivalent LIDs + KNL Stage 9 Development

Erosion Threshold Assessment

In July 2020, GEO Morphix completed an Erosion Threshold Assessment on the Kizell Drain downstream of the proposed development and identified two (2) critical erosion locations along the watercourse. The first location referred to as “KDR-4” extends from the outlet of the Beaver Pond to a partially confined wetland area upstream of the CN Rail to the north. The second location referred to as “KDR-3” extends from March Road to Legget Drive and is located between two large parking areas which drain directly to the riparian zone of the Kizell Drain.

From this analysis, it was determined that the channel bed material has been relatively resilient to erosion, with the bank materials more susceptible; as bank undercutting and sloughing were the most common forms of erosion observed throughout the watercourse. At KDR-4 (just downstream of the Beaver Pond) GEO Morphix determined that the critical bank and bed shear stress was 6.78 N/m² and 9.01 N/m², respectively. At KDR-4 (March Road and Legget Drive) GEO Morphix determined that the critical bank and bed shear stress was 8.5 N/m² and 11.29 N/m², respectively. Full details of this study can be found in GEO Morphix’s July 2020 report titled “Kizell Drain Downstream of 7000 Campeau Drive Geomorphological and Erosion Threshold Assessment”.

Erosion Analysis

To assess the existing and potential future erosive impacts on the Kizell Drain at these two critical locations, the various scenarios were converted to continuous hydrologic models and simulated using 39 years of hourly historical rainfall data taken from the Ottawa Airport. The model was also updated to make use of SWMHYMO’s erosion analysis tools at the critical locations, based on the respective bed and bank shear stresses determined above by GEO Morphix. For each scenario, the annual average exceedance volume (the total annual flow through a reach above the erosion threshold) and the Cumulative Work Index (CWI) (the numerical quantification of the amount of erosive pressure applied to a reach above a determined erosion threshold) have been calculated. Tables 3A and 3B below provide a full summary of this erosion analysis for the various scenarios.

From these tables, it was found that the Kanata Golf and Country Club development with the proposed SWM controls (KWEX_KGC) will result in the annual bank cumulative work index to increase by 5.56% and 1.28% at locations KDR-4 and KDR-3 respectively. With LID’s applied to the development that will capture 3 mm of runoff, the bank cumulative work index will decrease by 2.53% and 4.05% from existing conditions at the respective KDR-4 and KDR-3 locations. Increasing the capacity of the conceptual LID’s to capture up to 5 mm of runoff results in the bank cumulative work index to decrease by 6.76% and 6.61% from existing conditions, respectively.

The development of KNL Stage 9 (KWEX_KNL9) results in the bank cumulative work indices to increase by 27.01% and 39.54% from existing conditions. With both KNL9 and the Kanata Golf and Country Club development in place and with no LID’s implemented (KWEX_KGC_KNL9), the bank cumulative work indexes increase by 5.70% and 1.35% from the scenario where KNL9 is developed. When 3 mm LID’s are implemented with the Kanata Golf and Country Club development with KNL Stage 9 in place (KWEX_KGC- LIDs3mm_KNL9), the impacts of KNL are reduced, resulting in a decrease in bank cumulative work of 5.47% and 7.76% from the scenario where KNL Stage 9 is implemented.

Table 3A: Erosion Analysis Summary - KDR-4 (upstream of the CN Rail)

Bank Shear Stress Erosion Threshold = 6.78 N/m²

Modelled Scenarios (no LIDs)

	KWEX		KWEX_KNL9		KWEX_KGC		KWEX_KGC_KNL9	
	Vol Exc (m^3)	CWI (pa)	Vol Exc (m^3)	CWI (pa)	Vol Exc (m^3)	CWI (pa)	Vol Exc (m^3)	CWI (pa)
Result	2.16E+04	2.17E+05	2.86E+04	2.76E+05	2.33E+04	2.29E+05	3.06E+04	2.92E+05
Change from KW_EX	n/a	n/a	32.46%	27.01%	7.77%	5.56%	41.78%	34.26%
Change from KW_KNL9	n/a	n/a	n/a	n/a	n/a	n/a	7.03%	5.70%

Modelled Scenarios (with LIDs on KGC)

	KWEX_KGC- LIDs3mm		KWEX_KGC- LIDs5mm		KWEX_KGC- LIDs3mm_KNL9		KWEX_KGC- LIDs5mm_KNL9	
	Vol Exc (m^3)	CWI (pa)	Vol Exc (m^3)	CWI (pa)	Vol Exc (m^3)	CWI (pa)	Vol Exc (m^3)	CWI (pa)
Result	2.12E+04	2.12E+05	2.02E+04	2.03E+05	2.71E+04	2.61E+05	2.53E+04	2.46E+05
Change from KW_EX	-1.88%	-2.53%	-6.52%	-6.76%	25.31%	20.06%	17.09%	13.01%
Change from KW_KNL9	n/a	n/a	n/a	n/a	-5.40%	-5.47%	-11.61%	-11.03%

Bed Shear Stress Erosion Threshold = 9.01 N/m²

Modelled Scenarios (no LIDs)

	KWEX		KWEX_KNL9		KWEX_KGC		KWEX_KGC_KNL9	
	Vol Exc (m^3)	CWI (pa)	Vol Exc (m^3)	CWI (pa)	Vol Exc (m^3)	CWI (pa)	Vol Exc (m^3)	CWI (pa)
Result	6.20E+03	8.55E+04	7.55E+03	9.81E+04	6.50E+03	8.64E+04	7.89E+03	9.98E+04
Change from KW_EX	n/a	n/a	21.68%	14.70%	4.82%	1.04%	27.24%	16.76%
Change from KW_KNL9	n/a	n/a	n/a	n/a	n/a	n/a	4.57%	1.79%

KWEX_KGC

Modelled Scenarios (with LIDs on KGC)

	KWEX_KGC- LIDs3mm		KWEX_KGC- LIDs5mm		KWEX_KGC- LIDs3mm_KNL9		KWEX_KGC- LIDs5mm_KNL9	
	Vol Exc (m^3)	CWI (pa)	Vol Exc (m^3)	CWI (pa)	Vol Exc (m^3)	CWI (pa)	Vol Exc (m^3)	CWI (pa)
Result	6.12E+03	8.23E+04	5.93E+03	8.00E+04	7.24E+03	9.29E+04	6.91E+03	8.90E+04
Change from KW_EX	-1.29%	-3.76%	-4.45%	-6.45%	16.74%	8.71%	11.35%	4.12%
Change from KW_KNL9	n/a	n/a	n/a	n/a	-4.06%	-5.22%	-8.49%	-9.23%

Vol Exc: Average Annual volume exceeding the erosion threshold
CWI: Average Annual Cumulative Work Index

Scenario Summary:

KWEX	JFSA updated Existing Conditions
KWEX_KNL9	JFSA updated Existing Conditions + KNL Stage 9 Development
KWEX_KGC	JFSA updated Existing Conditions + The Kanata Golf and Country Club Development with SWM controls
KWEX_KGC_KNL9	JFSA updated Existing Conditions + The Kanata Golf and Country Club Development with SWM controls + KNL Stage 9 Development
KWEX_KGC- LIDs3mm	JFSA updated Existing Conditions + The Kanata Golf and Country Club Development with SWM controls with 3mm equivalent LIDs
KWEX_KGC- LIDs5mm	JFSA updated Existing Conditions + The Kanata Golf and Country Club Development with SWM controls with 5mm equivalent LIDs
KWEX_KGC- LIDs3mm_KNL9	JFSA updated Existing Conditions + The Kanata Golf and Country Club Development with SWM controls with 3mm equivalent LIDs + KNL Stage 9
KWEX_KGC- LIDs5mm_KNL9	JFSA updated Existing Conditions + The Kanata Golf and Country Club Development with SWM controls with 5mm equivalent LIDs + KNL Stage 9

Table 3B: Erosion Analysis Summary - KDR-3 (March Road)

Bank Shear Stress Erosion Threshold = 8.5N/m²

Modelled Scenarios (no LIDs)

	KWEX		KWEX_KNL9		KWEX_KGC		KWEX_KGC_KNL9	
	Vol Exc (m^3)	CWI (pa)	Vol Exc (m^3)	CWI (pa)	Vol Exc (m^3)	CWI (pa)	Vol Exc (m^3)	CWI (pa)
Result	1.54E+04	1.52E+05	2.13E+04	2.13E+05	1.57E+04	1.54E+05	2.18E+04	2.15E+05
Change from KW_EX	n/a	n/a	38.49%	39.54%	2.36%	1.28%	41.45%	41.43%
Change from KW_KNL9	n/a	n/a	n/a	n/a	n/a	n/a	2.14%	1.35%

Modelled Scenarios (with LIDs on KGC)

	KWEX_KGC- LIDs3mm		KWEX_KGC- LIDs5mm		KWEX_KGC- LIDs3mm_KNL9		KWEX_KGC- LIDs5mm_KNL9	
	Vol Exc (m^3)	CWI (pa)	Vol Exc (m^3)	CWI (pa)	Vol Exc (m^3)	CWI (pa)	Vol Exc (m^3)	CWI (pa)
Result	1.48E+04	1.46E+05	1.43E+04	1.42E+05	1.96E+04	1.96E+05	1.85E+04	1.86E+05
Change from KW_EX	-3.76%	-4.05%	-6.80%	-6.61%	27.34%	28.71%	20.14%	21.80%
Change from KW_KNL9	n/a	n/a	n/a	n/a	-8.05%	-7.76%	-13.24%	-12.71%

Bed Shear Stress Erosion Threshold = 11.29N/m²

Modelled Scenarios (no LIDs)

	KWEX		KWEX_KNL9		KWEX_KGC		KWEX_KGC_KNL9	
	Vol Exc (m^3)	CWI (pa)	Vol Exc (m^3)	CWI (pa)	Vol Exc (m^3)	CWI (pa)	Vol Exc (m^3)	CWI (pa)
Result	3.19E+03	5.37E+04	4.51E+03	7.64E+04	3.12E+03	5.22E+04	4.45E+03	7.53E+04
Change from KW_EX	n/a	n/a	41.37%	42.41%	-2.18%	-2.66%	39.68%	40.37%
Change from KW_KNL9	n/a	n/a	n/a	n/a	n/a	n/a	-1.20%	-1.44%

Modelled Scenarios (with LIDs on KGC)

	KWEX_KGC- LIDs3mm		KWEX_KGC- LIDs5mm		KWEX_KGC- LIDs3mm_KNL9		KWEX_KGC- LIDs5mm_KNL9	
	Vol Exc (m^3)	CWI (pa)	Vol Exc (m^3)	CWI (pa)	Vol Exc (m^3)	CWI (pa)	Vol Exc (m^3)	CWI (pa)
Result	3.02E+03	5.07E+04	2.97E+03	4.98E+04	4.15E+03	7.02E+04	3.97E+03	6.72E+04
Change from KW_EX	-5.18%	-5.63%	-6.72%	-7.12%	30.12%	30.84%	24.56%	25.26%
Change from KW_KNL9	n/a	n/a	n/a	n/a	-7.96%	-8.13%	-11.89%	-12.04%

Vol Exc: Average Annual volume exceeding the erosion threshold
CWI: Average Annual Cumulative Work Index

Scenario Summary:

KWEX	JFSA updated Existing Conditions
KWEX_KNL9	JFSA updated Existing Conditions + KNL Stage 9 Development
KWEX_KGC	JFSA updated Existing Conditions + The Kanata Golf and Country Club Development with SWM controls
KWEX_KGC_KNL9	JFSA updated Existing Conditions + The Kanata Golf and Country Club Development with SWM controls + KNL Stage 9 Development
KWEX_KGC- LIDs3mm	JFSA updated Existing Conditions + The Kanata Golf and Country Club Development with SWM controls with 3mm equivalent LIDs
KWEX_KGC- LIDs5mm	JFSA updated Existing Conditions + The Kanata Golf and Country Club Development with SWM controls with 5mm equivalent LIDs
KWEX_KGC- LIDs3mm_KNL9	JFSA updated Existing Conditions + The Kanata Golf and Country Club Development with SWM controls with 3mm equivalent LIDs + KNL Stage 9
KWEX_KGC- LIDs5mm_KNL9	JFSA updated Existing Conditions + The Kanata Golf and Country Club Development with SWM controls with 5mm equivalent LIDs + KNL Stage 9

Conclusion

From this analysis, it was found that the proposed redevelopment of the Kanata Golf and Country Club can be implemented with SWM measures in place to ensure no adverse impacts to peak flows out of the existing Beaver Pond, with only marginal increases in peak flows (0.4% and 0.3%) for the 5 and 10-Year SCS 24 hour storms respectively. The proposed development will result in no increases in 100-year peak flows downstream on Watts Creek at the Ottawa River. The implementation of LID's within the development to capture either 3mm or 5mm of runoff, have been found to result in the peak flows out of the Beaver Pond and downstream on Watts Creek at the Ottawa River to be less than existing conditions for all design storms.

A detailed erosion analysis was completed for each of the scenarios using 39 years of historical rainfall data. The annual average cumulative work index was calculated based on critical shear stress values determined by GEO Morphix at two sensitive sites within the watercourse. From this analysis, it was found that the proposed development would increase the existing cumulative work index at these critical locations by 5.56% and 1.28%. Through the implementation of LID's within the development to capture 3 mm of runoff would result in the cumulative work index to be reduced by 2.53% and 5.63% from existing conditions. The implementation of LID's within the development to capture 5 mm of runoff would result in the cumulative work index to be reduced by 6.61% and 7.12% from existing. This analysis confirms that the Kanata Golf and Country Club can be redeveloped, as proposed, without increasing downstream peak flows or increasing existing erosion concerns.

Yours truly,

J.F Sabourin and Associates Inc.

Jonathon Burnett, P.Eng
Water Resources Engineer, JFSA

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

Table 1A: Beaver Pond Inflow/Outflow Summary

Table 1B: Beaver Pond Inflow/Outflow Summary - With LIDs

Table 2A: Outlet to Ottawa River Summary

Table 2B: Outlet to Ottawa River Summary - With LID's

Table 3A: Erosion Analysis Summary - KDR-4 (upstream of the CN Rail)

Table 3B: Erosion Analysis Summary - KDR-3 (March Road)

NOTE: Due to the number and size of the various models used in this analysis, modelling files have been provided electronically.