TEWIN LANDS - EXISTING CONDITIONS

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1.1 Introduction

This Tewin Lands: Existing Conditions Water Budget Analysis is part of a set of technical reports which have been prepared as part of Phase 1 of the Tewin study process. The Tewin Study Area ("Study Area") lands were identified as a future urban development area in the new City of Ottawa Official Plan (2022). The Study Area is located in southeast Ottawa, generally bordered by Leitrim Road to the north, Farmers Way to the east, Thunder Road to the south, and Anderson Road and Ramsayville Road to the west. The Study Area is outlined in **Figure 1** below. These technical reports are intended to establish an understanding of the existing physical, social and ecological conditions that characterize the Study Area. Where appropriate, these reports also identify preliminary opportunities to help guide the next phase of the master planning process.

This information will be used to identify opportunities and strategic considerations that will inform the Tewin community design process going forward, as well as frame the preparation of additional site-specific technical studies and recommendation reports. Development at Tewin will explore new approaches to planning, design and development, including alternative strategies and solutions that can successfully implement the key community objectives.

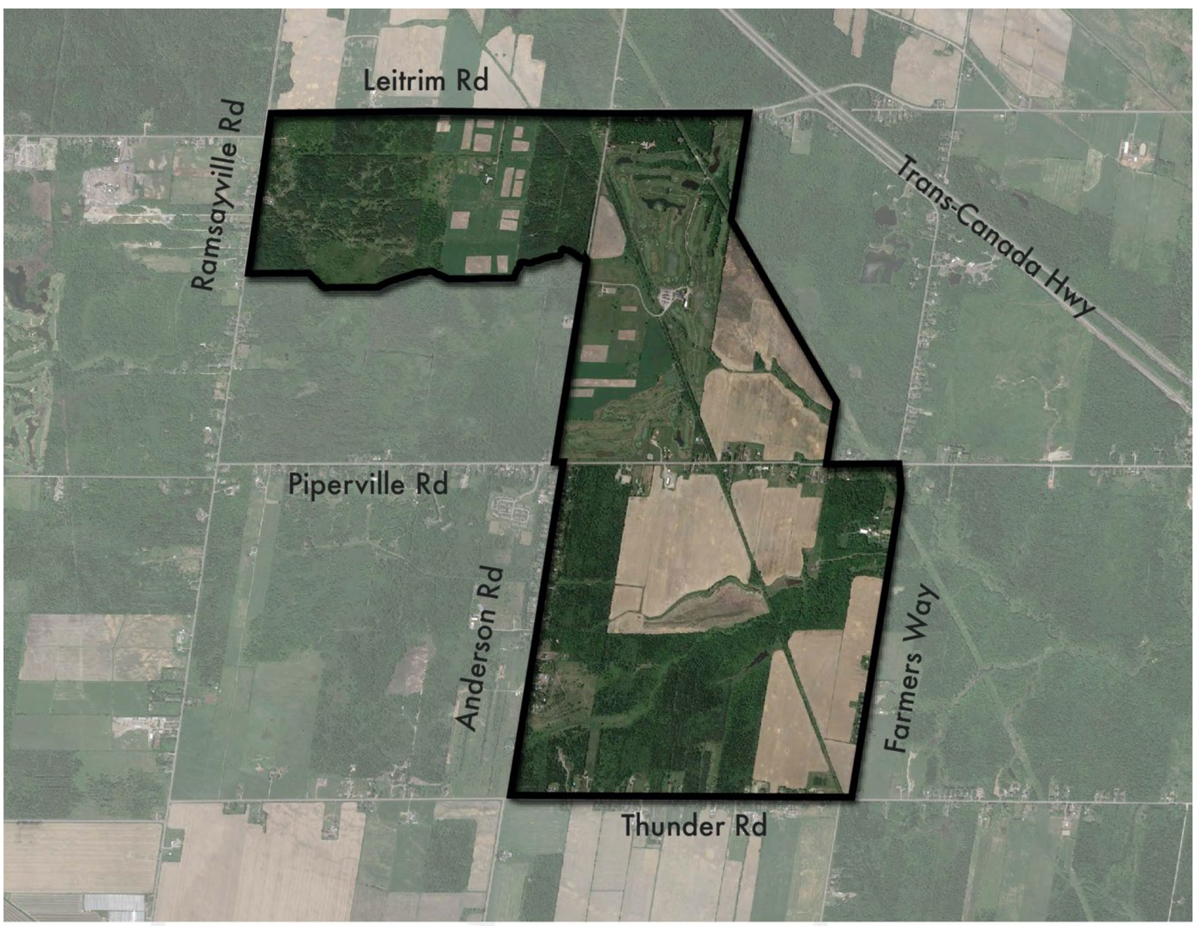

Figure 1: The Tewin Study Area is identified in black outline

1.2 Integrated Master Plan & Municipal Class EA Process

The ambition and scale of Tewin requires ongoing internal and external consultation. The purpose of the integrated Master Plan and Municipal Class EA process is to consolidate the various technical and community planning elements of the project to promote coordinated community engagement through streamlined and aligned decision making. This format will ensure critical partners, consultants and stakeholders are brought together at major milestones to identify and track challenges and opportunities through the development process.

The integrated Master Plan and Municipal Class EA process will include a public consultation strategy and technical study review timeline that achieves the requirements of the Master Plan and Municipal Class EA concurrently. The statutory Municipal Class EA meetings will be timed to align with the development of the community objectives, urban framework, preferred plans, and the draft secondary plan. Additional public and targeted consultations will be planned to complement the statutory consultation requirements. The development of the One Planet Action Plan (OPAP) will occur in parallel, with the final OPAP available at the time of final secondary plan Council approval. One Planet Living endorsement will follow Council approval of the secondary plan.

1.3 Tewin Overview and Community Vision

Tewin is planned to be a community of approximately 45,000 people and thousands of jobs. It will be more compact and dense than existing suburbs in Ottawa, with new urban areas integrated alongside valuable natural areas. Tewin will be an inclusive community, anchored in Algonquin wisdom and placekeeping principles, and welcoming to all. The community will have a meaningful mix of land uses and support active mobility, to achieve a complete, future ready community. The Tewin Project Team and City of Ottawa have committed to exploring appropriate options, alternatives and standards to enable Tewin to become a model of best practices in sustainable and inclusive community design in the North American context.

The integrated Master Plan and Municipal Class EA process will bring together various technical and community planning considerations.

The key objectives for Tewin are to create a community that is:

- Anchored in Algonquin wisdom, principles and placekeeping;
- A benchmark for community design, demonstrating achievement of the 5 Big Moves identified in the Ottawa Official Plan;
- Mobility-oriented and supportive, promoting a broad range of active forms of movement, where personal vehicles are optional;
- Characterized by a meaningful mix of housing, community amenities, jobs and services in order to achieve a complete, future-ready community;
- Designed to protect and integrate alongside valuable natural areas and agricultural lands; and
- Affordable, inclusive, healthy, welcoming and accessible to all.

1.4 Tewin Intent: A Forward-Thinking Framework

Development at Tewin will explore new approaches to planning, design and development, finding successful options and alternatives to implement the key community objectives, in some cases likely going beyond what current development standards would allow for. The Tewin Project Team and the City of Ottawa have articulated these in the “Tewin Intent” which sets out the following:

1. Bold and Innovative Thinking:
Tewin is about creating a new kind of community, a future-focused model for smart, healthy and sustainable development. It will be a people-centred place that seeks to create the conditions for well-being. The Tewin Project Team will be open to bold ideas, innovative approaches, creative solutions, efficient use of land and resources, emerging

technologies, smart city infrastructure that advances the City's goals and objectives, and other future-forward ideas and opportunities that will enable Tewin to reach its full potential.

2. Integrating Algonquin Values and Principles:
Algonquin principles, values and teachings will guide the planning, consultation, design and development process for Tewin. The integration of Algonquin principles and design intentions will ensure the community is nature-based and sensitive to Mother Earth while creating capacity-building and economic development opportunities for the Algonquin people.

3. Sustainability and Resilience:
Tewin will be a model community that will position Ottawa as a leader in integrated sustainable design with the goal of being a resilient and holistic community. Tewin will be guided by the One Planet Living framework and Algonquin values of respect for the earth. The Community Design Plan will respond to the City's High Performance Development Standard and Climate Change Master Plan, and will result in a Community Energy Plan. A Community Energy Plan and performance-based sustainability metrics that address climate mitigation and adaptation, and the other categories of the High Performance Development Standards will be established from the start and monitored over time.

4. Systems-Based Environmental Planning
Tewin's organization and functions will be designed to respect nature and integrate natural features and landscapes into its form, character, and spirit. To that end, the Tewin Project Team is committed to pursuing a systems-based approach to natural heritage protection, environmental management, and water management in a way that is inclusive and integrated and encourages stewardship and a positive relationship with the natural world. Natural features are regarded as opportunities rather than constraints, will be woven into the fabric of the community, and will be central to its design and character.

5. Alternative Design Solutions:
Designing a community of the future requires progressive and forward-thinking infrastructure solutions. The Tewin Project Team is committed to being solutions-oriented and will consider alternative design and engineering standards that prioritize natural systems, pedestrians, cyclists and transit users, and which efficiently use available land and resources.

Surface water management strategies that achieve quality, conveyance and storage objectives will be based on the fundamentals of natural cycles, green/soft infrastructure, and multi-use opportunities that complement the human realm. Infrastructure design will consider the needs of those involved in the construction, operation and maintenance of municipal services to find opportunities to efficiently service the community and showcase sustainable practices while meeting the community's needs.

A framework for assessing alternative design standards will be established to consider and review alternatives against existing standards within the context of goals and objectives for the City and Tewin.

6. Cost-Effectiveness and Efficiency:
Tewin will demonstrate best practices in efficient and compact development. As a dense, mixed-use community of scale, Tewin will achieve a critical mass of people and jobs to support new infrastructure investments. The Tewin Project Team is committed to exploring opportunities to optimize the community's efficiency through a range of strategies, including prioritizing space-efficient modes of transportation, use of technology, green infrastructure, innovative construction practices, shared-use agreements, and mixed-use forms of development that will promote the efficient use and optimization of land; housing affordability; and supporting the long-term financial viability of the community and city resources.

7. Integrated Planning Process:
We are committed to advancing Tewin through a comprehensive and integrated planning and environmental assessment process where possible or applicable. The process will bring together various planning, environmental, transportation,

urban design, infrastructure, economic, financial, social and technical considerations. The process will be underpinned by engagement with the Algonquin people, other stakeholders, and the public.

8. Collaboration and Problem Solving:
The Tewin Project Team and City of Ottawa Project Team are committed to working collaboratively together to move Tewin forward in an expedited way. We will plan with a spirit of collaboration and joint problem-solving to ensure that the development of Tewin meets the best interests of the City of Ottawa and the Algonquins of Ontario.

9. Communication and Transparency
The Tewin Project Team and the City of Ottawa Project Team commit to open and transparent communication throughout the project. This will require proactively sharing information between the groups as decisions are made and to ensure relevant communication materials are distributed in a timely manner.

The Tewin Project Team and the City of Ottawa Project Team will ensure that all parties, including City Council, residents, and other stakeholders, are provided with pertinent details. Effective information sharing will ensure the project achieves outcomes that are, to the greatest extent possible, known by all involved.

1.5 Existing Conditions Technical Reports

A range of specialized consultants have been studying the physical environment of the Study Area to support community design, servicing strategies and the future development of Tewin. This data has been collected and reported on in a set of Existing Conditions and Opportunities Reports, of which this document is one. The full suite of reports includes the following:

- **Tewin Existing Conditions and Preliminary Opportunities Report** dated September 2024 and prepared by Urban Strategies
- **Fluvial Geomorphology Study - Tewin Lands: Existing Conditions Summary Report - Bear Brook and Ramsay Creek Watersheds** dated October 2024 and prepared by GEO Morphix Ltd.
- **Tewin Lands: Existing Conditions Hydrogeological Study** dated September 2024 and prepared by Dillon Consulting
- **Existing Conditions - Geotechnical: Tewin Lands** dated September 2024 and prepared by Paterson Group
- **Tewin Lands: Natural Heritage Preliminary Existing Conditions Report** dated April 2024 and prepared by Kilgour and Associates
- **Tewin Lands: Cumulative Hydrologic Impact Assessment** dated April 2024 and prepared by J.F. Sabourin and Associates
- **Tewin Lands: 2021-22 Field Monitoring Report** dated April 2024 and prepared by J.F. Sabourin and Associates
- **Tewin Lands - Existing Conditions Water Budget** October 2024 and prepared by J.F. Sabourin and Associates
- **Tewin Mobility Existing Conditions** dated May2024 and prepared by CGH Transportation
- **Stage 1 Archeological Assessment Tewin Lands** dated July 14, 2023 and prepared by WSP Canada

1.6 Framework for Identifying Preliminary Opportunities

Given the unique scale, vision and project goals for Tewin, as well as the shared commitment to exploring new ways of advancing the community design process as expressed in the Tewin Intent, the Phase 1 reports for Tewin include a discussion of potential opportunities to be explored in subsequent stages of the integrated Master Plan and Municipal Class EA process. The identification of preliminary constraints and opportunities, as well as a preliminary community structure, is required in Phase 1 of the integrated Master Plan and Municipal Class EA process as per specific Terms of Reference that were established for each of the Tewin planning, environmental and transportation studies.

The opportunities introduced within these reports are based on a series of key policy directions and strategic considerations, including:

- **Ottawa's new Official Plan**, which promotes the creation of complete, transit-supportive communities;
- **Algonquin values and principles**, underscored by respect for nature, integration of water, and planning the natural environment to achieve long-term vitality over many generations;
- **The Tewin Intent**, which promotes innovative thinking and alternative, performance-based solutions;
- **One Planet Living**, a holistic framework for achieving environmental resiliency, sustainable development, and reduced carbon emissions;
- **Provincial policy** direction focused on supporting housing development and facilitating growth, in order to address the province's housing supply challenges; and,
- **An integrated, systems-based approach** to planning at Tewin that brings together diverse planning, environmental, technical and economic considerations.

TEWIN LANDS - EXISTING CONDITIONS WATER

In Ottawa, Ontario

OCTOBER 2024

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1 Introduction

JFSA Canada Inc (JFSA) was retained by David Schaeffer Engineering Ltd (DSEL) to prepare this hydrological assessment and water budget in support of development of the Tewin Lands located in the east end of the City of Ottawa. The objective of this report is to build upon the previous analysis completed by JFSA in June 2023 titled *Tewin Lands – Existing Conditions Water Budget Analysis* by further evaluating and quantifying the different aspects of the water cycle, such as precipitation, interception, evapotranspiration, surface runoff, and groundwater recharge under existing conditions. This assessment is based on historical precipitation data and field monitoring data collected from the site. The findings from this analysis will provide valuable insights to inform future water budget considerations for the development of the site.

For the previous 2023 report, a novel approach was taken in determining the water budget for the site, based on the available field data and existing studies. An average runoff coefficient was established based on continuous flow monitoring data, while a simultaneous analysis was also conducted downstream at the Water Survey Canada Bear Brook gauge. The annual average runoff coefficient indicated the percentage of rainfall returning as runoff, and a base flow separation approximated surface water versus horizontal groundwater contributions. Deep groundwater recharge volume was already known, leaving only evaporation/evapotranspiration to close out the water budget at the conclusion of the previous report.

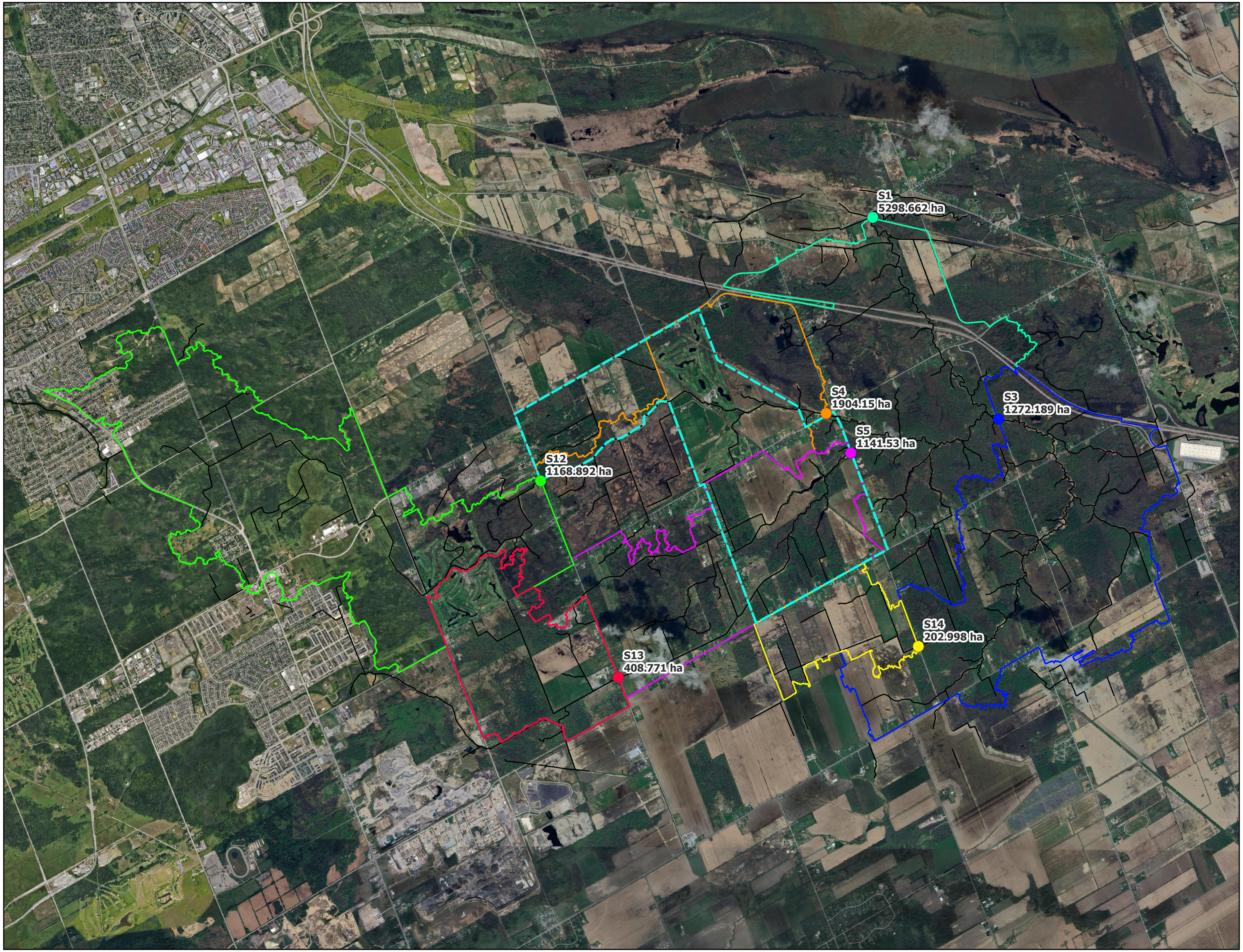
Since JFSA's 2023 report, *Tewin Lands – Existing Conditions Water Budget Analysis*, JFSA has expanded upon the previous water budget work and methodology, forming new and improved methods and tools for undertaking water balance analyses. This new approach accounts for each process within the hydrologic cycle, is completed in daily timesteps (as opposed to monthly) and makes use of available data (daily meteorological data, land cover classifications, soil type). This approach ultimately provides more accurate results by providing seasonal variability to the water balance and maintaining a level of complexity within the calculations that can produce realistic results.

Note this report is an update to a previous report dated May 2024, following review comments received from the City of Ottawa and South Nation Conservation Authority on August 12th, 2024. This updated report now includes a section in which further details about the new JFSA water budget approach are presented. Furthermore, previously reported flow volumes between July and October at one of the Tewin monitoring sites, S1, have been discarded upon further review as a blockage (i.e., beaver dam) downstream of S1 was identified, causing backwater and affecting discharge values measured beyond June 28th.

2 2022 Site Monitoring Data

JFSA along with Geo Morphix (GMX) completed continuous rainfall and flow monitoring for the year of 2022 from late April to early November on the Tewin Site, full details of this monitoring report are outlined in the JFSA June 2023 report titled *Tewin 2021-2022 Field Monitoring Report*. Note that although field data was also obtained for the site for the year 2021, the 2021 data only monitored water levels and not flows, whereas the monitoring program for implemented in 2022 was more extensive, covering a wider range of monitoring locations, and included continuous flow monitoring at various significant points. JFSA also monitored rainfall on the site through the year 2022, and as outlined in the *Tewin 2021-2022 Field Monitoring Report*, the rainfall volumes monitored on-site correlated reasonably well with the Ottawa International Airport rain gauge which is located approximately 10 km to the west of the Study Area. Full details and time series plots of the continuous field data used in this report can be found in the Appendices of the JFSA *Tewin 2021-2022 Field Monitoring Report*. Field monitoring efforts continued through the year 2023, with the surface water monitoring program being expanded and the monitoring locations refined. As of April 2024, JFSA is preparing for another monitoring season in and around the Tewin Lands Study Area.

Detailed topographic data obtained by the City of Ottawa in 2020 has been processed using GIS software to derive the drainage areas for each of the respective monitoring locations. **Figure 2** outlines the flow monitoring locations and their respective drainage areas based on this topographic data. **Figure A1** in **Appendix A** shows the watershed delineation within the Tewin Lands Study Area, which is the focus of this water balance analysis.



Legend

- Logger Sites
- Tewin Lands Study Area
- OHN Watercourses

Drainage Areas

- S1
- S3
- S4
- S5
- S12
- S13
- S14

Drainage areas delineated using 2020 Ottawa-Gatineau LiDAR and Ontario Hydro Network (OHN) watercourse data.

SCALE: 1:50000

0 1 2 km

JFSA CANADA INC.
WATER RESOURCE ENGINEERING, ENVIRONMENTAL MANAGEMENT AND LAND PLANNING CONSULTANTS

DSEL

Tewin Lands - Existing Conditions Water Budget Analysis

Figure 1: 2022 Logger Sites and Drainage Areas

PROJECT	0971
DRAWN	BT
DATE	May 2024

C:\Users\BrennanThomas\J.F. Sabourin and Associates Inc\JFSA-OTTAWA-SERVER - Documents\PROJ\0971\0971(01)-21 - Fieldwork\Design\GIS\sc\20221208-Logger Site Drainage

2.1 2022 Tewin Site Runoff Coefficients

The runoff coefficient (RC) for each monitoring location can be determined by comparing the flow data recorded at each location, against the associated drainage area and the rainfall that fell during that period. Runoff coefficients can be useful in determining annual water budgets as the runoff coefficient (RC) is simply a numerical value that represents the proportion or ratio of precipitation that becomes surface runoff. The runoff coefficient provides a key component of the overall water budget.

It is important to consider that runoff coefficients are influenced by various factors, including land cover, soil conditions, precipitation patterns, and vegetation growth. **Figures A2** and **A3** in **Appendix A** show the land use and soil factors that determine the RC for the Tewin Lands Study Area. These factors can vary seasonally, leading to changes in the runoff coefficient. For example, during the spring freshet, it is expected that vegetation is scarce and that the soils are either frozen or saturated from the snow accumulation over the winter. As such, it would be expected that most areas would have a higher-than-average RC. Depending on the amount of preceding snow accumulation and ambient temperatures during a freshet rainfall event, it is possible to have a runoff coefficient greater than 1 (more runoff than rainfall). Conversely, during the summer months when vegetation is more abundant and the soils are dryer, it is expected that the RC would be lower than average, due to an increased interception and evapotranspiration potential and dry soils. As such, the data recorded by the monitoring locations have been discretized monthly, to capture the variation in runoff coefficients expected throughout the year.

The 2022 monitoring period started on April 20th and ended on November 2nd. However, due to the limited number of days in April and November, the data obtained in these months have been excluded from the analysis. **Table 1** below outlines the total monthly flow volumes (in 1,000 m³) recorded at each of the monitoring locations for the various months.

**Table 1: Tewin Monitoring Sites - Total Monthly Flow Volumes (1000 m³)
May - October 2022**

Location Area (ha)	S1 5,298.7	S3 1,272.2	S4 1,904.2	S5 1,141.5	S12 1,168.9	S14 203.0
May	595.8	421.1	---	159.6	493.1	70.0
June	482.3	150.3	524.7	86.8	260.2	33.9
July	---	32.7	118.7	0.4	36.9	8.2
August	---	198.7	583.6	124.2	143.6	12.1
September	---	59.1	199.4	22.2	46.4	25.4
October	---	51.8	182.6	0.6	43.6	10.0
Total	**1078.1**	**913.7**	**1,609.0**	**393.7**	**1,023.7**	**159.4**

(Grey shading:) Data discounted from analysis due to known monitoring equipment issues or abnormal conditions (e.g., blockage downstream)

Comparing the total runoff volumes recorded during this window for all locations, there is hydrologic continuity for the majority of the monitoring sites; when two monitoring sites are located upstream/downstream of each other, the total flow volume at the downstream site generally exceeds that of the upstream site (e.g., S3 is located downstream of S14, S4 is located downstream of S12). Note that the flows obtained from S13 (upstream of S5) have been discounted from this analysis as on July 12, 2022, the MantaRay monitoring equipment at S13 had to be removed from the channel, due to excessive vegetation growth affecting the reliability of the data. This leads to the rating curves used to derive flows being questionable. Besides, it was identified that a blockage downstream of S1 (i.e., beaver dam) was causing backwater which affected the discharge values estimated after June 28th at that location. Hence, flows obtained from S1 past June have been excluded from this analysis. The values presented in **Table 1** have been standardized by converting them into runoff coefficients. The monthly runoff coefficients presented in **Table 2** were calculated by dividing the total runoff volume for each month by the total rainfall volume for each month.

Table 2: Tewin Monitoring Sites
Monthly Runoff Coefficients: May - October 2022

Month	Rainfall Volume (mm)	S1 5,298.7 ha	S3 1,272.2 ha	S4 1,904.2 ha	S5 1,141.5 ha	S12 1,168.9 ha	S14 203.0 ha	Weighted Average RC*
May	82.5	0.14	0.40	---	0.17	0.51	0.42	0.29
June	87.7	0.10	0.13	0.31	0.09	0.25	0.19	0.20
July	82.1	---	0.03	0.08	0.00	0.04	0.05	0.04
August	189.3	---	0.08	0.16	0.06	0.06	0.03	0.11
September	81.0	---	0.06	0.13	0.02	0.05	0.15	0.08
October	30.0	---	0.14	0.32	0.00	0.12	0.16	0.18

(Shaded cells:) Data discounted from analysis due to known monitoring equipment issues or abnormal conditions (e.g., blockage downstream)

Note: * Weighted-average RC based on S3, S4 and S5.

As expected, for any given month there is variation in the runoff coefficients between the monitoring locations, and this is due to the composition of the various land use types present within each location. The majority of monitoring locations are not homogenous with respect to land use and generally encompass various mixes of farmlands, forests and development, all of which impact the monitoring location runoff coefficients to differing degrees depending on their composition. Hence, to come up with representative monthly runoff coefficients for the drainage areas associated with the monitoring sites considered in this analysis, it was deemed appropriate to use the weighted-average method on S3, S4 and S5. Note that the runoff coefficients for S12 and S14 have not been used in the weighted-average calculations as these two monitoring sites are located upstream of S4 and S3 respectively; in other words, the impact of S12 and S14 in terms of runoff coefficients is accounted for as part of S4 and S3. Furthermore, although the available data at S1 is limited compared to other monitoring sites, the weighted-average runoff coefficients obtained by using S3, S4 and S5 are deemed fairly representative of S1 given that S3, S4 and S5 are included in S1.

An observable trend can be seen when examining the average runoff coefficients obtained from this analysis. During the late spring to early summer (May-June), the average runoff coefficient tends to be high due to wet soils and limited vegetation growth. In the middle of summer (July-August), the runoff coefficients reach a relatively low point due to drier soils and higher evapotranspiration rates. However, as the late summer and early fall months approach, with decreasing evapotranspiration and reduced vegetation (e.g., leaves falling from trees), the runoff coefficients show an increase compared to the preceding months.

2.2 2022 Bear Brook Gauge Runoff Coefficients

The runoff coefficient analysis has also been completed using the flow data recorded at Water Survey Canada's (WSC) Bear Brook Gauge near Bourget (WSC Gauge - 02LB008). The total runoff volumes were recorded at this gauge from January 1st to December 31st, 2022, and summed monthly. The total precipitation data for the months of January to April and November to December were recorded at the Ottawa International Airport rain/snow gauge, and the precipitation data for the months of May to June were recorded using JFSA's Tewin rain gauge.

Table 3: Bear Brook Gauge near Bourget (44,800 ha)
Monthly Runoff Coefficients: May – October 2022

Month	Total Precipitation (mm)	Runoff (1000 m³)	Runoff (mm)	Runoff Coefficient
January[1]	40.2	2,340.0	5.22	0.13
February[1]	58.9	9,780.0	21.83	0.37
March[1]	58.0	76,400.0	170.54	2.94
April[1]	83.6	43,800.0	97.77	1.17
May[2]	82.5	17,010.9	37.97	0.46
June[2]	87.7	9,014.9	20.12	0.23
July[2]	82.1	1,161.4	2.59	0.03
August[2]	189.3	4,089.0	9.13	0.05
September[2]	81	4,463.4	9.96	0.12
October[2]	30	2,419.9	5.40	0.18
November[1]	64.3	6,400.0	14.29	0.22
December[1]	105.7	13,800	30.80	0.29

[1] Ottawa International Airport precipitation data.

[2] JFSA Tewin rain gauge data.

Table 4 compares the average monthly runoff coefficients derived for the Tewin Monitoring location (**Table 2**) against those derived for the Bear Brook gauge (**Table 3**). From this table, it is seen that the Bear Brook gauge generally shows the same trend in runoff coefficients as the Tewin sites with coefficients being highest in the spring, lowest mid-summer and rising again in early fall. There are slight differences from month to month between the two locations. However, in consideration of the full monitoring window there is an average difference of **0.03**. As such it is reasonable to conclude that the Bear Brook gauge is a reliable representation of the seasonal variation of the existing runoff coefficients for the Tewin site.

Table 4: Comparison of Bear Brook Gauge vs Average Tewin Sites
Monthly Runoff Coefficients: May - October 2022

Month	(A) Bear Brook	(B) Tewin Weighted-Average	(A – B) RC Difference
May	0.46	0.29	0.17
June	0.23	0.20	0.03
July	0.03	0.04	-0.01
August	0.05	0.11	-0.06
September	0.12	0.08	0.04
October	0.18	0.18	0.00
		Average	**0.03**

3 Annual Bear Brook Gauge Runoff Coefficients

The analysis completed above is confined to May to October; when precipitation is mostly in the form of rainfall and the flow monitoring locations are not subject to freezing. To have a more complete understanding of the site's water budget, the analysis needs to be assessed for the whole year. Fortunately, the Bear Brook gauge has been operating and reporting flows year-round for over 68 years. As established above, the Bear Brook gauge is a reasonable representation of the Tewin site conditions and the 68 years of data from the gauge can be used as a proxy to provide a complete water budget for the Tewin site.

Daily flow data recorded at the WSC Bear Brook gauge has been extracted from the years 1949 to 2021 (with some gaps in data), and the average monthly flows are calculated based on this historical data. The average runoff volume for each month was multiplied by the number of days in each month to provide a monthly average runoff volume. This volume was then converted to a depth based on the total drainage area at this gauge as specified by Water Survey Canada (**44,800 ha**).

Next, monthly average precipitation normals for the Ottawa International Airport were extracted from Environment Canada. As the flow data at the gauge data dates back to 1949, the climate normals for 1961-1990 and 1981-2021 were both extracted and the average of these two data sets was used for the analysis. The average monthly runoff volumes (in mm) recorded at the gauge were then divided by the average monthly precipitation. Lastly, the total average runoff volume was divided by the annual average rainfall volume to determine an average annual runoff coefficient of **0.48.**

As was previously identified, a similar pattern of runoff coefficient fluctuation is observed throughout the seasons in this analysis. It is also worth noting that the runoff coefficients during March and April exceed a value of 1.0, which means the runoff volume is exceeding the rainfall volume for that month. This is because as the weather warms up, the accumulated snow from previous months (January/February) melts, resulting in runoff coefficients surpassing the rainfall volume that fell during that month.

Table 5: Bear Brook Gauge near Bourget Average Monthly Runoff Coefficients

Date	Average Monthly Flow[1] (m^3/s)	Days in Month	Average Monthly Runoff Volume ($1000\ m^3$)	Average Monthly Runoff[2] (mm)	Average Monthly Precipitation[3] (mm)	Runoff Coefficient
January	3.79	31	10,144	23	62	**0.37**
February	3.96	28.25	9,671	22	56	**0.38**
March	15.59	31	41,754	93	65	**1.44**
April	24.62	30	63,803	142	72	**1.98**
May	5.18	31	13,885	31	78	**0.40**
June	3.23	30	8,359	19	85	**0.22**
July	1.64	31	4,388	10	90	**0.11**
August	1.18	31	3,149	7	89	**0.08**
September	1.52	30	3,943	9	87	**0.10**
October	3.39	31	9,073	20	80	**0.25**
November	5.53	30	14,342	32	84	**0.38**
December	5.69	31	15,249	34	79	**0.43**
Total		**365.25**	**197,759**	**441**	**927**	**0.48**

[1] Daily flows recorded at WSC's Bear Brook gauge from 1949 to 2021
[2] Total drainage area of 44,800 ha
[3] Average of Ottawa International Airport Climate normals from 1961-1990 and 1981-2010

3.1 Bear Brook Gauge Baseflow Separation

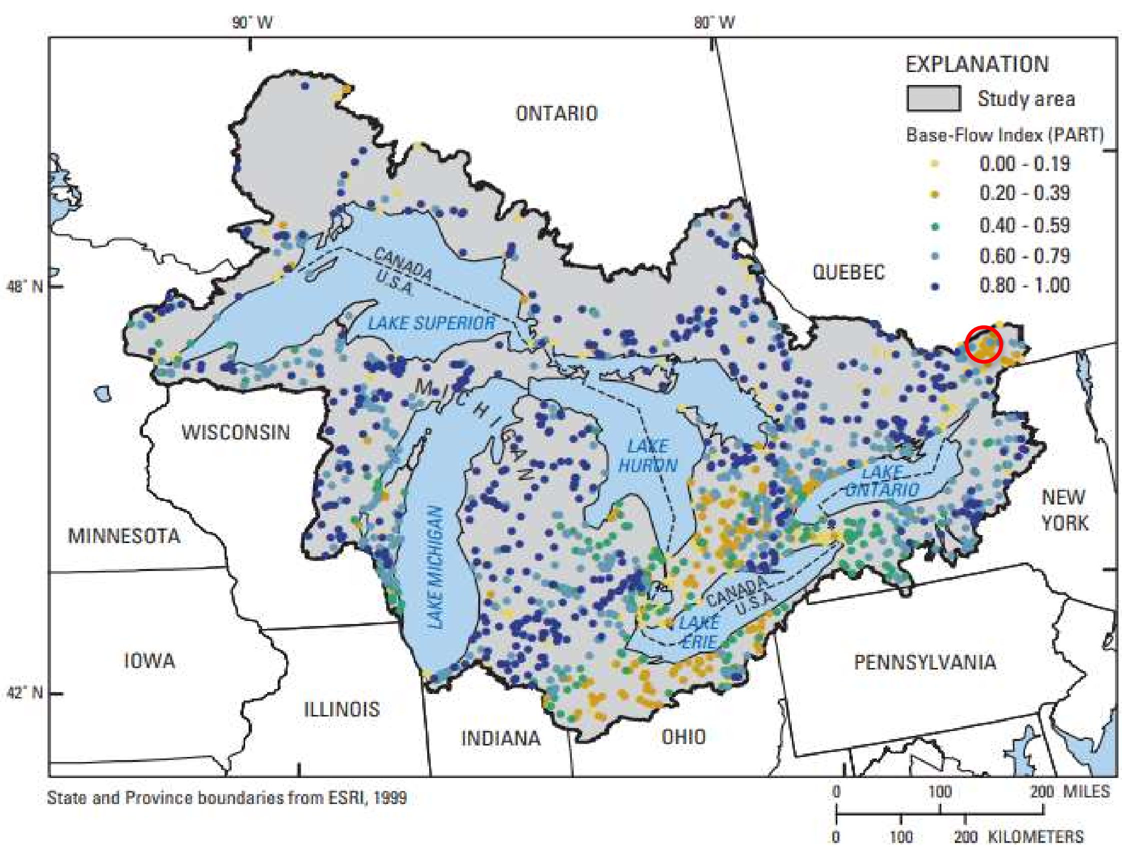
A baseflow separation analysis was conducted on the historical flow data recorded at the Bear Brook gauge. The study employed the Lyne & Hollick baseflow separation method with an alpha parameter of 0.95, falling within the typical range. A typical result, which includes a plot of total flow and estimated baseflow using the Lyne & Hollick method, is provided in Appendix B.

The baseflow index (BFI) varies from year to year, but the average BFI for this site was determined to be 0.47. In other words, approximately 47% of the streamflow in the watershed is derived from baseflow and interflow (through groundwater contributions), while the remaining 53% is from surface runoff or direct precipitation and snowmelt. These findings conceptually align with the conclusions drawn by Dillon in their April 2024 study titled "*Tewin Lands - Existing Conditions Hydrogeological Study*":

"Overall, the hydrogeology of the development area is dominated by low permeability silty clay soils. There is no significant deep movement of groundwater due to a thick layer of very low permeability grey clay. The shallow groundwater flow system is dominated by horizontal movement towards surface water features."

A BFI of 0.47 for this location also aligns with the baseflow separation completed by the U.S. Geological Survey (USGS) in their 2005 report titled "Base Flow in the Great Lakes Basin." **Figure 3** in the report, shown below, indicates the approximate location of the subject site with a red circle, demonstrating a BFI in the range of 0.2-0.59.

Figure 3: Baseflow Index (BFI) – USGS 2005 Study



4 Tewin Pre-Development Water Budget

4.1 Water Budget Methodology

There exist several methods to conduct water budget analyses. Commonly used methods include the use of maps and tables, continuous models, and monthly water balance calculations. These methods, although displaying numerous advantages such as simplicity and practicality, present important limitations that make them inadequate for certain applications. When conducting water budgets, maps and tables provide poor insights about the variability of the hydrologic cycle components. For instance, average annual evapotranspiration data are not informative of the evapotranspiration fluctuations on a daily or monthly basis, which can strongly impact the actual water budget outcome. While continuous models represent a viable option to perform more detailed water budget assessments (with the use of hourly rainfall data for instance), the currently available data does not allow for consideration of winter and spring conditions, which represents a major drawback as some related phenomena such as the spring freshet have been found to bring a non negligible contribution to the water budget depending on the site. Finally, monthly water balance calculations are found to oversimplify the hydrologic processes thus producing unrealistic results in certain periods; during summer months, this method may suggest the absence of runoff as a result of the relatively high monthly evapotranspiration compared to the precipitation rates.

In light of all these observations and their implications to the water budget outcome, JFSA has developed a new approach to water balance analyses which provides a fair representation and due consideration of the various hydrologic cycle processes. Furthermore, this new approach is completed in daily timesteps (as opposed to monthly) and makes use of available data (daily meteorological data, land cover classifications, soil type). This approach ultimately provides more accurate results by providing seasonal variability to the water budget and maintaining a level of complexity within the calculations that can produce realistic results. Details pertaining to the new JFSA approach can be found below.

Input Parameters

The primary input parameters to the new JFSA approach consist of daily meteorological data. For Ottawa, such data can be obtained from the Environment Canada website at various locations. In the scope of this water budget analysis, the Ottawa CDA station was considered. The sourced daily data includes the maximum, minimum and mean temperatures, total rainfall, total snowfall, snowpack on the ground.

Additional input parameters to the JFSA water budget model include land use and soil type information of the site, as well as its latitude. Land use and soil type information is used to derive a CN value that is representative of the site and that will be used as variable in the surface runoff estimation. Site latitude is used to estimate the daylight hours of the site which will then be used to apply daylight correction factors to the potential evapotranspiration. Initial abstraction values should also be entered by the user for interception losses estimation; maximum and minimum initial abstraction values are required and the choice of the initial abstraction to be used in this range is season-dependent.

Finally, the tool requires the user to define the desired period of water budget analysis by entering the start year and end year.

Hydrologic Cycle Processes

Several hydrologic processes are simulated daily based on the input parameters previously introduced.

- ### Rain + Snowmelt

The amounts of rainfall and snowmelt are estimated on a daily basis then combined to form the daily input. Unlike rainfall which is readily available, snowmelt is computed using snowmelt models based on degree-day type equations. In the scope of this study, snowmelt model 5 which consists of a modification of snowmelt model 4 (Southern Ontario) is used. Note that snowmelt model 5 uses the mean daily air temperature to estimate the potential snowmelt. Based on the snowpack, the actual snowmelt is determined and the snowpack adjusted. Note that that the snowpack is adjusted on a daily basis based on the snowfall and snowmelt.

- ### Evapotranspiration

The daily potential evapotranspiration rate is determined based on the daily computed heat index and the Thornthwaite evaporation equations. Following the adjustment of the potential evapotranspiration values for day length, the actual daily evapotranspiration losses are estimated based on the daily rain + snowmelt input.

- ### Interception

The tool uses initial abstraction (Ia) values to determine daily interception losses. In the scope of this water budget analysis, based on published data and JFSA research/experience, daily minimum and maximum initial abstraction values have been assigned to areas within the site based on land use and weighted-average Ia values were ultimately derived.

- ### Surface Runoff

The SCS method is used to quantify the daily surface runoff generated from within the site using the aforementioned CN and Ia parameters. To account for potential frozen conditions of the soil, the daily freezing index is computed and used to estimate the frost depth of the ground which is considered when calculating the potential maximum storage S as part of the SCS method.

- ### Infiltration to Soil Storage (Interflow + Baseflow + Deep Aquifer Recharge)

Daily infiltration to soil storage is quantified by deducting the daily interception losses, evapotranspiration losses and surface runoff from the daily rain+snowmelt input. Note that the evapotranspiration losses that are applied are influenced by the computed frost depth of the ground. The estimated amount of infiltrated water is then used to update the amount of water stored in the soil, with this water being made available to three hydrologic processes that are interflow, baseflow and deep aquifer recharge. The interflow is first calculated as a fraction of the water in the soil based on a calibration coefficient. A similar approach is used for baseflow estimation upon deducting the interflow from the amount of water stored in the soil. Note that deep aquifer recharge information is provided by the hydrogeologist in the scope of this water budget analysis. Finally, at the end of each daily computation, the amount of water stored in the soil is depleted according to the estimated interflow, baseflow and deep aquifer recharge.

Water Budget

Based on the various hydrologic processes described above, the water budget for the desired can be completed. The daily rain + snowmelt excess or surplus represents the daily rain + snowmelt input minus the daily interception and evapotranspiration losses. This surplus can either be surface runoff or infiltration. The infiltration fraction of the surplus is added to the amount of water in the soil which is partially consumed by interflow, baseflow and deep aquifer recharge on a daily basis. Note that the total runoff from the site includes surface runoff, interflow and baseflow.

As a results summary, the new JFSA water budget tool is able to generate average monthly and yearly values for each simulated hydrologic process.

4.2 Water Budget Results

The daily continuous simulations presented in **Appendix C** indicates that, on average, **53%** of the annual rainfall within the Ramsey Creek watershed at the Tewin site will result in runoff (Surface runoff + interflow + baseflow). For the Bear Brook watershed, the daily continuous simulations presented in **Appendix D** indicate that, on average, **52%** of the annual rainfall at the Tewin site will result in runoff. Based on Dillon's "*Tewin Lands - Existing Conditions Hydrogeological Study" report* (Appendix E), the Tewin site is expected to infiltrate **20 mm/year** that will go back into the ground as recharge. Further correspondence in March 2024 with Brad MacLean, a Hydrogeochemist and Associate with Dillon Consulting, estimated that of the 20 mm/year, approximately **1%**, or **0.2 mm/year** will be deep aquifer recharge (water that exits through the bottom of the model). Most of the groundwater recharge will either discharge to surface water features or move horizontally out of the Study Area. JFSA's daily continuous simulations had estimated deep aquifer recharge as approximately **0.45 mm/year**, or **0.05%** of the overall water budget. For this analysis, **0.05%** was used in calculating the Tewin Water Budget. Based on an annual average precipitation volume of **943 mm/year**, the full annual water budget for the site can be deduced, as outlined in **Appendix C** and **D**. From this analysis, it is found that for the Ramsey Creek watershed within the Tewin Lands, **53%** of the annual precipitation will runoff, approximately **0.05%** will infiltrate into the deep groundwater layer and **47%** will evaporate/evapotranspiration back into the atmosphere. For the portion of the Bear Brook watershed within the Tewin Lands, **52%** of the annual precipitation will runoff, approximately **0.05%** will infiltrate into the deep groundwater layer and **48%** will evaporate/evapotranspiration back into the atmosphere. The results are summarized below in **Table 6**.

Table 6: Tewin Annual Water Budget Summary

Watershed	Runoff	Evaporation / Evapotranspiration	Deep Groundwater Recharge
Ramsey Creek	53%	47%	0.05%
Bear Brook	52%	48%	0.05%

5 Conclusion

A pre-development hydrologic water budget analysis has been completed for the Tewin development site located in the east end of Ottawa. As a part of this study, a detailed analysis of the 2022 site monitoring data was completed, which included continuous rainfall and flow monitoring. From this analysis, it was observed that runoff coefficients varied throughout the year due to factors such as land cover, soil conditions, precipitation patterns, and vegetation growth, with monthly runoff coefficients showing higher values in late spring and early summer, lower values in mid-summer, and an increase again in late summer and early fall.

To validate the findings, the runoff coefficients obtained from the Tewin monitoring locations were compared to those derived from the Bear Brook Gauge near Bourget. The comparison showed a similar trend in runoff coefficients, indicating that the Bear Brook Gauge can reasonably represent the seasonal variation of runoff coefficients for the Tewin site. The average difference between the two locations' runoff coefficients was found to be **0.03**, supporting the use of the Bear Brook Gauge data as a proxy for the Tewin site.

Consequently, an additional analysis using 68 years of historical flow data from WSC's Bear Brook gauge was then used to provide a complete picture of the annual water budget. The analysis showed consistent patterns of runoff coefficient fluctuation throughout the seasons, with runoff coefficients exceeding 1.0 during the snowmelt period in March and April. This finding highlights the importance of considering snow accumulation and melt in the water budget calculations. This analysis showed that within the Tewin Lands, **53%** of the annual precipitation in the Ramsey Creek Watershed, and **52%** within the Bear Brook watershed returns in the form of runoff. Applying a baseflow separation analysis to this flow data determined that of that **52-53%** of runoff, approximately **47%** is in the form of baseflow from groundwater contributions. The average annual runoff coefficient was then used in conjunction with the hydrogeological study completed by Dillon to determine the site's full water budget. From this analysis, it was found that of the annual precipitation that falls within the Ramsey Creek watershed, **53%** will runoff, **0.05%** will infiltrate into the deep groundwater layer and **47%** will evaporate. For the annual precipitation within the Bear Brook watershed, **52%** will runoff, **0.05%** will infiltrate into the deep groundwater layer, and **48%** will evaporate/evapotranspiration back into the atmosphere.

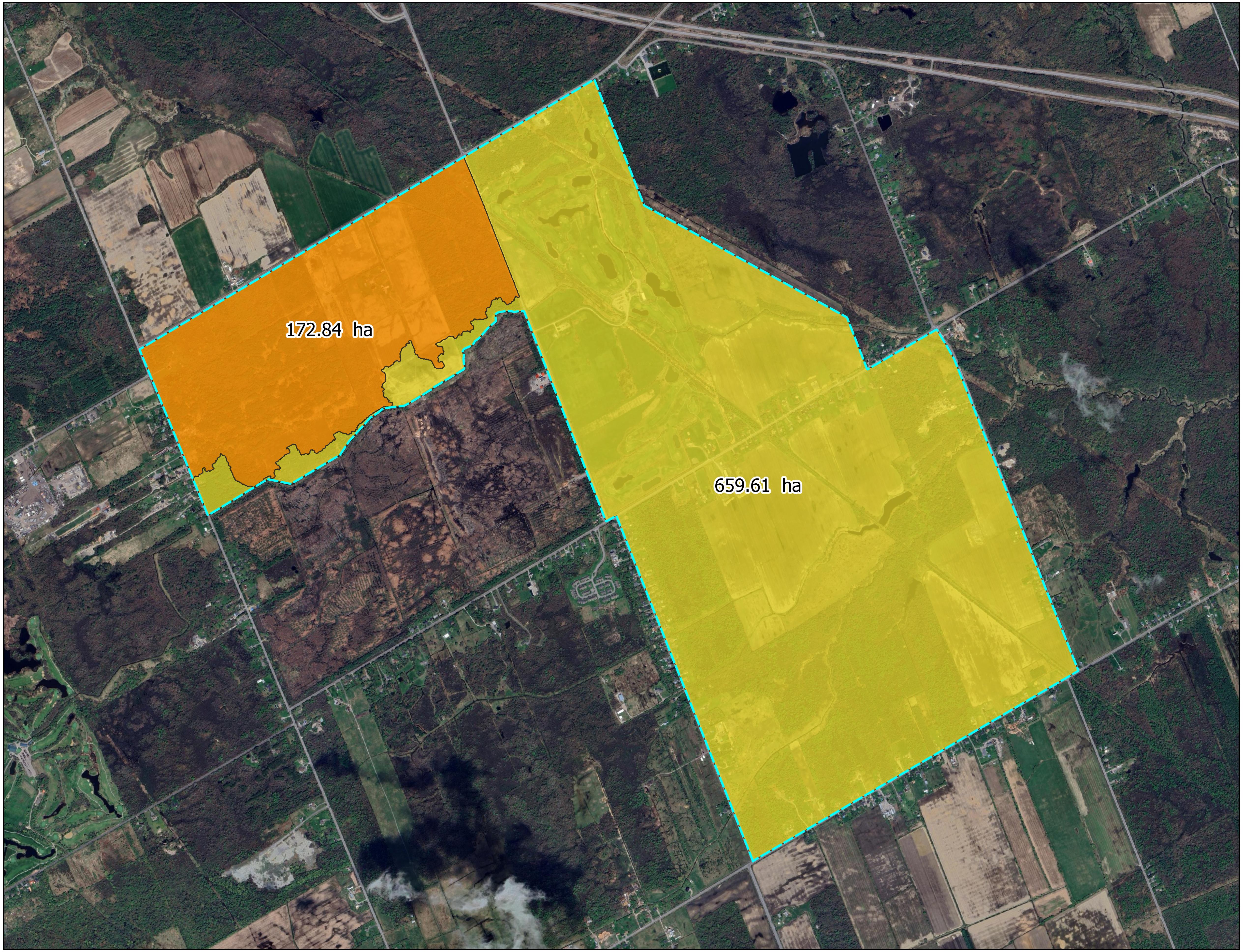
In conclusion, the analysis provides a comprehensive understanding of the water budget for the Tewin development site under existing conditions, incorporating data from site monitoring and historical flow recorded at the Bear Brook Gauge. The findings of this memo can be used to inform future water budget considerations for the proposed development site.

6 JFSA CANADA INC. STATEMENT OF LIMITATIONS

JFSA Canada Inc. (JFSA) has prepared this report, and performed the services described in this report, in a manner consistent with the level of care and skill normally exercised by members of the engineering and science professions currently practicing under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and financial and physical constraints applicable to the services. No other warranty, expressed or implied, is made. This report has been prepared for the exclusive use of the client representative, for the specific site, objective, and purpose described to JFSA by the client. The factual data, interpretations and recommendations pertain to a specific project as described in this report and are not applicable to any other project or site location. Any change of site conditions, purpose and/or development plans may alter the validity of the report. The report, which specifically includes all tables, figures and appendices, is based on data and information assembled by JFSA, and is based on the conditions at the site and study area at the time of the work and on the information provided by others. JFSA has relied in good faith on all information provided and does not accept responsibility for any deficiencies, misstatements, or inaccuracies contained in the report as a result of omissions, misinterpretation, or fraudulent acts of the persons contacted or errors or omissions in the reviewed documentation and data. Any use which a third party makes of this report, or any reliance on, or decisions to be made based on it, are the responsibilities of such third parties. JFSA accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

Appendix A

Figures



Legend

- Tewin Lands Study Area
- Ramsay Creek
- Bear Brook

SCALE: 1:20000

0 500 1,000 m

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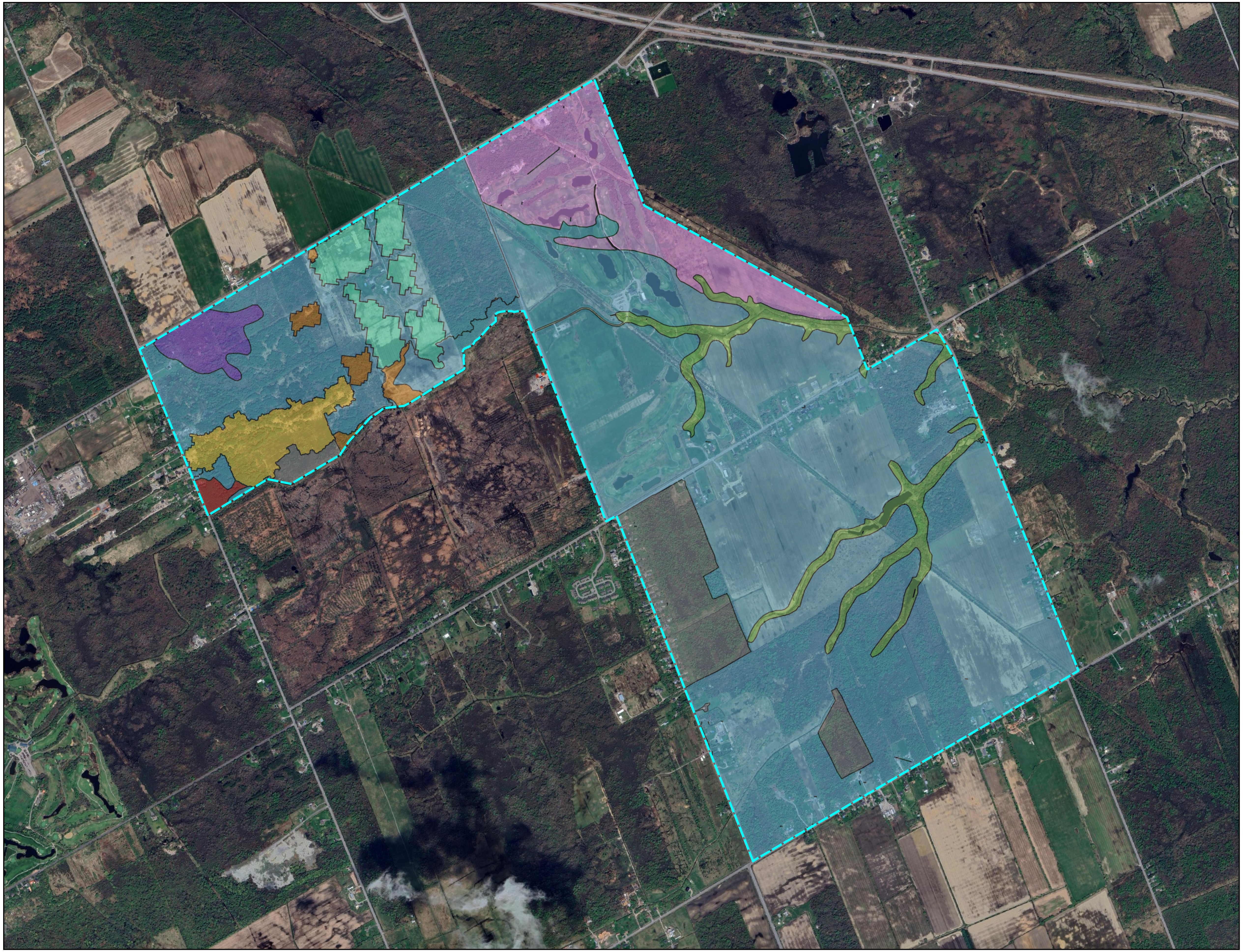
Tewin Lands

Figure A1: Watershed Delineation Within Tewin Lands Study Area

PROJECT	0971
DRAWN	BT
DATE	May 2024

C:\Users\BrennanThomas\J.F. Sabourin and Associates Inc\JFSA-OTTAWA-SERVER - Documents\PROJ\0971\0971(07)-24-Feature Based Water Budget\Design\GIS\20240313-Water Balance Inputs



Legend

Tewin Lands Study Area

Soil Name (SCS Soil Type)

- ALLENDALE (C)
- CARLSBAD (A)
- CARSONBY (C)
- CHENEY (C)
- ERODED CHANNEL (C)
- ERODED CHANNEL (N)
- MOUNTAIN (C)
- NOT MAPPED (C)
- NOT MAPPED (N)
- ST SAMUEL (C)

SCALE: 1:20000

0 500 1,000 m

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Tewin Lands

Figure A2: Soil Type

PROJECT	0971
DRAWN	BT
DATE	May 2024

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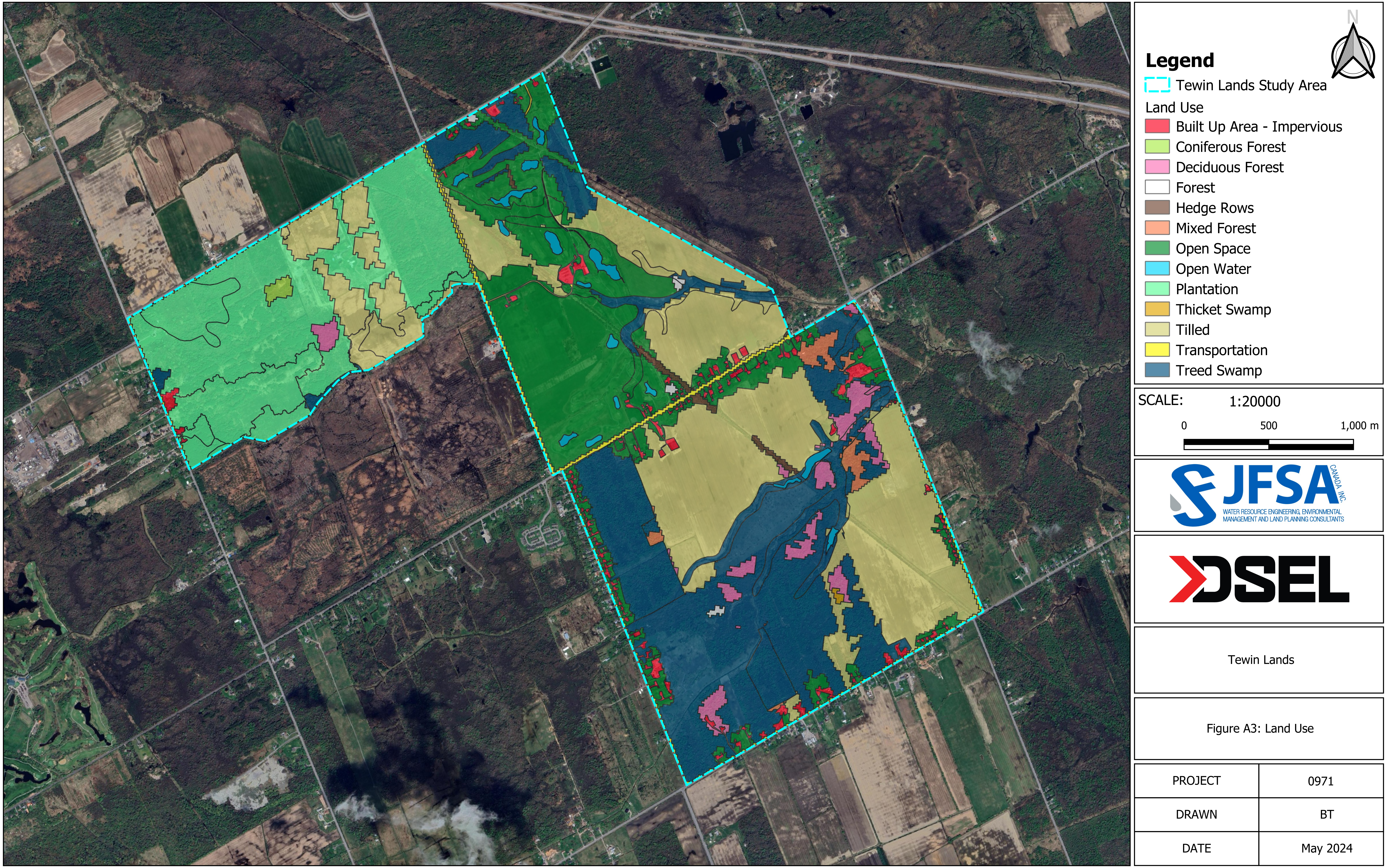

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Tewin Lands

Figure A3: Land Use

PROJECT	0971
DRAWN	BT
DATE	May 2024

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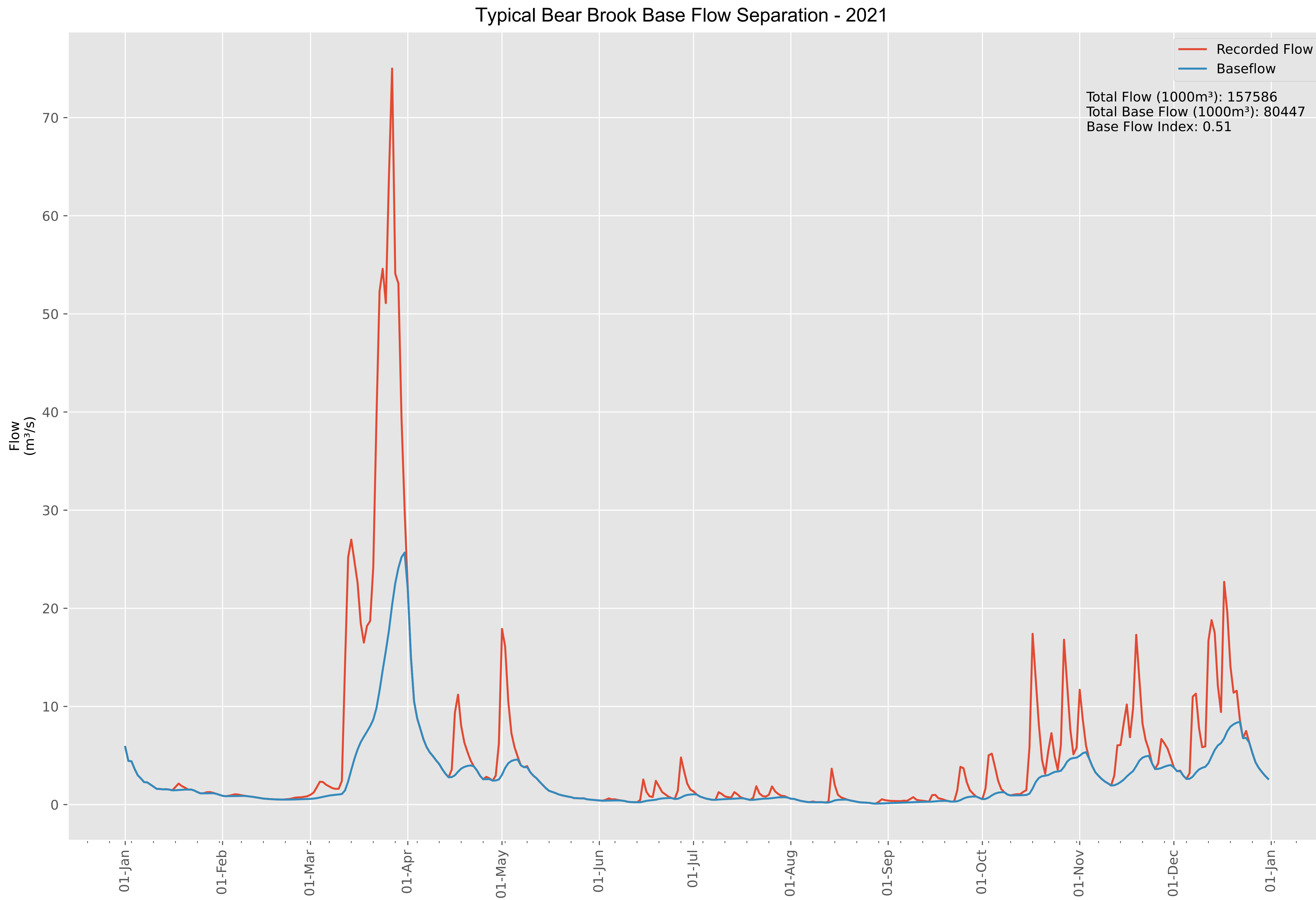
Appendix B

Bear Brook Gauge – Typical Baseflow Separation



Typical Bear Brook Base Flow Separation - 2021
Recorded Flow
Baseflow
Total Flow (1000m³): 157586
Total Base Flow (1000m³): 80447
Base Flow Index: 0.51
Flow
(m³/s)
0
10
20
30
40
50
60
70
01-Jan
01-Feb
01-Mar
01-Apr
01-May
01-Jun
01-Jul
01-Aug
01-Sep
01-Oct
01-Nov
01-Dec
01-Jan

Appendix C

Annual Water Budget – Ramsey Creek Watershed Within Tewin Lands

TEWIN Lands Draining to Ramsey Creek / Part 1

Annual Water Budget for Tewin Lands with Ramsay Creek Watershed

Catchment	Unit Area	Land Use	Soil Name	Soil Type	Hydro Cond	CN	Ia_max (mm)	Ia_min (mm)	Area breakdown (%)	Evaporation (%)	Transpiration (%)	Surface Runoff (%)	Infiltration to Interflow (%)	Infiltration to Baseflow (%)	Infiltration to Deep Aquifer (%)	
RT6-D	0.88	Treed Swamp	ALLENDALE	C	Fair	50	15.0	5.0	0.5%	39.5%	14.5%	14.7%	26.4%	5.0%	0.05%	100.0%
RT8-D	1.71	Coniferous Forest	MOUNTAIN	C	Fair	73	10.0	2.0	1.0%	34.2%	16.9%	17.7%	26.2%	5.1%	0.05%	100.0%
RC-5	2.01	Deciduous Forest	MOUNTAIN	C	Fair	73	10.0	2.0	1.2%	34.2%	16.9%	17.7%	26.2%	5.1%	0.05%	100.0%
RC-5	104.21	Plantation	ALLENDALE	C	Fair	73	5.0	2.0	60.3%	25.0%	22.9%	18.5%	28.2%	5.4%	0.05%	100.0%
RT8-C	12.84	Plantation	CARLSBAD	A	Fair	36	5.0	2.0	7.4%	25.0%	23.9%	15.1%	30.5%	5.5%	0.06%	100.0%
RT8-F	22.62	Plantation	NOT MAPPED	C	Fair	73	5.0	2.0	13.1%	24.3%	24.3%	16.5%	29.5%	5.4%	0.05%	100.0%
RC-5	24.87	Tilled	ERODED CHANNEL	C	Fair	79	5.0	2.0	14.4%	25.0%	22.4%	20.1%	27.1%	5.4%	0.05%	100.0%
RT6-D	0.00	Tilled	CARSONBY	C	Fair	79	5.0	2.0	0.0%	25.0%	22.4%	20.1%	27.1%	5.4%	0.05%	100.0%
RT8-C	0.28	Tilled	MOUNTAIN	C	Fair	79	5.0	2.0	0.2%	25.0%	22.4%	20.1%	27.1%	5.4%	0.05%	100.0%
	3.46	Transportation				100	2.0	0.0	2.0%	11.0%		89.0%				100.0%
Total	172.88				Weighted CN=	71.5			100.00%							
					Weighted Ia_mx=	5.1										
					Weighted Ia_mn=	2.0										

Total Annual Precipitation = 942 mm

Catchment	Unit Area	Land Use	Soil Name	Soil Type	Hydro Cond	CN	Ia_max (mm)	Ia_min (mm)	Area breakdown	Evaporation (mm)	Transpiration (mm)	Surface Runoff (mm)	Infiltration to Interflow (mm)	Infiltration to Baseflow (mm)	Deep Aquifer (mm)	
RT6-D	0.88	Treed Swamp	ALLENDALE	C	Fair	50	15.0	5.0	0.5%	372	136	138	249	47	0	942
RT8-D	1.71	Coniferous Forest	MOUNTAIN	C	Fair	73	10.0	2.0	1.0%	322	159	166	247	48	0	942
RC-5	2.01	Deciduous Forest	MOUNTAIN	C	Fair	73	10.0	2.0	1.2%	322	159	166	247	48	0	942
RC-5	104.21	Plantation	ALLENDALE	C	Fair	73	5.0	2.0	60.3%	236	215	174	265	51	0	942
RT8-C	12.84	Plantation	CARLSBAD	A	Fair	36	5.0	2.0	7.4%	236	225	142	287	51	1	942
RT8-F	22.62	Plantation	NOT MAPPED	C	Fair	73	5.0	2.0	13.1%	228	229	155	278	51	0	942
RC-5	24.87	Tilled	ERODED CHANNEL	C	Fair	79	5.0	2.0	14.4%	236	211	189	256	51	0	942
RT6-D	0.00	Tilled	CARSONBY	C	Fair	79	5.0	2.0	0.0%	236	211	189	256	51	0	942
RT8-C	0.28	Tilled	MOUNTAIN	C	Fair	79	5.0	2.0	0.2%	236	211	189	256	51	0	942
	3.46	Transportation				100	2.0	0.0	2.0%	104	0	838	0	0	0	942
Total	172.88				Weighted CN=	71.5			100%							
					Weighted Ia_mx=	5.1				235	211	184	261	50	0.47	
					Weighted Ia_mn=	2.0				Total losses (mm)=	446	Total Surface Flow (mm)=		496	0.47	
										Percent=	47%	Percent=		53%	0%	

TEWIN Lands Draining to Ramsey Creek / Part 2 – Monthly Summaries

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTALS or AVERAGES	
	1	2	3	4	5	6	7	8	9	10	11	12		
	31	28.25	31	30	31	30	31	31	30	31	30	31		
Number of days=	682	619	665	630	661	660	682	678	658	681	659	680	7955	T
Average Monthly Temperature (Deg.C)=	-8.96	-7.68	-1.72	6.51	14.04	18.96	21.53	20.57	16.33	9.29	2.39	-4.90	7.20	A
Heat Index, i=	0.00	0.00	0.00	1.49	4.77	7.53	9.12	8.51	6.00	2.55	0.33	0.00	40.30	T
Factor "a"= 1.1328														
Unadjusted Potential Evapotranspiration (mm)=	0.00	0.00	0.00	27.53	65.79	92.47	106.80	101.38	78.04	41.18	8.86	0.00	522.05	T
Daylight hours based on Latitude=	9.16	10.37	11.87	13.48	14.86	15.59	15.28	14.10	12.58	11.00	9.58	8.80	12.22	A
Adjusted Potential Evapotranspiration (mm)=	0.00	0.00	0.00	30.92	81.47	120.14	135.98	119.16	81.83	37.74	7.07	0.00	614.32	T
Total Rain (mm)=	20.86	16.20	36.26	75.20	83.12	100.77	89.77	89.54	87.75	94.01	54.19	38.82	786.49	T
Total Snow (cm)=	40.55	44.49	25.42	7.50	0.00	0.00	0.00	0.00	0.00	1.16	14.71	45.07	178.91	T
Total Precip (mm)=	54.61	54.56	59.86	82.48	83.12	100.82	89.77	89.54	87.75	95.35	67.52	78.05	943.45	T
Snowmelt+Rain (mm)=	39.52	38.51	96.11	109.87	83.12	100.77	89.77	89.54	87.48	94.90	63.00	50.85	943.45	T
Maximum Daily Snowmelt+Rain (mm)=	40.39	26.70	43.87	47.17	48.20	69.30	84.60	68.00	108.60	70.40	35.50	56.20		
Frost Depth (cm)=	64.47	102.99	118.53	109.44	64.76	11.41	0.00	0.00	0.00	0.00	0.00	14.95	40.55	A
Average Evaporation from Ia (mm)=	0.00	0.00	0.00	18.20	27.15	39.73	38.28	34.44	36.38	33.03	10.22	0.99	238.42	T
	0%	0%	0%	22%	33%	39%	43%	38%	41%	35%	15%	1%	25.27%	A
Average Water in Soil Storage (mm)=	24.11	14.53	19.87	27.25	22.97	11.31	3.54	3.79	3.94	8.27	17.12	24.95	15.14	A
Actual Transpiration (mm)=	0.00	0.00	0.00	0.00	11.95	48.60	42.82	43.63	34.90	26.39	6.52	0.00	214.82	T
	0%	0%	0%	0%	14%	48%	48%	49%	40%	28%	10%	0%	22.77%	A
Direct Surface Runoff (mm)=	2.81	16.27	57.05	52.65	13.21	4.82	4.52	4.86	4.69	4.37	2.94	3.19	171.38	T
	5%	30%	95%	64%	16%	5%	5%	5%	5%	5%	4%	4%	18.17%	A
Infiltration to Interflow (mm)=	38.77	18.85	24.27	32.64	33.80	17.34	5.69	6.21	6.48	14.38	27.85	41.00	267.27	T
	71%	35%	41%	40%	41%	17%	6%	7%	7%	15%	41%	53%	28.33%	A
Infiltration to Baseflow (mm)=	5.81	5.13	5.40	5.38	5.47	3.26	1.50	1.88	2.16	3.94	5.19	5.84	50.95	T
	11%	9%	9%	7%	7%	3%	2%	2%	2%	4%	8%	7%	5.40%	A
Infiltration to Deep Aquafer (mm)=	0.06	0.05	0.05	0.05	0.06	0.03	0.02	0.02	0.02	0.04	0.05	0.06	0.51	T
	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.05%	A
													100.0%	
Total Runoff (Runoff+Interflow+Baseflow) (mm)=	47.39	40.26	86.71	90.68	52.47	25.41	11.70	12.95	13.33	22.69	35.98	50.04	489.61	
	87%	74%	145%	110%	63%	25%	13%	14%	15%	24%	53%	64%	52%	

Appendix D

Annual Water Budget – Bear Brook Watershed Within Tewin Lands

TEWIN Lands Draining to Bear Brook / Part 1

Annual Water Budget for Tewin Lands with Brear Brook Watershed

Land Use	Unit Area	Soil Name	Soil Type	Hydro Cond	CN	Ia_max (mm)	Ia_min (mm)	Area breakdown (%)	Evaporation (%)	Transpiration (%)	Surface Runoff (%)	Infiltration to Interflow (%)	Infiltration to Baseflow (%)	Infiltration to Deep Aquifer (%)	
Deciduous Forest	0.007	CHENEY	C	Fair	73	10.0	2.0	0.00%	34.2%	16.9%	17.7%	26.2%	5.1%	0.05%	100.0%
Deciduous Forest	1.033	ERODED CHANNEL	N	Fair	73	10.0	2.0	0.16%	34.2%	16.9%	17.7%	26.2%	5.1%	0.05%	100.0%
Deciduous Forest	15.627	ALLENDALE	C	Fair	73	10.0	2.0	2.37%	34.2%	16.9%	17.7%	26.2%	5.1%	0.05%	100.0%
Forest	0.183	ERODED CHANNEL	N	Fair	73	10.0	2.0	0.03%	34.2%	16.9%	17.7%	26.2%	5.1%	0.05%	100.0%
Forest	0.235	CHENEY	C	Fair	73	10.0	2.0	0.04%	34.2%	16.9%	17.7%	26.2%	5.1%	0.05%	100.0%
Forest	1.015	ALLENDALE	C	Fair	73	10.0	2.0	0.15%	34.2%	16.9%	17.7%	26.2%	5.1%	0.05%	100.0%
Hedge Rows	0.064	ERODED CHANNEL	N	Fair	70	5.0	2.0	0.01%	25.0%	23.0%	17.9%	28.6%	5.4%	0.05%	100.0%
Hedge Rows	0.293	CHENEY	C	Fair	70	5.0	2.0	0.04%	25.0%	23.0%	17.9%	28.6%	5.4%	0.05%	100.0%
Hedge Rows	3.094	ALLENDALE	C	Fair	70	5.0	2.0	0.47%	25.0%	23.0%	17.9%	28.6%	5.4%	0.05%	100.0%
Mixed Forest	0.23	ERODED CHANNEL	N	Fair	73	10.0	2.0	0.03%	34.2%	16.9%	17.7%	26.2%	5.1%	0.05%	100.0%
Mixed Forest	7.303	ALLENDALE	C	Fair	73	10.0	2.0	1.11%	34.2%	16.9%	17.7%	26.2%	5.1%	0.05%	100.0%
Open Space	2.29	ERODED CHANNEL	N	Fair	79	5.0	2.0	0.35%	25.0%	22.4%	20.1%	27.1%	5.4%	0.05%	100.0%
Open Space	5.262	NOT MAPPED	N	Fair	79	5.0	2.0	0.80%	25.0%	22.4%	20.1%	27.1%	5.4%	0.05%	100.0%
Open Space	26.289	CHENEY	C	Fair	79	5.0	2.0	3.98%	25.0%	22.4%	20.1%	27.1%	5.4%	0.05%	100.0%
Open Space	123.523	ALLENDALE	C	Fair	79	5.0	2.0	18.72%	25.0%	22.4%	20.1%	27.1%	5.4%	0.05%	100.0%
Plantation	0.027	MOUNTAIN	C	Fair	73	5.0	2.0	0.00%	24.3%	24.3%	16.5%	29.5%	5.4%	0.05%	100.0%
Plantation	2.495	ST SAMUEL	C	Fair	73	5.0	2.0	0.38%	24.3%	24.3%	16.5%	29.5%	5.4%	0.05%	100.0%
Plantation	4.122	NOT MAPPED	N	Fair	73	5.0	2.0	0.62%	24.3%	24.3%	16.5%	29.5%	5.4%	0.05%	100.0%
Plantation	4.211	ALLENDALE	C	Fair	73	5.0	2.0	0.64%	24.3%	24.3%	16.5%	29.5%	5.4%	0.05%	100.0%
Thicket Swamp	0.406	ALLENDALE	C	Fair	50	15.0	5.0	0.06%	39.5%	14.5%	14.7%	26.4%	5.0%	0.05%	100.0%
Tilled	2.802	MOUNTAIN	C	Fair	79	5.0	2.0	0.42%	25.0%	22.4%	20.1%	27.1%	5.4%	0.05%	100.0%
Tilled	3.863	ERODED CHANNEL	N	Fair	79	5.0	2.0	0.59%	25.0%	22.4%	20.1%	27.1%	5.4%	0.05%	100.0%
Tilled	20.583	CHENEY	C	Fair	79	5.0	2.0	3.12%	25.0%	22.4%	20.1%	27.1%	5.4%	0.05%	100.0%
Tilled	188.158	ALLENDALE	C	Fair	79	5.0	2.0	28.52%	25.0%	22.4%	20.1%	27.1%	5.4%	0.05%	100.0%
Treed Swamp	0.78	MOUNTAIN	C	Fair	50	15.0	5.0	0.12%	39.5%	14.5%	14.7%	26.4%	5.0%	0.05%	100.0%
Treed Swamp	20.647	CHENEY	C	Fair	50	15.0	5.0	3.13%	39.5%	14.5%	14.7%	26.4%	5.0%	0.05%	100.0%
Treed Swamp	25.646	ERODED CHANNEL	N	Fair	50	15.0	5.0	3.89%	39.5%	14.5%	14.7%	26.4%	5.0%	0.05%	100.0%
Treed Swamp	38.517	NOT MAPPED	N	Fair	50	15.0	5.0	5.84%	39.5%	14.5%	14.7%	26.4%	5.0%	0.05%	100.0%
Treed Swamp	123.11	ALLENDALE	C	Fair	50	15.0	5.0	18.66%	39.5%	14.5%	14.7%	26.4%	5.0%	0.05%	100.0%
Transportation	29.149		C	Fair	100	2.0	0.0	4.42%	11.0%		89.0%				100.0%
Open Water	8.781		C	Fair	100	2.0	0.0	1.33%	11.0%		89.0%				100.0%
Total Area (ha)	659.745			Weighted CN=	70.6			100.0%							
				Weighted Ia_mx=	8.2										
				Weighted Ia_mn=	2.8										

TEWIN Lands Draining to Bear Brook / Part 2

Land Use	Unit Area	Soil Name	Soil Type	Hydro Cond	CN	Ia_max (mm)	Ia_min (mm)	Area breakdown (%)	Evaporation (mm)	Transpiration (mm)	Surface Runoff (mm)	Infiltration to Interflow (mm)	Infiltration to Baseflow (mm)	Infiltration to Deep Aquifer (mm)	
Deciduous Forest	0.007	CHENEY	C	Fair	73	10.0	2.0	0.00%	322	159	166	247	48	0	942
Deciduous Forest	1.033	ERODED CHANNEL	N	Fair	73	10.0	2.0	0.16%	322	159	166	247	48	0	942
Deciduous Forest	15.627	ALLENDALE	C	Fair	73	10.0	2.0	2.37%	322	159	166	247	48	0	942
Forest	0.183	ERODED CHANNEL	N	Fair	73	10.0	2.0	0.03%	322	159	166	247	48	0	942
Forest	0.235	CHENEY	C	Fair	73	10.0	2.0	0.04%	322	159	166	247	48	0	942
Forest	1.015	ALLENDALE	C	Fair	73	10.0	2.0	0.15%	322	159	166	247	48	0	942
Hedge Rows	0.064	ERODED CHANNEL	N	Fair	70	5.0	2.0	0.01%	236	217	169	269	51	0	942
Hedge Rows	0.293	CHENEY	C	Fair	70	5.0	2.0	0.04%	236	217	169	269	51	0	942
Hedge Rows	3.094	ALLENDALE	C	Fair	70	5.0	2.0	0.47%	236	217	169	269	51	0	942
Mixed Forest	0.23	ERODED CHANNEL	N	Fair	73	10.0	2.0	0.03%	322	159	166	247	48	0	942
Mixed Forest	7.303	ALLENDALE	C	Fair	73	10.0	2.0	1.11%	322	159	166	247	48	0	942
Open Space	2.29	ERODED CHANNEL	N	Fair	79	5.0	2.0	0.35%	236	211	189	256	51	0	942
Open Space	5.262	NOT MAPPED	N	Fair	79	5.0	2.0	0.80%	236	211	189	256	51	0	942
Open Space	26.289	CHENEY	C	Fair	79	5.0	2.0	3.98%	236	211	189	256	51	0	942
Open Space	123.523	ALLENDALE	C	Fair	79	5.0	2.0	18.72%	236	211	189	256	51	0	942
Plantation	0.027	MOUNTAIN	C	Fair	73	5.0	2.0	0.00%	228	229	155	278	51	0	942
Plantation	2.495	ST SAMUEL	C	Fair	73	5.0	2.0	0.38%	228	229	155	278	51	0	942
Plantation	4.122	NOT MAPPED	N	Fair	73	5.0	2.0	0.62%	228	229	155	278	51	0	942
Plantation	4.211	ALLENDALE	C	Fair	73	5.0	2.0	0.64%	228	229	155	278	51	0	942
Thicket Swamp	0.406	ALLENDALE	C	Fair	50	15.0	5.0	0.06%	372	136	138	249	47	0	942
Tilled	2.802	MOUNTAIN	C	Fair	79	5.0	2.0	0.42%	236	211	189	256	51	0	942
Tilled	3.863	ERODED CHANNEL	N	Fair	79	5.0	2.0	0.59%	236	211	189	256	51	0	942
Tilled	20.583	CHENEY	C	Fair	79	5.0	2.0	3.12%	236	211	189	256	51	0	942
Tilled	188.158	ALLENDALE	C	Fair	79	5.0	2.0	28.52%	236	211	189	256	51	0	942
Treed Swamp	0.78	MOUNTAIN	C	Fair	50	15.0	5.0	0.12%	372	136	138	249	47	0	942
Treed Swamp	20.647	CHENEY	C	Fair	50	15.0	5.0	3.13%	372	136	138	249	47	0	942
Treed Swamp	25.646	ERODED CHANNEL	N	Fair	50	15.0	5.0	3.89%	372	136	138	249	47	0	942
Treed Swamp	38.517	NOT MAPPED	N	Fair	50	15.0	5.0	5.84%	372	136	138	249	47	0	942
Treed Swamp	123.11	ALLENDALE	C	Fair	50	15.0	5.0	18.66%	372	136	138	249	47	0	942
Transportation	29.149		C	Fair	100	2.0	0.0	4.42%	104	0	838	0	0	0	942
Open Water	8.781		C	Fair	100	2.0	0.0	1.33%	104	0	838	0	0	0	942
Total Area (ha)	659.745			Weighted CN=	70.6			100%							
				Weighted Ia_mx=	8.2				274	173	208	239	46	0	
				Weighted Ia_mn=	2.8				Total losses (mm)=	448	Total Surface Flow (mm)=		494	0.44	
									Percent=	48%		Percent=	52%	0%	

TEWIN Lands Draining to Bear Brook / Part 3 – Monthly Summaries

													TOTALS	
	1	2	3	4	5	6	7	8	9	10	11	12	or	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	AVERAGES	
	31	28.25	31	30	31	30	31	31	30	31	30	31		
Number of days=	682	619	665	630	661	660	682	678	658	681	659	680	7955	T
Average Monthly Temperature (Deg.C)=	-8.96	-7.68	-1.72	6.51	14.04	18.96	21.53	20.57	16.33	9.29	2.39	-4.90	7.20	A
Heat Index, i=	0.00	0.00	0.00	1.49	4.77	7.53	9.12	8.51	6.00	2.55	0.33	0.00	40.30	T
Factor "a"= 1.1328														
Unadjusted Potential Evapotranspiration (mm)=	0.00	0.00	0.00	27.53	65.79	92.47	106.80	101.38	78.04	41.18	8.86	0.00	522.05	T
Daylight hours based on Latitude=	9.16	10.37	11.87	13.48	14.86	15.59	15.28	14.10	12.58	11.00	9.58	8.80	12.22	A
Adjusted Potential Evapotranspiration (mm)=	0.00	0.00	0.00	30.92	81.47	120.14	135.98	119.16	81.83	37.74	7.07	0.00	614.32	T
Total Rain (mm)=	20.86	16.20	36.26	75.20	83.12	100.77	89.77	89.54	87.75	94.01	54.19	38.82	786.49	T
Total Snow (cm)=	40.55	44.49	25.42	7.50	0.00	0.00	0.00	0.00	0.00	1.16	14.71	45.07	178.91	T
Total Precip (mm)=	54.61	54.56	59.86	82.48	83.12	100.82	89.77	89.54	87.75	95.35	67.52	78.05	943.45	T
Snowmelt+Rain (mm)=	39.52	38.51	96.11	109.87	83.12	100.77	89.77	89.54	87.48	94.90	63.00	50.85	943.45	T
Maximum Daily Snowmelt+Rain (mm)=	40.39	26.70	43.87	47.17	48.20	69.30	84.60	68.00	108.60	70.40	35.50	56.20		
Frost Depth (cm)=	64.47	102.99	118.53	109.44	64.76	11.41	0.00	0.00	0.00	0.00	0.00	14.95	40.55	A
Average Evaporation from Ia (mm)=	0.00	0.00	0.00	21.50	33.35	51.55	50.83	45.57	46.85	39.19	11.33	1.10	301.26	T
	0%	0%	0%	26%	40%	51%	57%	51%	53%	41%	17%	1%	31.93%	A
Average Water in Soil Storage (mm)=	24.11	14.56	19.90	26.85	21.37	9.27	2.59	2.90	3.27	7.11	16.16	24.65	14.40	A
Actual Transpiration (mm)=	0.00	0.00	0.00	0.00	11.04	41.12	31.73	35.53	27.80	23.23	6.41	0.00	176.84	T
	0%	0%	0%	0%	13%	41%	35%	40%	32%	24%	9%	0%	18.74%	A
Direct Surface Runoff (mm)=	2.69	16.23	57.00	50.88	11.78	3.74	3.50	3.70	3.88	3.80	2.76	3.04	163.01	T
	5%	30%	95%	62%	14%	4%	4%	4%	4%	4%	4%	4%	17.28%	A
Infiltration to Interflow (mm)=	38.79	18.90	24.31	32.08	31.27	14.13	4.21	4.73	5.35	12.45	26.37	40.54	253.11	T
	71%	35%	41%	39%	38%	14%	5%	5%	6%	13%	39%	52%	26.83%	A
Infiltration to Baseflow (mm)=	5.81	5.13	5.40	5.38	5.41	2.90	1.13	1.47	1.71	3.46	5.08	5.84	48.72	T
	11%	9%	9%	7%	7%	3%	1%	2%	2%	4%	8%	7%	5.16%	A
Infiltration to Deep Aquafer (mm)=	0.06	0.05	0.05	0.05	0.05	0.03	0.01	0.01	0.02	0.03	0.05	0.06	0.49	T
	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.05%	A
													100.0%	
Total Runoff (Runoff+Interflow+Baseflow) (mm)=	47.28	40.26	86.71	88.34	48.46	20.76	8.84	9.90	10.94	19.71	34.21	49.43	464.84	
	87%	74%	145%	107%	58%	21%	10%	11%	12%	21%	51%	63%	49%	